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Import Risk Analysis: *Rosa* Nursery stock from All Countries

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Cover photo: example of budwood, and rose in bloom at a nursery. Photo credit: D. Anthony

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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 graft and insect transmissible pathogens in *Rosa* spp. on the nursery stock pathway. It assesses the likelihood of entry, exposure, establishment and spread of those pathogens (phytoplasmas and viruses) in relation to nursery stock and assesses the potential impacts of those pathogens should they enter and establish in New Zealand. This document has been internally and externally peer-reviewed and is now released publically. 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 Summary

A review of the Nursery Stock Import Health Standard has determined that a risk assessment needs to be completed for *Rosa* Nursery Stock. This risk assessment examined the risks posed by graft borne and vector transmitted pathogens of roses imported from all countries. On this pathway 5 organisms were identified to be risks (Chapters 2 & 3), and 17 organisms and diseases as hazards (Chapter 4) that could not be assessed further as there was insufficient information on them.

Organisms assessed as risks

The likelihood of entry for '*Candidatus* Phytoplasma asteris' subgroups B and D is considered to be moderate, the likelihood of exposure is high and the likelihood of establishment moderate to high. The economic and environmental consequences are uncertain and could be negligible to high depending on factors discussed in section 2.1.2.5; sociocultural consequences are considered to be low.

The likelihood of entry for '*Candidatus* Phytoplasma aurantifolia' is considered to be low with uncertainty regarding the occurrence of this phytoplasma on rose species in other countries; exposure is high; establishment and spread moderate to high. The economic and environmental consequences are uncertain and could range from negligible to high, as discussed in section 5.2.2.5; human health consequences are negligible and socio-cultural are low to moderate.

The likelihood of entry for '*Candidatus* Phytoplasma mali' is considered to be moderate, exposure is high, establishment and spread moderate to high. The economic and environmental consequences are uncertain (as discussed in section 5.3.2.5) and could range from very low to high; human health consequences are negligible, and socio-cultural consequences are low.

The likelihood of entry for *Blackberry chlorotic ringspot virus* is considered to be low-moderate; the likelihood of exposure is considered to be high; and the likelihood of establishment and spread is considered to be moderate to high. The economic consequences are dependent on disease expression and affected host, thus range from negligible to moderate. The environmental consequences are uncertain, socio-cultural consequences are dependent on disease expression and affected host, thus range from low to negligible. There are no known consequences to human health.

The likelihood of entry for *Rose rosette virus* and/or rose rosette disease is considered low-moderate, exposure is high and establishment is vector dependent therefore could range from very low to moderate. Economic consequences are vector dependent therefore are considered low-moderate (as discussed in 3.2.2.5), environmental and human health consequences are negligible and socio-cultural consequences are low.

Hazard organisms unable to be assessed further due to lack of information about them

The following organisms and diseases remain as hazards: Rose chlorotic ringspot virus, Rose colour break 'virus', Rose necrotic mosaic virus, Rose rugosa distortion virus, Rose yellow leaf virus, Rose yellow mosaic virus, *Tobacco streak ilarvirus* (strains absent from NZ) and Tomato Varamin virus; *Candidatus* Phytoplasma prunorum; Rubus stunt phytoplasma;

Xylella fastidiosa; Rose bud proliferation, Rose cowl forming disease, Rose leaf curl, Rose ring pattern, rose streak disease, rose stunt.

1.1 Purpose

The purpose of this document is to assess the risks associated with graft and vector transmitted pathogens entering New Zealand on imported *Rosa* species nursery stock from all countries. This import risk analysis was undertaken to support a review of the risk management provisions for *Rosa* nursery stock in the Import Health Standard (IHS) 155.02.06: Importation of Nursery Stock.

1.2 Background

MAF Biosecurity NewZealand, (now known as Ministry for Primary Industries) imposed emergency mitigation measures on imported *Rosa* nursery stock from all countries to New Zealand in late 2010. These emergency measures were based on an initial risk assessment for phytoplasmas associated with *Rosa* species. The emergency measures are intended to be temporary until full risk assessments of hazard organisms are completed, whereupon review will determine the adequacy of the emergency mitigation measures against the assessed risks.

1.3 Scope

The risks of graft and vector transmitted pathogens associated with *Rosa* nursery stock entering, establishing and causing unwanted impacts in New Zealand are assessed in this Import Risk Analysis (IRA). This IRA is undertaken for imported, commercially produced *Rosa* nursery stock for 'All Countries'. For the purposes of this IRA *Rosa* nursery stock is defined as: 'whole plants with leaves and roots in a soil-less sterile rooting media; dormant cuttings consisting of stem only, or including buds but without leaves or roots; tissue cultures in sealed bags or containers'.

The scope of this Import Risk Analysis does not include import pathways involving pollen, seeds, cut flowers or foliage, illegal importation along the passenger pathway or any other risk pathway; nor does it assess the invertebrates identified as vectors of the pathogens that are assessed. Fungi and invertebrates are excluded from this IRA but may be covered in a second stage at a later date. Options for management of any risks identified are not discussed in this document but will be addressed in the Risk Management Proposal (RMP).

In this assessment of risk, it is assumed that current commercial production methods used in nurseries do not include specific risk management activities in growing and preparing their produce for export and that the basic conditions for importation apply.

Commodity description

The botanical description of *Rosa*, members of Rosaceae in New Zealand and the rose industry in New Zealand are briefly discussed in Appendix 4, page 69.

1.4 Hazard identification and risk assessment

This process identified over 350 pathogens and disorders associated with *Rosa* species.

- of these, 51 organisms (bacteria, phytoplasmas, viruses and diseases of unknown ætiology) were determined as potential hazards (Appendix 1);
- 29 organisms were excluded based on specific criteria (Appendix 2);

- 22 organisms were assessed to be Hazards based on the criteria of association with the commodity, absence from New Zealand and potential to establish and have unwanted impacts in New Zealand;
- there is insufficient information currently available to enable further assessment of the risk posed by 17 hazard organisms; these hazards are discussed in Chapter 4;
- 5 organisms (3 phytoplasmas and 2 viruses) are considered risk organisms on *Rosa* nursery stock (Chapters 2 & 3).

The risk organisms (in bold type) and the hazard organisms are listed in Table 1.

Table 1. Summary of organisms associated with Rosa nursery stock that have been assessed in this risk analysis

Organism type	Organisms assessed (risk organisms are in bold, hazard organisms in plain text)	Chapter	Relevant exporting country
Phytoplasmas	***Ca.* Phytoplasma asteris**	2	Europe, Asia, Nth & Sth America, Africa
	***Ca.* Phytoplasma aurantifolia**	2	Bolivia, Cuba, Iran, UAE, Oman, UK, Italy, Australia, New Caledonia, Vanuatu, Tonga
	***Ca.* Phytoplasma mali**	2	Europe, Turkey, Syria
	Ca. Phytoplasma prunorum	4	Europe, Turkey , Azerbajdzhan
	Rubus stunt phytoplasma	4	Europe, Russia
Viruses	***Blackberry chlorotic ringspot virus***	3	USA, Scotland
	Rose chlorotic ringspot virus	4	USA
	Rose colour break 'virus'	4	England, Australia
	Rose necrotic mosaic virus	4	USA
	Rose rosette virus/ Rose rosette disease	3	USA
	Rose rugosa distortion virus	4	USA
	Rose yellow leaf virus	4	USA
	Rose yellow mosaic virus	4	USA
	Tobacco streak virus (strains absent from NZ)	4	USA, widespread on other hosts
	Tomato Varamin virus	4	Iran, Kenya (as Tomato yellow ring virus)
Bacteria	*Xylella fastidiosa*	4	USA
Diseases of unknown ætiology	Rose bud proliferation	4	Europe
	Rose cowl forming disease	4	Europe
	Rose leaf curl	4	USA
	Rose ring pattern	4	USA
	Rose streak disease	4	Europe, USA
	Rose stunt	4	Europe

2 Risk assessment of potential hazard organisms: Phytoplasmas

2.1 '*Candidatus* Phytoplasma asteris' (aster yellows phytoplasma)

Scientific name: '*Candidatus* Phytoplasma asteris' [Class: Mollicutes; Order: Acholeplasmatales; Family: Acholeplasmataceae]
Other relevant scientific names: Phytoplasma group 16Sr-I
Common name: aster yellows phytoplasma

2.1.1 Hazard identification

2.1.1.1 Pathogen synopsis

Phytoplasmas are phloem-limited bacteria that lack cell walls and have not been cultured *in vitro* (Davis 1998; Bertaccini 2007). They are associated with a wide range of symptoms affecting all plant parts; typical symptoms include 'little leaf", abnormal root growth, overall stunting, shoot proliferation, leaf yellowing, flower phyllody and viresence, as well as a general decline that is sometimes fatal (Agrios 2005).

2.1.1.2 Taxonomy

Phytoplasmas form a distinct clade in the Class *Mollicutes*. The phytoplasma clade has been proposed to represent at least a genus, with each subclade (16Sr RNA group) proposed to represent at least species (Gundersen *et al.*, 1994). The *'Candidatus* Phytoplasma asteris' group (16Sr-I) is the largest of these groups, but it has also been divided into subgroups (A, B, C, D, E and various others, Lee *et al.*, 2004).

The species concept has been defined within the phytoplasmas (IRPCM 2004), but the appropriate level at which to conduct a risk assessment is often unclear. Since the subgroups of the *'Ca*. P. asteris' 16Sr1 group phytoplasmas appear to represent distinct phylogenetic lineages, mostly differing in distribution and host range, Lee *et al.* (2004) suggest that for quarantine purposes it would be appropriate to consider them separately. This assessment therefore primarily considers subgroup B of the *'Ca*. P. asteris' clade which is associated with disease in roses and will make brief reference to subgroup D which has recently been reported in rose.

Subgroup B is widespread and diverse. There are dozens of isolates within this subgroup, described from different hosts in different regions (Lee *et al.* 2004). It is unclear whether any of these also differ in host range, distribution or other properties that may affect a risk analysis. It is assumed here that they do not to any significant degree, but further information characterising variation within '*Ca*. P. asteris' subgroup B may affect the results of this risk analysis.

Subgroup D appears to be much less widespread and less diverse with fewer isolates to date.

2.1.1.3 New Zealand status

None of the subgroups of '*Candidatus* Phytoplasma asteris' are known to be present in New Zealand. Not recorded in: PPIN (2009); Pearson *et al.* (2006); Liefting *et al.* (2007).

2.1.1.4 Exporting countries status

All countries of the world are considered exporting countries for the purpose of this risk analysis.

2.1.1.5 Geographic distribution

The following distributions for the aster yellows subgroups B and D are indicative only. The '*Ca*. P. asteris' subgroup B is the most widespread subgroup of the '*Ca*. P. asteris', and is found in Europe (*e.g*. France and Germany, Schneider *et al.* 1993; Poland, Kamińska *et al.* 2001), Asia (*e.g*. Japan, Lee *et al.* 1998) North America (Lee *et al.* 2004), South America (*e.g*. Chile, Fiore *et al.* 2007; Argentina, Torres *et al.* 2004) and Africa, (*e.g*. South Africa, Engelbrecht *et al.* 2010).

'*Ca*. P. asteris' subgroup D is reported from China (Gao *et al.* 2008), Taiwan (Lee *et al.* 2004), Japan (Nakamura *et al.* 1998) and India (Chaturvedi *et al.* 2009b cited in Rao *et al.* 2011)

2.1.1.6 Commodity associations

There are three definitive records of '*Candidatus* Phytoplasma asteris' (*i.e.* 16SrI) in roses: from Poland (Kamińska *et al.* 2006), India (Chaturvedi *et al.* 2009; Rao *et al.* 2011) and China (Gao *et al.* 2008). The record from Poland is of subgroup B; the Chinese record is of subgroup D; the record for India is less clear as it appears the two subgroups reported appear to be for the same isolate: Genbank accession # FJ429364; Chaturvedi *et al.* (2010) reports subgroup B and Rao *et al.* (2011) reports subgroup D. In Poland, '*Candidatus* Phytoplasma asteris' subgroup B was associated with a number of commercial hybrid cultivars in Poland (Kamińska *et al.*, 2003, Kamińska *et al.*, 2001, Kamińska *et al.*, 2005, Kamińska *et al.* 2006).

There is another unconfirmed phytoplasma record from India (Singh *et al.* 1987) and one from South Africa (Meyer, 1960). The South African record by Meyer (1960) described 'little leaf' of roses, and stated that it was especially common in Transvaal. The symptoms of 'little leaf' are consistent with recent descriptions of symptoms of '*Ca.* P. asteris' in roses. Therefore, 'little leaf' of roses in South Africa may be an early report of a phytoplasma, and may potentially be '*Ca.* P. asteris' (Kamińska 2011, personal communication to S. Clark).

Phytoplasmas are systemic within infected plants, although limited to the phloem. The severity of symptoms in roses fluctuates from severe to asymptomatic; but notably, the phytoplasma occurs in asymptomatic rose plants (Kamińska *et al.* 2006).

2.1.1.7 Plant associations

The '*Ca.* P. asteris' group of phytoplasmas (16Sr-I) has the most diverse and widespread host range of any group of phytoplasmas, reported to be associated with more than 80 plant species (Lee *et al.*, 2004). '*Ca*. P. asteris' subgroup B infects a wide range of hosts including food crops, trees, ornamentals and weeds (Lee *et al.*, 2004). The wide host range of subgroup B is considered to be a result of the large number and polyphagous nature of its insect vectors, rather than the specificity of the phytoplasma itself (Lee *et al.* 2000).

Recorded hosts include: ***Rosa* spp. (rose)** (Kamińska *et al.* 2006); *Allium cepa* (onion), *Apium graveolens* (celery), *Brassica* spp., *Calendula officinalis* (marigold), *Hydrangea macrophylla* (hydrangea), *Lactuca sativa* (lettuce), *Lycopersicon esculentum* (tomato), *Medicago sativa* (alfalfa), *Nasturtium microphyllum* (watercress), *Olea europaea* (olive),

Plantago major (plantain), *Populus nigra* 'Italica' (Lombardy poplar), *Pyrus communis* (pear), *Salix* spp. (willows), *Solanum melongena* (eggplant), *Solanum tuberosum* (potato), *Trifolium* spp. (clover), *Vitis* spp. (grape), *Zea mays* (maize) (Lee *et al.* 2004); wheat, canola, barley and flax (Canada Newswire 31 July 2012 http://www.digitaljournal.com/pr/818143)

Subgroup D is reported from *Paulownia* species (Paulowniaceae) and *Rosa rugosa* (Rosaceae) in China (Gao *et al.* 2008). In July 2010 symptoms suggestive of phytoplasma infection were observed in *Impatiens balsamina* (Balsaminaceae) in China, and subsequently in September 2011 rose balsam phyllody (closely related to subgroup 16SrI-D) was then reported from China (Li *et al.* 2011).

2.1.1.8 Potential for establishment and impacts

'Candidatus Phytoplasma asteris' subgroups B and D occur in countries with climates similar to parts of New Zealand. Further, as there are vectors in New Zealand that can potentially transmit '*Ca*. P. asteris' subgroups B and D (see Biology section), and recorded hosts occur in New Zealand, then these subgroups can potentially establish in New Zealand. '*Candidatus* Phytoplasma asteris' subgroups B and D damage their host plants, so are likely to have unwanted impacts in New Zealand.

2.1.1.9 Hazard identification conclusion

Given that '*Candidatus* Phytoplasma asteris' subgroups B and D:

- are reported from *Rosa* spp ;
- are distributed widely in the world;
- but are not reported from New Zealand;
- are potentially able to establish in New Zealand and have unwanted impacts;

they are considered a hazard on *Rosa* spp. nursery stock from all countries in this risk analysis.

2.1.2 Risk assessment

2.1.2.1 Biology

Phytoplasmas are phloem-limited bacteria that lack cell walls and have not been cultured *in vitro* (Davis 1998; Bertaccini 2007).

Disease transmission:
There are three known mechanisms of transmission of phytoplasmas: propagation or grafting of infected material; vascular connections made between infected and non-infected host plants by parasitic plants *e.g.* dodder (*Cuscuta* spp.); and transmission by phloem-feeding insect vectors. There some reports of possible seed transmission (Weintraub and Beanland, 2006; Calari *et al.* 2011). These reports have not been substantiated and it is generally accepted that phytoplasmas are not seed transmitted. Phytoplasmas are not reported to be spread by mechanical transmission (Lee *et al.* 2000).

Phloem-feeding leafhoppers (family Cicadellidae) belonging to the genera *Macrosteles*, *Euscelis, Scaphytopius* and *Aphrodes* are the main vectors of the aster yellows phytoplasma (Lee *et al.*, 2004); [there is a *Macrosteles* species in New Zealand (MacFarlane *et al.* 2010)]. The subgroups vary in the specificity of their relationships with insect vectors; subgroup B is reported to have a low vector specificity (Lee *et al.*, 1998). A pentatomid, *Halyomorpha halys* –brown marmorated stinkbug, has been confirmed as a vector of paulownia witches broom (aster yellows subgroup D) (Weintraub and Beanland 2006).

Disease symptoms and progression:
The symptoms and progression of '*Ca.* P. asteris' subgroup B disease described below are based on observations in commercial rose gardens in Poland (Kamińska *et al.* 2006):

- The percentage of affected roses varied depending on the year, cultivar and farm.
- Symptoms were varied and the severity fluctuated.
- Affected roses had stunted growth, bud proliferation, leaf discolouration and malformation, leaf drop, deficiency of flower buds, or flowers of very poor quality with degenerated floral parts. Some cultivars had increased production of thorns.
- The most severe symptoms were observed in early spring, included dieback and some affected plants died in summer.
- However, most of the diseased roses or some parts of them showed improvement and in summer developed new growth.
- In the following year most of the affected roses recovered, but they had retarded growth, unclear leaf malformation and/or chlorosis and poor flower production.
- Most roses showing severe symptoms were removed. But because of the tendency of plants to recover, growers assumed the plants had a physiological disorder, and plants were allowed to grow. However, the number of symptomatic plants gradually increased within two years of symptoms being first noticed, until symptoms (albeit variable) were widespread in cultivars.

The symptoms observed for subgroup D in roses include stunting, yellowing, witches-broom and dieback (Gao *et al.* 2008).

Disease Latency:
Kamińska *et al.* (2006) showed that phytoplasma infection occurs in roses that are asymptomatic of disease, *i.e*. that latent phytoplasma infection occurs. This finding applied to at least two categories of plants that were symptomless: 1) plants that had recovered and then showed no clear symptoms; 2) older plants that had no symptoms, but where the younger plants had had flower proliferation. The description in Kamińska *et al.* (2006) of the presence of phytoplasma in a third category is ambiguous and so is not further described here.

Other evidence that phytoplasma infection occurs asymptomatically in *Rosa,* and other species, are the reports of European stone fruit yellows (16SrX-B) in *Rosa canina* in France (Jarausch *et al.* 2001), of '*Ca.* P. asteris' being present in asymptomatic ashleaf maple trees in Poland (Kamińska and Śliwa, 2005), and of '*Ca.* P. asteris' being present in asymptomatic grapevines in Canada (Olivier *et al.* 2009).

Association of phytoplasmas with 'little leaf' disease:
'Little leaf' is a common symptom associated with phytoplasma diseases, but very rarely with viruses[1]. The description of '*Ca.* P. asteris' (subgroup unreported) associated with roses in India describes symptoms of 'little leaf' disease, yellowing and shortening of internodes. The association of '*Ca.* P. asteris' with these roses was confirmed by molecular analysis of DNA extracts (Chaturvedi *et al.* 2009).

The report of 'little leaf' on roses in South Africa (Meyer 1960) is possibly an early report of a phytoplasma because the symptoms are highly consistent (Kaminksa 2011, pers. comm. to S. Clark). It is not possible to determine from symptoms alone which group or subgroup of phytoplasma caused the 'little leaf' disease, but '*Ca.* P. asteris' is a likely candidate.

Association of phytoplasmas with 'rose rosette' disease:
Horst and Cloyd (2007) state that "the causal agent of rose rosette has now been reported to be caused by an aster yellows phytoplasma belonging to group 16SrI-B (apple proliferation group[2]) [sic] ….is believed to be transmitted by the woolly mite *Phyllocoptes fructiphilus* Keifer, an eriophyid mite" They add that "to date, only leafhoppers (which have phloem-piercing mouthparts) have been known to transit [sic] phytoplasmas'. The conclusions of Horst and Cloyd are likely to be overturned by a very recent study. Laney *et al.* 2011) have characterised a virus which is strongly associated with the rose rosette disease (see 6.3).

2.1.2.2 Entry assessment

Rosa nursery stock entering New Zealand is likely to be arriving either as whole plants with leaves and roots, in a soil-less sterile rooting media; or as dormant cuttings consisting of stem only, possibly with buds but without roots or leaves; or as tissue cultures in sealed bags or containers.

'Candidatus Phytoplasma asteris' subgroup B is widespread in the world and subgroup D is reported from China, Taiwan, Japan and India.

It is expected that only healthy looking plants would be selected for export. It is common for infected plants to have symptoms such as yellowing, and/or leaf malformation and these are likely to be rejected for export. But infected plants can also be asymptomatic and therefore appear healthy.

It would be difficult to detect symptoms in dormant cuttings and tissue cultures, more so if the parent plants were infected with phytoplasma and asymptomatic.

'Candidatus Phytoplasma asteris' is a phloem limited organism and so can potentially enter New Zealand by any form of *Rosa* nursery stock.

The likelihood of entry is considered to be moderate.

2.1.2.3 Exposure assessment

The act of using the *Rosa* nursery stock for the intended purpose, i.e. planting, propagating and grafting, will fulfil the requirements of exposure. That is, the phytoplasma will occur in

1. A search of CAB Abstracts 1990 to 2011 using search terms 'little leaf' AND 'virus*' produced 42 records, whereas there were 132 records using the search terms 'little leaf' AND 'phytoplasma*'. Closer inspection of the abstracts of the 42 'virus*' records revealed that over >92% of these reports associated the 'little leaf' symptoms to phytoplasmas (previously known as mycoplasma-like organisms) or virus-like organisms. Only 8% associated the 'little leaf' symptoms to a virus.
2. Note that Horst and Cloyd (2007) have made an error here; 'apple proliferation group' is group 16SrX-A

a living host plant in the New Zealand environment and thus be exposed to potential insect vectors.

The likelihood of exposure is considered to be high.

2.1.2.4 Assessment of establishment and spread

'Candidatus Phytoplasma asteris' occurs in tropical to cool temperate regions. There is no evidence to suggest that its distribution is limited by climate and so in New Zealand it is unlikely that climate would limit its ability to establish. Many reported host plants are common in New Zealand as either agricultural, horticultural or amenity species (*e.g.* maize, barley, wheat, tomato, onion, carrots, roses, pear, poplar and willow); weeds (*e.g.* plantain) or garden plants (*e.g.* hydrangea, roses, marigolds). Host plant availability is very unlikely to inhibit establishment.

Plants that show symptoms of a phytoplasma infection are unlikely to be propagated from. However, a recently infected plant, or plants with a latent infection (asymptomatic) of '*Ca.* P. asteris', could be propagated from thereby inadvertently spreading the phytoplasma. Movement of infected plants throughout the country also increases the spread and exposure to different suites of potential vectors.

Although none of the reported vectors of '*Ca.* P. asteris' are present in New Zealand, this cannot be interpreted to mean that New Zealand does not have other insects capable of spreading this phytoplasma. '*Ca.* P. asteris' has a wide range of reported insect vectors, but this list of reported vectors is likely to be incomplete.

It is possible that the establishment and spread of '*Ca.* P. asteris' in New Zealand might be limited by a lack of vectors, but this is considered unlikely. There is a species present in New Zealand from the vector genus *Macrosteles* (Larivière 2005; and updates). In addition, two species of the *Zeoliarus* genera are known to transmit '*Candidatus* Phytoplasma australiense' in New Zealand; *Zeoliarus atkinsoni* only feeds on native flax and transmits the phytoplasma from *Phormium* to *Phormium* (Liefting *et al.* 1997), whereas *Zeoliarus oppositus* has been demonstrated to transmit the phytoplasma from *Coprosma* to *Coprosma* and *Coprosma* to *Cordyline* (Beever *et al.* 2008). As *Z. oppositus* is a polyphagous feeder, and is a potential vector of '*Candidatus* Phytoplasma asteris' (particularly as subgroup B is reported to have low vector specificity (Lee *et al.* 1998)), it therefore has the potential to transmit phytoplasmas to a wide range of host plants. New Zealand also has planthoppers that could vector phytoplasmas.

Given that:

- The known vectors of these phytoplasmas are not present in New Zealand, but:
- There are many potential insect vectors;
- Many hosts of the phytoplasmas are in New Zealand;
- Some hosts may be asymptomatic and be propagated from;
- Climate is unlikely to be a barrier to establishment;

The likelihood of establishment and spread of the 'Candidatus Phytoplasma asteris' subgroups B and D is considered to moderate to high.

2.1.2.5 Consequence assessment

Phytoplasmas are associated with a wide range of symptoms affecting all plant parts; typical symptoms include 'little leaf', abnormal root growth, overall stunting, shoot proliferation, leaf yellowing, flower phyllody and virescence, as well as a general decline that is sometimes fatal (Agrios 2005). Symptoms can be misleading, with similar symptoms in the same host caused by different phytoplasmas, different strains causing different symptoms in the same host (Davis and Sinclair 1998), and different symptoms in different hosts caused by very similar phytoplasmas (Lee *et al.* 2004).

The consequences of '*Ca*. P. asteris' in New Zealand will depend on which vectors transmit it. If there are few or no vectors, or the vectors are confined to a limited range of plants, the impacts will be minimal. If '*Ca*. P. asteris' is transmitted by one of the widespread and common vector species with a wide host range, the impacts will be large. There is currently not enough known about the potential vectors of aster yellows in New Zealand to determine how significant an impact it would have in New Zealand, and there is a high degree of uncertainty about the impacts.

Economic consequences

'Candidatus Phytoplasma asteris' has been reported overseas on a number of crops which are agriculturally or horticulturally important to New Zealand. The largest horticultural export earner for the year to end of June 2011, was grapes (as wine), worth $1085.4 million and the fourth largest was onions, worth $110.2 million. For the same time period frozen potatoes earned $89 million, frozen sweet corn $40.5 million, fresh potatoes, tomatoes, carrots and brassicas jointly earned $49.9 million. On the domestic market potatoes, corn, tomatoes, carrots, brassicas and onions combined earned $719.3 million (Plant and Food Research 2011).

Several symptoms of '*Ca*. P. asteris' affect flowers, such as: virescence (greening of flowers), phyllody (conversion of petals and sepals to more leaf-like structures) and sterility of flowers. These types of symptoms would have severe impacts for seed or ornamental crops. Export earnings to the end of June 2010 were $35.1 million from flowers and foliage, $57.4 million from vegetable seeds and $41.3million from other seeds, bulbs and plants (Plant and Food Research 2010). Other symptoms are likely to reduce the yield and quality of fruit.

*The potential economic consequences of '*Ca. *P.asteris' subgroups B and D are highly uncertain and depend on the phytoplasma/vector relationship. The economic consequences could range from negligible (if there are few or no vectors, or if vectors transmit the phytoplasma ineffectively) to high (if it were to be transmitted by a widespread, polyphagous vector affecting high value perennial crops like grape).*

Environmental consequences

Phytoplasmas are one of the few pathogen groups in New Zealand to have been associated with a serious epidemic in native plant populations (Liefting *et al.*, 2007, Phillips *et al.*, 2008). '*Ca* .P. asteris'-infected leafhoppers that feed on native plants may infect those plants. Because the host range of '*Ca* .P. asteris' appears to be largely determined by the specificity of the insect vectors, the native plants infected and the level of damage that occurs will depend on which leafhoppers in New Zealand act as a vector and whether or not the plant is susceptible. This is difficult to predict given the limited information on the ability of insects in New Zealand to transmit '*Ca*. P. asteris' subgroup B. However, given that a phytoplasma interacting with a native polyphagous vector produced a serious epidemic in the endemic

cabbage tree (*Cordyline australis*) (Beever *et al.*, 2004), there is cause for concern about the impacts of other phytoplasmas in native ecosytems.

The potential environmental consequences of 'Ca. P. asteris' subgroups B and D are highly uncertain and depend on the phytoplasma/vector relationship. The environmental consequences could range from negligible (if there are few or no vectors or if vectors transmit the phytoplasma ineffectively) to high (if it were to be transmitted by a widespread, polyphagous vector affecting native plants).

Human health consequences

There are no known human health consequences associated with '*Ca*. P. asteris' subgroups.

Socio-cultural consequences

Overseas, '*Ca*. P. asteris' has infected a number of amenity plants, such as willow, poplar and paulownia. Other reported hosts include roses, hydrangeas, delphiniums, marigolds, tomatoes, carrots and potatoes which are commonly grown by home gardeners. If '*Ca*. P. asteris' affects similar species in New Zealand as it does abroad then it is expected that there will be impacts upon amenity and domestic plantings.

The potential socio-cultural consequences of 'Ca. P. asteris' subgroups B and D are considered to be low.

Risk estimation

The likelihood of entry for *Ca*. P. asteris subgroups B and D is moderate, the likelihood of exposure is high and the likelihood of establishment mod-high. The economic and environmental consequences are uncertain and could be negligible to high depending on factors discussed in section 2.1.2.5; sociocultural consequences are considered to be low.

As a result the risk estimate for 'Ca. P. asteris' subgroups B and D is non-negligible and it is classified as a risk in the commodity. The risk is worth considering and further analysis may be undertaken to decide if additional measures are warranted.

Risk management for this phytoplasma is discussed in the Risk Management Proposal document.

2.2 '*Candidatus* Phytoplasma aurantifolia' (lime phytoplasma)

Scientific name:	'*Candidatus* Phytoplasma aurantifolia' Zreik *et al*. 1995 [Class: Mollicutes; Order: Acholeplasmatales; Family: Acholeplasmataceae]
Other relevant scientific names:	Phytoplasma group 16SrII
Common names:	lime witches' broom phytoplasma; witches' broom disease of lime (WBDL)

2.2.1 Hazard identification

2.2.1.1 Description

Phytoplasmas are phloem-limited bacteria that lack cell walls and have not been cultured (Davis and Sinclair 1998; Bertaccini 2007). They are associated with a wide range of symptoms affecting all plant parts; typical symptoms include 'little leaf', abnormal root growth, overall stunting, shoot proliferation, leaf yellowing, flower phyllody and viresence, as well as a general decline that is sometimes fatal (Agrios 2005)

2.2.1.2 Taxonomy

Phytoplasmas form a distinct clade in the Class *Mollicutes*. The phytoplasma clade has been proposed to represent at least a genus, with each subclade (16Sr RNA group) proposed to represent at least species (Gundersen *et al*. 1994). In 2004 the IRPCM Phytoplasma/Spiroplasma Working Team-Phytoplasma taxonomy group suggested rules around the description of organisms as novel taxa within the taxon '*Ca.* Phytoplasma'. *'Candidatus* Phytoplasma aurantifolia' is the species that includes the Peanut witches broom group 16SrII. '*Candidatus* P. aurantifolia' was first reported from lime trees in Oman (Zreik *et al*. 1995). 16SrII comprises several subgroups (A, B, C, D, E, F). For the purpose of this document, this risk analysis of '*Ca.* P. aurantifolia' will be carried out at the level of the group 16SrII given the reporting of '*Ca.* P. aurantifolia' in rose was not defined at any level below 16SrII '*Ca* P. aurantifolia'.

2.2.1.3 New Zealand status

The phytoplasma '*Candidatus* Phytoplasma aurantifolia', nor any of the subgroups of **'***Candidatus* Phytoplasma aurantifolia' (16SrII) are known to be present in New Zealand. Not recorded in: PPIN (2011); Pearson *et al*. (2006); Liefting *et al*. (2007).

2.2.1.4 Geographic distribution

Up to January 2013 the distribution of 'Ca. P. aurantifolia' included the European, Asian, Australian and South American continents and several island nations.

'*Ca.* P. aurantifolia' (16SrII) has been reported from India (Ghosh *et al*. 1999, Arocha *et al.* 2009), Indonesia (Harling *et al*. 2009) Iran (Salehi *et al*. 2007), Japan (Naito *et al*. 2007), UAE and Oman (Zreik *et al*. 1995), Italy (Parrella *et al.* 2008), Cuba (Arocha *et al*. 2006), Bolivia (Arocha *et al*. 2010), UK (Reeder *et al*. 2010), Australia (WA, Saqib *et al*. 2005) New Caledonia, Vanuatu and Tonga (Davis *et al*. 2006).

2.2.1.5 Commodity associations

Ca. Phytoplasma aurantifolia has been reported from *Rosa* sp. in Bolivia (Arocha *et al.* 2010). At the time of writing it has not been reported in *Rosa* from elsewhere. Although there is only one record for '*Ca.* P. aurantifolia' in *Rosa*, this is a very recent record and is therefore considered in this import risk assessment.

Phytoplasmas are systemic within infected plants, although limited to the phloem. Therefore, phytoplasmas may be associated with all parts of the rose plant that are imported.

2.2.1.6 Plant associations

'*Ca.* P. aurantifolia' has been reported from a range of families which include plants of economic importance such as *Citrus*, *Prunus* and *Vitis* The host range of phytoplasmas is very dependent on the insect vectors (Bertaccini & Duduk 2009). Zirak *et al.* (2009) state "the presence of wide host range of '*Ca.* P. aurantifolia' in trees, perennials, and annual plants in south and centre of Iran suggests the involvement of common and efficient unknown insect vector(s) and the fact that it will probably create epidemics in the near future."

The following table includes some of the known hosts of '*Ca.* P. aurantifolia', but it is inferred from Zirak *et al.* (2009) that there are numerous other hosts.

Table 2. Some of the reported hosts of *'Ca.* P. aurantifolia'

Plant host	Phytoplasma was reported as:	Vector (putative* or known)	Country reported from	References
Rosa sp.(Rosaceae); *Podocarpus macrophylla* (Podocarpaceae); *Physallis ixocarpa*, tomatillo (Solanaceae)	'*Ca.* P. aurantifolia' (16SrII group)	-	Bolivia	Arocha *et al.* 2010
Citrus aurantifolia (Rutaceae)	Proposed name'*Ca.* P. aurantifolia'	*Hishimonus phycitis**	Oman, UAE, Iran	Zreik *et al.* 1995; Bové *et al.* 2000
Citrus aurantifolia, (Rutaceae) *C. reticulata* hybrid (Rutaceae)	'*Ca.*P.aurantifolia'	*Hishimonus phycitis*	Iran	Salehi *et al.* 2007
Prunus dulcis, almond (Rosaceae)	WB group (16SrII) '*Ca.* P. aurantifolia'	-	Iran	Zirak *et al.* 2009
Cicer arietinum chickpeas (Fabaceae)	16SrII group '*Ca.* P. aurantifolia'	-	Australia (WA)	Saqib *et al.* 2005
Cyanthileum cinereum (Asteraceae)	'*Ca.* P.aurantifolia' (16SrII) group	-	Tonga	Davis *et al.* 2006
Ipomoea batatas (Convolvulaceae)	'*Ca.* P.aurantifolia' (16SrII) group	-	Tonga, New Caledonia, Vanuatu	Davis *et al.* 2006
Lycopersicon esculentum [sic], tomato (Solanaceae) Accepted name now *Solanum lycopersicon*	'*Ca.* P.aurantifolia' (16SrII) group	-	New Caledonia	Davis *et al.* 2006
Carica papaya, papaya (Caricaceae),	16SrII group '*Ca.* P. aurantifolia'	*Empoasca papayae**	Cuba	Arocha *et al.* 2007

Anoda acerifolia (Malvaceae), *Euphorbia heterophylla* (Euphorbiaceae), *Malvastrum coromandelianum* (Malvaceae), *Rhyncosia minima* (Fabaceae)				
Pelargonium capitatum (Geraniaceae)	'*Ca.*P.aurantifolia' (16SrII) group	-	Australia	Lee *et al.* 2010
Chrysanthemum grandiflorum (Asteraceae)	"a strain of *Ca.* P. aurantifolia"	*Orosius orientalis**	Japan	Naito *et al.* 2007
Fallopia japonica Japanese knotweed (Polygonaceae)	'*Ca.* P. aurantifolia'	-	UK	Reeder *et al.* 2010
Prunus persica, peach (Rosaceae)	'*Ca.* P. aurantifolia'	-	Iran	Zirak *et al.* 2010
Foeniculum vulgare, fennel (Apiaceae)	WB group, a strain of '*Ca.*P.aurantifolia'	-	India	Bhat *et al.* 2008
Catharanthus roseus, pink periwinkle (Apocyanaceae); Troyer citrange; *Citrus jambhiri*, rough lemon; *C. limonia*, Rangpur lime (Rutaceae)	WBD	-	India,	Ghosh *et al.* 1999
Capsicum spp., chilli; *Solanum betaceum*, tamarillo (Solanaceae)	Group 16SrII '*Ca.*P.aurantifolia'	-	Indonesia	Harling *et al.* 2009
Carica papayae, papaya (Caricaceae)	16SrII group ('*Ca.* P. aurantifolia')	-	India	Rao *et al.* 2011
Zygocactus truncates Christmas cactus (Cactaceae)	Strain '*Ca.* P.aurantifolia' group 16SrII	-	China	Cai *et al.* 2007
Vitis vinifera, grapevine (Vitaceae)	'*Ca.* P. aurantifolia' ribosomal subgroup 16SrII-B	-	South Africa	Botti and Bertaccini 2006

2.2.1.7 Potential for establishment and impacts

'*Ca.* P. aurantifolia' occurs in countries with climates similar to parts of New Zealand. Further, as there are vectors in New Zealand that can potentially transmit '*Ca.* P. aurantifolia' (see Biology section), and recorded hosts occur in New Zealand, then it can potentially establish in New Zealand. '*Ca.* P. aurantifolia' causes damage to its host plants, some of which are of economic importance, therefore can potentially cause unwanted impacts in New Zealand.

2.2.1.8 Hazard identification conclusion

Given that '*Ca.* P. aurantifolia'

- Is not known to be present in New Zealand;
- Is present in many of the countries we trade with;
- Is known to be associated with *Rosa* spp.;
- Potentially can establish in New Zealand and have unwanted impacts;

It is therefore considered a hazard in this risk analysis.

2.2.2 Risk assessment

2.2.2.1 Biology

The organism '*Ca.* P. aurantifolia' was first reported from *Citrus aurantifolia*, Mexican lime trees in Oman where it caused Witches broom disease of lime, (WBDL). Since then it has been reported elsewhere on other hosts. In 2009 a 16SrII phytoplasma was reported in roses in Bolivia, but there does not appear to be any further information on it related to roses. The one plant that has received a great deal of research attention is the Mexican/acid lime. Therefore the information supplied is largely that of work done on this phytoplasma in lime trees.

WBDL caused by '*Ca.* P. aurantifolia' is a lethal disease, usually causing death of trees 5-10 years after the first witches broom symptoms appear.

Disease transmission:
Phytoplasmas are not reported to be spread by mechanical transmission (Lee *et al*. 2000).

'*Ca.* P. aurantifolia' can be graft transmitted, or naturally transmitted via insect vectors such as leafhoppers [Orders Cicadelloidea and Fulgoroidea] and the parasitic plant, dodder. There is some puzzlement regarding the origins of this phytoplasma. It may have already been in the Arabian Peninsula/Iran region and only started spreading with the introduction of a leafhopper from the Indian subcontinent, or it may have originated in the Indian subcontinent and arrived with the leafhopper, *Hishimonus phycitis*, which is known to vector other phytoplasma-associated diseases (Zreik *et al.* 1995; Bové *et al*. 2000). It does confirm that vectors play a critical role in phytoplasma infections of new plants.

Insect vectors that have been reported transmitting '*Ca.* P. aurantifolia' are the Cicadellid leafhoppers *Empoasca papaya* Oman– (Cuba, Arocha *et al*. 2007), *Hishimonus phycitis* (Distant) – (Iran, Salehi *et al*. 2007) and the highly polyphagous *Empoasca decipiens* Paoli– (Saudi Arabia, Alhudaib *et al*. 2009; Italy, Parrella *et al.* 2008). It is likely there are others but as yet confirmation of this has not been published.

The relationship between insects and phytoplasmas is complex and variable. The following two paragraphs on vector-phytoplasma transmission are a simplified overview from the review by Weintraub and Beanland (2006). Acquisition of phytoplasma is passive, and occurs during phloem feeding. The acquisition time can be within a few minutes but is more commonly hours, with a higher likelihood of acquisition the longer feeding occurs on an infected plant. Phytoplasma titre within a plant may also affect acquisition. There is a latent period between acquisition and transmission to a new host, which is temperature dependent,

and "ranges from a few minutes to 80 days". During the latent period phytoplasmas replicate in the body of the competent vector.

For transmission to occur phytoplasmas must penetrate certain salivary gland cells and high levels must accumulate in the posterior acinar cells before they can be transmitted. At each point of the process, should the phytoplasmas fail to enter and exit specific tissues the insect becomes a dead-end host with no transmission of the phytoplasmas. For instance, there are three membrane barriers in the salivary glands that must be crossed before phytoplasmas may be ejected with saliva. Phytoplasma-infected leafhoppers may not necessarily transmit phytoplasmas to a healthy plant. Additionally, leafhoppers can alter their feeding behaviours depending on the plant host, and thus influence the titre of phytoplasma ingested or not acquire phytoplasmas. Leafhoppers do not readily feed from the phloem of non-preferred hosts and therefore some plants are unlikely to become infected.

Graft transmission is another route by which '*Ca.* P. aurantifolia' infects new plants. Propagation for new plants in both citrus and in roses is often done by grafting. Ghosh *et al*. (1999) report that within 8-14 months all grafted lime seedlings developed symptoms similar to those observed on adult trees. They also reported that the phytoplasma was transmitted by grafting to Troyer citrange, rough lemon and Rangpur lime; it took 20 months for symptoms to develop in sweet orange (mosambi), mandarin (Nagpur), and trifoliate orange. Salehi *et al.* 2002 reported dodder or graft inoculation of WBDL to 25 herbaceous plants, with 7 (*e.g. Solanum lycopersicon3, Nicotiana glutinosa, N. tabacum, S. melongena, S. nigrum*) showing symptoms such as floral virescence, proliferation of crown buds and stem buds, small leaves and stunting. However none of these plants were found to be naturally infected.

Seed transmission of phytoplasmas is mostly thought not to occur. As there is no direct connection between sieve elements and embryo, some researchers dispute seed transmission. The presence of phytoplasma in seed coat and embryo is not enough to assume seed transmission occurs. Seed transmission of phytoplasma has been reported for tomato, oilseed rape and lime plantlets (Botti and Bertaccini 2006). The study used seeds that were from infected or symptomatic plants and germinated under sterile conditions in a growth chamber at 24˚C and a 16h/d photoperiod. Tests were carried out on 2 and 3 week old tomato and winter oilseed rape seedlings and on 3-5 month old lime seedlings using direct PCR (16S ribosomal primers P1/P7), RFLP analyses and sequencing of selected cloned amplicons to verifly phytoplasma identity, then nested PCR. Some of the samples yielded positive results with phytoplasmas from 16Sr1, 16SrXII and 16Sr II identified (Botti and Bertaccini 2006). However, Faghihi *et al*. (2010) conducted experiments germinating 6,000 infected and non-infected lime seeds, sampled every 3 months over a 2 year period and concluded "that seed transmission of WBDL phytoplasma does not occur in lime….that WBDL phytoplasma may be detected in seed of infected plants but is confined to the seed coat". Faghihi *et al*. (2010) noted that the weight of seed from fruit from symptomatic branches was 50% less than seed from fruit off asymptomatic branches. Although the majority (80%) of seed sourced from symptomatic fruit was viable, Faghihi *et al*. (2010) stated that often seedlings derived this way were less vigorous.

Symptoms, latency and progression:
Symptoms vary somewhat between affected species:

- rose: little leaf, yellowing (Arocha *et al*. 2010)

3 Reported in Salehi et al. (2002) by its former name-*Lycopersicum esculentum*

- lime: small chlorotic leaves, highly proliferated shoots, shortened internodes, premature leaf-drop, distortion of infected twigs and dieback of branches with advanced stage infection (Ghosh *et al*. 1999);
- chrysanthemum: virescence (greening) of flowers, phyllody, yellowing of leaf edges, proliferation of lateral shoots (Naito *et al.* 2007)
- papaya: yellowing, crinkling and leaf-tip necrosis, drying out of the upper leaves which progresses to death of entire plant (Rao *et al*. 2011)
- peach: yellowing and rosetting of leaves (Zirak *et al*. 2010)
- almond: isolates that were phytoplasmas related to the peanut witches broom group 16SrII induced shoot proliferation, yellowing and little leaf (Zirak *et al*. 2009).
- Grapevine: premature yellowing or reddening, downward rolling of leaves, and in some cases extensive lack of cane lignification (Botti and Bertaccini 2006)

Disease latency or apparent absence of symptoms appears to be characteristic of several phytoplasmas (*e.g*. 16Sr X-B in *Rosa canina*, France- Jarausch *et al*. 2001; *Ca*. P. asteris in grapevine, Canada- Olivier *et al*. 2009). There is no indication that this occurs with '*Ca.* P. aurantifolia' in lime trees and there is no information regarding this in roses. However Ghosh *et al*. (1999) commented that it took 20 months to see symptoms after graft inoculation of orange, mandarin and trifoliate orange. Zirak *et al*. (2009) noted that samples from almond collected in the spring were harder to detect phytoplasma in. A similar difficulty is reported for '*Ca.* P. mali' in apples, and also for phytoplasmas in stonefruit taken in late spring. It is suggested this is related to the time needed for development of phytoplasmas in stems, branches and new leaves (Zirak *et al*. 2009). It is assumed this may be the case for roses as well given that they too are a mostly deciduous genus within the Rosaceae.

2.2.2.2 Entry assessment

Rosa nursery stock entering New Zealand is likely to be arriving either as whole plants with leaves and roots, in a soil-less sterile rooting media; or as dormant cuttings consisting of stem only, possibly with buds but without roots or leaves; or as tissue cultures in sealed bags or containers. This risk analysis is for *Rosa* species from all countries, and there are several from where '*Ca.* P. aurantifolia' is reported.

It is expected that cuttings would only be taken from plants with proven health. However, if the plant was recently infected and not yet presenting symptoms or the symptoms were very mild and not detected then the plant, cutting or tissue culture could enter New Zealand carrying the phytoplasma.

To date, '*Ca*. P. aurantifolia' has been reported recently (in 2010) from *Rosa* species only in Bolivia; the specific 16SrII subgroup was not reported. It is not certain if other 16SrII subgroups of '*Ca.* P. aurantifolia' would infect *Rosa* species. There may be unreported cases of the 16SrII phytoplasma group in *Rosa* species, and the 16SrII phytoplasma group is present in countries New Zealand imports live plant material from.

*The likelihood of entry is considered to be low, with some uncertainty regarding occurrence of '*Ca. *P. aurantifolia' in* Rosa *species in other countries.*

2.2.2.3 Exposure assessment

Rosa nursery stock is destined to be planted, propagated or grafted and therefore any phytoplasma will be transmitted by propagation or grafting and subsequently will be exposed to potential insect vectors.

The likelihood of exposure is considered to be high.

2.2.2.4 Assessment of establishment and spread

'*Ca.* P. aurantifolia' is present in countries with similar ecoclimatic areas to New Zealand, and is in reported from host plants that will grow readily in New Zealand conditions (*e.g. Rosa, Prunus, Citrus, Vitis*). Additionally, many of the weedy and ornamental hosts are already present in New Zealand (*e.g.* dodder, *Convolvulus*, *Plantago*, fennel, periwinkle, *Fallopia* are all wild; *Pelargonium capitatum*, and *Podocarpus macrophyllus* are in cultivation; NZFlora 2011). New Zealand also has a suite of potential insect vectors.

Symptomatic plants are unlikely to be propagated from. However an infected plant with an early infection or no obvious disease expression could be propagated from and thereby spread the phytoplasma unintentionally. Movement of infected plants or plant material through the country increases the spread and exposure to potential vectors.

The reported known and putative vectors, the Cicadellids *Hishimonus phycitis, Empoasca papaya* and *Orosius orientalis*, are not in New Zealand, but this cannot be interpreted to mean New Zealand does not have insects capable of transmitting '*Ca.* P. aurantifolia'. There are many species of leafhoppers/planthoppers present in New Zealand (MacFarlane *et al.* 2010). The native Cixiids *Zeoliarus atkinsoni* and *Z. oppositus* both are known to transmit '*Ca.* P. australiense' in New Zealand (Liefting *et al.* 1997; Beever *et al*. 2008). There are host plants, particularly in the weed species that are widespread within New Zealand and therefore potential reservoirs of disease.

Given that:

- The known and putative vectors of '*Ca.* P. aurantifolia' are not present in New Zealand, but;
- New Zealand has a suite of potential insect vectors;
- Many of the known hosts of '*Ca.* P. aurantifolia' are widespread in New Zealand;
- Climate is unlikely to be a barrier;

The likelihood of establishment and spread of '*Ca. P. aurantifolia*' *is considered to be moderate to high*

2.2.2.5 Consequence assessment

The consequences of '*Ca.* P. aurantifolia' in New Zealand will depend on which vectors transmit it. If there are few or no vectors, or if the vectors have a limited range of host plants the impacts may be minimal. If the vectors have a wide host range then this increases the impacts. Currently there is not enough known about potential vectors of '*Ca.* P. aurantifolia' in New Zealand to determine how significant an impact it would have on New Zealand, and there is a high degree of uncertainty about the impacts.

Economic consequences

Hosts of '*Ca.*P.aurantifolia' that have economic importance to New Zealand include tomato, citrus, grapevines, peach, sweet potato, roses and chrysanthemums.

New Zealand's biggest horticultural export was grapes as wine, earning $1085 million in 2011. Kumara (sweet potato) earned $25 million on the domestic market; citrus earned $49 million on the domestic market with exports earning $7.4 million and tomatoes earned $113

million domestically and $18.5 million as exports in the year to June 2011 (Plant and Food Research 2011).

It is likely that symptoms of little leaf, chlorosis or reddening, leaf rosetting, rolling and premature leaf drop will affect the plants ability to photosynthesise and reduce yields; shoot proliferation, distortion, lack of lignification and dieback are likely to reduce yields and affect plant health; virescence and phyllody in flowers for the cutflower market renders them unsaleable.

The potential economic impact of '*Ca. P. aurantifolia*' *within New Zealand is very uncertain and depends on the phytoplasma/vector relationship. The economic consequences could range from negligible (no vectors, or inefficient vectors) to moderate (widespread polyphagous vector/s transmitting the phytoplasma to high value crops).*

Environmental consequences

Phytoplasmas are one of the few pathogen groups in New Zealand to have been associated with a serious epidemic in native plant populations (Liefting *et al*. 2007; Phillips *et al.* 2008). It is uncertain that an infected vector feeding on native plants would transmit the phytoplasma. As the host range of a phytoplasma is largely determined by the specificity of its insect vectors, the native plants affected in New Zealand are likely to be determined by which leafhoppers/planthoppers can act as vectors. This is currently unpredictable as there is no information available on the ability of insects in New Zealand to transmit '*Ca. P. aurantifolia',* other than the awareness that there are potential vectors in the Cicadellidae.

However, given that a phytoplasma interacting with a native polyphagous vector caused a serious epidemic in the endemic cabbage tree (*Cordyline australis*) (Beever et al. 2004) there is reason to be concerned about the impacts of other phytoplasmas in native ecosystems. Additionally, it would be very difficult to control such a disease within a native ecosystem compared to the ability to control within a cultivated system.

The potential economic impact of 'Ca. P. aurantifolia' within New Zealand is very uncertain and depends on the phytoplasma/vector relationship. The environmental consequences could range from negligible (no vectors, or inefficient vectors) to high (widespread polyphagous vector/s transmitting the phytoplasma to native and endemic plant, and a greatly reduced ability to control for this in native ecosystems).

Human health consequences

There are no known human health consequences of '*Ca.*P.aurantifolia'.

Socio-cultural consequences

Some of the hosts listed in this risk analysis are common in domestic and amenity gardens. Roses and chrysanthemums are widely grown and enthusiasts exhibit blooms at horticultural shows; citrus is widely grown, with limes becoming increasingly popular. Kumara has cultural significance to Maori as a food crop and therefore is taonga (treasure).

It is likely that '*Ca.* P. aurantifola' would have an impact upon the growers of these plants.

The potential socio-cultural consequences of 'Ca. P. aurantifolia' are considered to be low, and moderate if kumara is affected.

2.2.2.6 Risk estimation

The likelihood of entry is considered to be low; exposure is high; establishment and spread moderate to high. The economic and environmental consequences are uncertain and could

range from negligible to high, as discussed in section 5.2.2.5; human health consequences are negligible and socio-cultural are low to moderate.

*As a result the risk estimate for '*Ca*. P. aurantifolia' is non-negligible and it is classified as a risk in the commodity. Therefore the risk is worth considering and further analysis may be undertaken to decide if additional risk management measures are warranted.*

2.3 '*Candidatus* Phytoplasma mali' (apple proliferation phytoplasma)

Scientific name: '*Candidatus* Phytoplasma mali' [Class: Mollicutes; Order: Acholeplasmatales; Family: Acholeplasmataceae]
Other relevant scientific names: Phytoplasma group 16SrX-A
Common name: apple proliferation phytoplasma (AP)

2.3.1 Hazard identification

2.3.1.1 Pathogen synopsis

Phytoplasmas are phloem-limited bacteria that lack cell walls and have not been cultured *in vitro* (Davis 1998; Bertaccini 2007). They are associated with a wide range of symptoms affecting all plant parts; typical symptoms include 'little leaf', abnormal root growth, overall stunting, shoot proliferation, leaf yellowing, flower phyllody and viresence, as well as a general decline that is sometimes fatal (Agrios 2005).

2.3.1.2 Taxonomy

Phytoplasmas form a distinct clade in the Class *Mollicutes*. The phytoplasma clade has been proposed to represent at least a genus, with each subclade (16Sr RNA group) proposed to represent at least species (Gundersen *et al.* 1994). The apple proliferation phytoplasma, '*Candidatus* Phytoplasma mali' is the representative phytoplasma for the subgroup 16SrX-A. For the purposes of this risk assessment it will be referred to as '*Ca.* P. mali'.

2.3.1.3 New Zealand status

None of the subgroups of '*Ca.* P. mali' are known to be present in New Zealand. Not recorded in: PPIN (2011); Pearson *et al.* (2006); Liefting *et al.* (2007).

2.3.1.4 Exporting country status

All countries of the world are considered exporting countries for the purposes of this risk analysis.

2.3.1.5 Geographic distribution

'Ca. P. mali' is found in most of Europe, Turkey and Syria (Sullivan 2011). It has been eradicated from the UK (Davies *et al*. 1986), and has **not** been reported from the Americas, Australia, Africa or most of Asia (Sullivan 2011).

2.3.1.6 Commodity associations

'Ca. P. mali', 16SrX-A is reported from rose in Poland (Kamińska and Śliwa 2004). Although there is only one report at this time, it is a recent record, and from a European Union (EU) member country. The EU operates as a 'single market' allowing goods, people, services and money to move freely as in a single country without the former obstructions of national borders and barriers (http://europa.eu/pol/singl/). There is the potential for this phytoplasma to be in roses elsewhere in the EU. New Zealand imports *Rosa* nursery stock from European Union member countries (*e.g*. Germany).

Phytoplasmas are systemic within infected plants, although limited to the phloem. The severity of symptoms in apple trees fluctuates from severe to asymptomatic; but notably, the phytoplasma occurs in asymptomatic apple trees (Baric *et al.* 2011a) and it may be asymptomatic in rose plants. '*Ca.* P. *mali'* may potentially be associated with all parts of the rose plant that are imported.

2.3.1.7 Plant associations

'Ca. P. mali' has been reported from: *Rosa* sp.(Kamińska and Śliwa 2004) *Malus domestica* (apple), *Prunus avium* (cherry), *Prunus armeniaca* (apricot), *Prunus domestica* (plum), *Dahlia*, *Lilium* (lily) (Kamińska and Śliwa 2008b,a), *Catharanthus roseus* (pink periwinkle), (Hort. Perdue 2011), magnolia (Kamińska 2006) *Pyrus communis* (pear), *Prunus salicina* (Japanese plum), *Vitis vinifera* (grape), *Convolvulus arvensis* (bindweed) *Corylus avenella* (hazel), *Cynodon dactylon* (Bermuda grass) (CPC 2011)

2.3.1.8 Potential for establishment and impacts

'Candidatus Phytoplasma mali' (apple proliferation or AP) occurs in countries with climates similar to parts of New Zealand. Further, as there are vectors in New Zealand that can potentially transmit '*Ca.* P. mali' (see Biology section), and recorded hosts occur in New Zealand, then it can potentially establish in New Zealand. '*Ca.* P. mali' causes damage to its host plants, so can potentially cause unwanted impacts in New Zealand.

2.3.1.9 Hazard identification conclusion

Given that '*Ca.* P. mali'

- Is reported from rose plants;
- Is not reported from New Zealand;
- Is reported from countries New Zealand imports *Rosa* nursery stock from;
- Has the potential to establish in New Zealand and have unwanted impacts;

It is therefore considered a hazard on *Rosa* nursery stock in this risk analysis.

2.3.2 Risk assessment

2.3.2.1 Biology

Phytoplasma are restricted to the phloem.

Most information on the biology of '*Ca.* P. mali' is from infection of *Malus* species. It is uncertain if the following information can be extrapolated to *Rosa* species, but for the purpose of this risk analysis it is assumed it can be.

Disease transmission:
Transmission is by insect vectors in nature (Tedeschi and Alma 2004), by natural root bridges (Baric *et al.* 2008; Ciccotti *et al.* 2008) and by grafting for propagation (Seemüller *et al.* 1984).

Insects that have been confirmed as vectors of '*Ca.* P. mali' are the psyllids *Cacopsylla melanoneura*, *C. picta* (synonym *C. costalis*) and the leafhopper *Fieberiella florii* (Tedeschi

and Alma 2006). The leafhopper is also present in North America, is polyphagous mainly on Rosaceae, and is known to vector the phytoplasma (16SrIII) causing X-disease (Tedeschi & Alma 2006). The psyllid *Cacopsylla mali* has been implicated as a vector of apple proliferation but there does not appear to be confirmation of this. Additionally the spittlebug *Philaenus spumarius* has been implicated in other phytoplasma transmission, and was reported to vector '*Ca.* P. mali' experimentally from apple to apple, and apple to *Catharanthus roseus* (Hegab and El-Zohairy 1986), however this has not been confirmed since first reported. It is uncertain what insect may vector '*Ca*. P. mali' to rose plants.

Phytoplasmas are transmitted in a persistent-propagative manner (Tedeschi and Alma 2004). A phloem sap-sucking insect may acquire the phytoplasma from infected plants. The phytoplasma then needs to multiply in the vector before it can be transmitted.
After crossing the midgut the phytoplasmas multiply in the haemolymph and then circulate within the vector to the salivary glands. They may be expelled from the salivary glands during feeding probes which will inoculate the plant phloem. This cycle takes between 15 and 30 days. The phytoplasmas are not shed during moult, and so infectivity is retained for the lifetime of the insect vector, although transmission efficiency is reduced in adults (Tedeschi and Alma 2004).

In Italy *C. melanoneura* and *C. picta* are capable of transmitting the phytoplasma as both adults and nymphs (Tedechi and Alma 2004). The overwintering adults migrate from their overwinter hosts to apple orchards at the end of winter and again towards the end of spring. Carraro *et al.* (2008) showed that overwintering *C. picta* adults are infective when they move to apples in the spring and remain so for the entire period they are present. Both *C. melanoneura* and *C. picta* reproduce on apple, and the spring generation leaves the apple trees for other hosts until mid-summer (Mattedi *et al.* 2008).

In Germany *C. picta* is a confirmed vector, however, Mayer *et al.* (2009) have clearly shown that although *C. melanoneura* is able to acquire the phytoplasma it is not able to transmit it. Their results also showed that "a certain minimum phytoplasma load in the insect body is necessary for an efficient transmission and that the rating of the phytoplasma titre is important to estimate whether an insect species is an efficient vector or not". This was a conclusion also reached by Pedrazzoli *et al.* (2007). Mayer *et al.* (2009) noted the phytoplasma was unable to reach an efficient transmission titre in *C. melanoneura* as it probably could not reach the salivary glands to multiply there. They question the possibility of different populations of *C. melanoneura* with different capacities[4] for acquiring and transmitting '*Ca.* P. mali' existing. Thus *C. melanoneura* is not considered a vector of '*Ca*.P. mali' in Germany, but it is a vector in Italy. More recently, Baric *et al.* (2011b) considers that certain '*Ca.* P. mali' subtypes are more effectively transmitted by specific psyllids.

Root bridges or grafts can naturally occur in medium to old aged orchards (Baric *et al.* 2008; Ciccotti *et al.* 2008). Herbicide has been shown to travel between trees of the same species via root bridges, (Baric *et al.* 2008), and subsequently movement of '*Ca*. P. mali' was tested and confirmed between trees via root bridges (Ciccotti *et al.* 2008).

Grafting is the usual method of commercial propagation of plant material, and grafting with latently infected scions is a recognised form of phytoplasma transmission (Seemüller *et al.* 1984).

4 see Mayer *et al.* 2009, p 736 for more detail

Receptivity of the grafted plant and the phytoplasma concentration in the bud affect the likelihood of phytoplasma transmission (Pedrazzoli *et al.* 2008). The period of bud collection influences the concentration and vitality of the phytoplasma. This is because the presence of '*Ca.* P. mali' is thought to be cyclical in apple. This is explained more fully in symptoms and progression below.

Symptoms, latency and disease progression:
The description of symptoms of '*Ca.* Phytoplasma mali' in roses is in conjunction with an infection of '*Ca.* P. asteris' (Kamińska and Śliwa 2004), so it is not clear what symptoms may be attributed to '*Ca.* P. mali' in roses.

- Apples: witches broom of infected shoots, enlarged stipules (Cieślińska and Kruczyńska 2011); stunted growth, witches broom, leaf rosette, leaf yellowing or reddening, reduced yield, small tasteless fruit, general decline, sometimes death (Baric *et al.* 2011);
- Rose: (infected also with '*Ca.* P. asteris') stunted growth, leaf and flower malformation, shoot and flower proliferation (Kamińska and Śliwa 2004);
- Lily: leaf malformation and necrosis, flower bud abscission (Kamińska and Śliwa 2008b);
- Dahlia: bushy growth accompanied byshoot proliferation, narrowed leaf and flower bud deficiency (Kamińska and Śliwa 2008a);
- Cherry: wilting, dying, floral and phloem necrosis (Mehle *et al.* 2007);
- Apricot: stem necrosis and leaf wilting (Mehle *et al.* 2007);
- Plum: late blooming (Mehle *et al.* 2007);
- Grapes (Merlot): implicated in premature berry dehydration in Chile (Matus *et al.* 2008)

Baric *et al.* (2011a) note that the presence of high concentrations of the '*Ca.* P. mali' cells in the aerial phloem is involved in the development of severe symptoms. This would suggest it is not the presence of the phytoplasma alone, but the titre of phytoplasma that is responsible for symptom expression. Therefore, plants not expressing any symptoms may have the phytoplasma present but in low concentrations. In contrast, phytoplasma concentration in rootstock does not have a direct effect on either symptom expression or the intensity of aerial colonisation by the phytoplasma (Baric *et al.* 2011a).

The phloem in roots is continually regenerating, but in the aerial parts of the plant the sieve elements degenerate during winter (Baric *et al.* 2011). It has been reported that '*Ca.* P. mali' is absent from the aerial parts of the tree at that particular time of the year, and then returns (Pedrazzoli *et al.* 2008). Baric *et al.* (2011) have confirmed the seasonal cycle of phytoplasma *concentration* (as opposed to presence). In shoots, the phytoplasma could be detected from 81% of the samples from symptomatic trees, and in 20% of samples from asymptomatic trees with monthly sampling over a 20 month period. The highest percentage of phytoplasma-positive shoot samples was found between September and February (northern hemisphere autumn-winter). In roots (in the same sampling period) '*Ca.* P. mali' was detected in 100% of samples from both symptomatic and asymptomatic trees. Thus the phytoplasma is present throughout the year, but in varying concentrations. This is possibly due to a functional replacement phloem in the shoots formed as a consequence of the phytoplasma infection and persisting throughout winter (Schaper and Seemüller 1982; Baric *et al.* 2011a). This is likely to affect transmission by graft.

Additionally Baric *et al.* (2011a) note that lower temperatures seem to have a beneficial effect on phytoplasma multiplication since higher titres of phytoplasma were found in micropropagated plantlets kept up to 3 months at 4˚C, rather than at a constant 20˚C, confirming observations by Kamińska *et al.* (2002).

2.3.2.2 Entry assessment

Rosa nursery stock entering New Zealand is likely to be arriving either as whole plants with leaves and roots, in a soil-less sterile rooting media; or as dormant cuttings consisting of stem only, possibly with buds but without roots or leaves; or as tissue cultures in sealed bags or containers.

'Ca. P. mali' can be present in a plant whether it is expressing symptoms or is asymptomatic. It can also be present throughout the plant in varying concentrations all year. It is expected that cuttings would only be taken from plants that appear healthy. However, given that '*Ca.* P. mali' can be latent in plants, it is possible that it could enter New Zealand in dormant budwood and tissue cultures as well as in whole plants that have not expressed symptoms.

The likelihood of entry is considered to be moderate.

2.3.2.3 Exposure assessment

The act of using the *Rosa* nursery stock for the intended purpose, *i.e.* planting, propagating and grafting, will fulfil the requirements of exposure. That is, the phytoplasma will occur in a living host plant in the New Zealand environment and thus be exposed to potential insect vectors.

The likelihood of exposure is considered to be high.

2.3.2.4 Assessment of establishment and spread

'Ca. P. mali' is present in cool to temperate regions. There is no evidence to suggest its distribution is limited by climate and so in New Zealand it is unlikely climate would limit its ability to establish. Many reported host plants are common in New Zealand either as horticultural species (apple, plum, apricot, cherry, grapes), ornamentals (magnolia, cherry), garden plants (rose, dahlia, lily) or weeds (convolvulus, wild cherry). Host plant availability is unlikely to inhibit establishment.

Symptomatic plants are unlikely to be propagated from. However a recently infected plant or plants with latent infection of '*Ca.* P. mali' could be propagated from thereby inadvertently spreading the phytoplasma. Movement of infected plants throughout the country also increases the spread and exposure to different suites of potential hosts. Additionally, as symptoms may not always be seen or the causal agent correctly diagnosed there is the potential for domestic and/or wild infections of phytoplasma remaining in some host plants, *e.g.* wild cherry, to act as reservoirs for renewed infection if there are suitable vectors.

The reported vectors are not present in New Zealand. The spittlebug *Philaenus spumarius* is present in New Zealand but its role as a vector of '*Ca.* P. mali' has not been confirmed since the first report (refer to 2.3.2.1). It is possible the establishment and spread of '*Ca.* P. mali' in New Zealand might be limited by a lack of vectors, but this is considered unlikely. There are psyllids in New Zealand associated with vectoring liberibacters (*e.g. Bactericera cockerelli* vectors *Ca.* Liberibacter solanacearum) (Secor *et al*. 2009) and planthoppers that are known to vector phytoplasmas.

Given that:

- The known vectors are not present in New Zealand, but:
- There are several potential insect vectors;
- Host plants for the phytoplasma are widespread throughout New Zealand;
- Climate is unlikely to be a barrier to establishment;

*The likelihood of establishment and spread of '*Ca*. P. mali' is considered to be moderate to high.*

2.3.2.5 Consequence assessment

As seen in section 2.3.2.1 the symptoms can be variable depending on the amount of phytoplasma in the plant, the type of plant it is, and if there are other pathogens present. Typical symptoms include witches broom of infected shoots, malformation of leaves and flowers, wilting, chlorosis, reduced yield, general decline, necrosis and eventual death.

The consequences of '*Ca.* P. mali' establishment will depend on what strains of the phytoplasma arrive in NZ and what vectors transmit it. If there are few or no vectors, or if the vectors are confined to a limited range of plants then the impacts will be minimal. If '*Ca*. P. mali' is transmitted by a common and widespread vector with a broad host range the impacts will be large. There is not yet enough known about potential vectors of phytoplasma in New Zealand to determine the degree of impact it would have here, and there is some uncertainty about the impacts.

Economic consequences

Some of the reported hosts for '*Ca.* P. mali' are important export crops for New Zealand, especially apples and grapes for wine.

The largest horticultural export earner for the year to the end of June 2011 was grapes (as wine), worth $1085 million. For the same period fresh apples earned $363.3 million, apple juice $19.6 million, apple preparations $9.2 million, fresh apricots and cherries $6.7 million and 23.8 million respectively and *Lilium* corms $16.4 million. On the domestic market apples earned $45 million and stonefruit $25 million from 2008-2010 (Plant and Food Research 2011). There is no figure for earnings from *Rosa* species as whole plants for sale or as cutflowers although they are known to be highly favoured.

'Ca. P. mali' causes a size reduction of up to 50% in apple fruit, also a weight and quality reduction. The plant can lose vigour and become susceptible to other plant pathogens such as powdery mildew (*Podosphaera leucotricha*) and silver leaf fungus (*Chondrostereum purpureum*). Up to 80% losses occur during the acute phase of the disease although a considerable percentage of fruit remains undersized after this period. Damage to cherry includes floral and phloem necrosis, which would lead to low fruit set and therefore reduced yield. As there is no way of curing infected trees, diseased trees are uprooted in order to contain the disease (Baric *et al.* 2008) and there would be considerable cost in tree removal and re-establishing stock.

*The potential economic impacts of '*Ca*. P. mali' within New Zealand are uncertain and depend on the phytoplasma/vector relationship. Consequences could range from very low (no vector/s or inefficient vector) to high (if transmitted by polyphagous, widespread vectors affecting high value crops).*

Environmental consequences

Phytoplasmas are one of the few pathogen groups in New Zealand to have been associated with a serious epidemic in native plant populations (Liefting *et al.* 2007; Phillips *et al.* 2008). It is uncertain that an infected vector feeding on native plants would transmit the phytoplasma. As the host range of a phytoplasma is largely determined by the specificity of its insect vectors, the native plants affected in New Zealand are likely to be determined by which psyllids can act as vectors. This is difficult to predict as there is no information available on the ability of insects in New Zealand to transmit 'Ca. P. mali', other than awareness that there are potential vectors in the Psylloidea.

However, given that a phytoplasma interacting with a native polyphagous vector caused a serious epidemic in the endemic cabbage tree (*Cordyline australis*) (Beever *et al.* 2004) there is reason to be concerned about the impacts of other phytoplasmas in native ecosystems. Additionally, it would be extremely difficult to control such a disease within a native ecosystem compared to the ability to control within a cultivated system.

The potential environmental impact of 'Ca. P. mali' within New Zealand is very uncertain and depends on the phytoplasma/vector relationship. The environmental consequences could range from negligible (no vectors, or inefficient vectors) to high (widespread polyphagous vector/s transmitting the phytoplasma to native and endemic plant, and a greatly reduced ability to control for this in native ecosystems).

Human health consequences

There are no known human health consequences of '*Ca.* P. mali'.

Socio-cultural consequences

Apple, plum, cherry, roses, dahlia and lilies are common in New Zealand home gardens. The four latter plants are also widely used in amenity plantings. If '*Ca.* P. mali' affects similar species in New Zealand as it does abroad then it is expected that there will be impacts upon amenity and domestic plantings.

Latent infections in domestic or amenity plantings may act as reservoirs for renewed phtoplasma infections.

The potential socio-cultural consequences of 'Ca. P. mali' are considered to be low

Risk estimation

The likelihood of entry for *Ca*. P. mali is considered to be low, exposure is high, establishment and spread moderate to high. The economic and environmental consequences are uncertain (as discussed in section 5.3.2.5) and could range from very low to high; human health consequences are negligible, and socio-cultural consequences are low.

As a result the risk estimate for 'Ca. P. mali' is non-negligible and it is classified as a risk in the commodity. The risk is worth considering and further analysis may be undertaken to decide if additional measures are warranted.

Risk management for this phytoplasma is discussed in the Risk Management Proposal document.

2.4 References for Chapter 2

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3 Risk assessment of potential hazard organisms: Viruses

3.1 *Blackberry chlorotic ringspot virus*- BCRV

Scientific name: *Blackberry chlorotic ringspot virus*
Family: genus [Bromoviridae: Ilarvirus]
Acronym: BCRV

3.1.1 Hazard identification

3.1.1.1 Pathogen synopsis

BCRV is a positive-sense, single stranded RNA virus of the genus Ilarvirus, transmitted by mechanical inoculation of sap, grafting and seed. It is relatively new to science so little is known about its potential impacts.

3.1.1.2 Taxonomy

The taxonomy of this virus has recently been accepted by ICTV. Jones *et al.* (2006) and Tzanetakis *et al.* (2010) consider it is a member of Subgroup 1 of the genus *Ilarvirus* based on molecular analyses they carried out.
This virus was isolated from rose in the USA, and was initially referred to as "Rose virus, (RsV-1)". However it was renamed to *Blackberry chlorotic ringspot virus* (BCRV) in GenBank when it was realised it shared 85-93% amino acid identity with the BCRV isolated from blackberry in Scotland. Tzanetakis *et al.* (2006) state these two isolations should be considered strains of the same virus, BCRV.

3.1.1.3 New Zealand status

BCRV is not recorded in: Pearson *et al.* (2006); PPIN 2012; Melliza *et al.* (2013).

3.1.1.4 Exporting country status

All countries in the world are considered exporting countries for the purposes of this risk analysis.

3.1.1.5 Geographic distribution

BCRV has been reported from Scotland (Jones *et al.* 2006) and from the USA (Tzanetakis *et al.* 2006).

3.1.1.6 Commodity associations

BCRV has been isolated from *Rosa* spp. in the USA (Tzanetakis *et al.* 2006) and *Rosa multiflora* in the USA (Poudel 2011) and therefore BCRV can occur in association with nursery stock of *Rosa.*

3.1.1.7 Plant associations

BCRV has been reported from blackberry (*Rubus fruticosus*) in Scotland (Jones *et al.* 2006), and blackberry (Tzanetakis *et al.* 2006), raspberry and apple[5] - *Malus domestica* in the USA (Poudel 2011).

BCRVwas mechanically transmitted to *Chenopodium quinoa* and *Brassica rapa* (Poudel 2011). Jones *et al.* (2006) mechanically inoculated test plants with BCRV and reported finding the virus in the following test plants: *Chenopodium amaranticolor, C. murale, C. quinoa, Cucumis sativus, Nicotiana tabacum, Phaseolus vulgaris, Tetragonia expansa* with symptom expression; and in the following asymptomatically: *Gomphrena globosa, Nicotiana benthamiana, N. clevelandii,* and *Spinacea oleracea* (spinach).

Scions of field infected Bedford Giant blackberry have been used to graft inoculate the virus into other *Rubus* species and cultivars including Norfolk Giant raspberry and *Rubus occidentalis* -black raspberry, Himalaya Giant blackberry, Tayberry, and the raspberry cultivars: Autumn Bliss, Delight, Latham, Malling Landmark, Willamette and *Rubus macraei* (Jones *et al.* 2006).

3.1.1.8 Potential for establishment and impacts

This virus has been reported from countries with similar ecoclimatic conditions to parts of New Zealand. The hosts for this virus are also present in New Zealand, it is potentially able to establish in this country and may have unwanted impacts on the apple and berry industries and commercial rose growers.

3.1.1.9 Hazard identification conclusion

Given that *Blackberry chlorotic ringspot virus*

- is reported from *Rosa* spp.;
- has been reported from countries New Zealand trades with;
- but is not reported from New Zealand;
- is potentially able to establish in New Zealand and have unwanted impacts;

it is considered to be a hazard on *Rosa* spp. nursery stock from all countries in this risk analysis.

3.1.2 Risk assessment

3.1.2.1 Biology

There is extremely limited information on this virus in rose species, as the research interest has been focussed on berry crops. Therefore the following information has largely come from work on blackberry and raspberry in Scotland and USA.

Disease transmission:

5 The virus was found in one apple sample taken from an area where the virus was known to be. This sample tested positive in two consecutive PCRs and sequencing confirmed it was BCRV

The virus is known to be mechanically, graft (Jones *et al.* 2006) and seed transmitted (Poudel 2011). Poudel (2011) found that the virus was mechanically transmitted to both *Chenopodium quinoa* and *Brassica rapa* with symptoms expressed in the former but not the latter, although *B. rapa* was systemically infected. The virus had a high level of seed transmission (about 50%) in *R. multiflora* and *C. quinoa* (Poudel 2011). BCRV is an *Ilavirus* and as such might have the capability to be transmitted in infected pollen, often carried by insects such as thrips and bees (Jones *et al.* 2006; Poudel 2011).

Disease symptoms and progression:
Symptoms of BCRV are not described for rose, and are confounded in blackberry as in the USA this virus is often detected with other viruses contributing to Blackberry yellow vein disease[6] (BYVD). Poudel (2011) did note there was a higher incidence of BCRV in wild blackberry populations and commented that "in blackberry single virus infection is normally asymptomatic." Similarly, Jones *et al.* (2006) described symptoms on blackberry in Scotland and also found other viruses present at the same time as BCRV. However, Himalaya Giant blackberry and Tayberry which were graft inoculated with BCRV and known to also be asymptomatically infected with *Black raspberry necrotic virus* (BRNV) and *Raspberry leaf spot virus* (RLSV) developed chlorotic spots, ringspots and line pattern symptoms.

Jones *et al.* (2006) also described symptoms in some of the mechanically innoculated plants; two species of *Chenopodium*, showed variously chlorotic local lesions, faint systemic chlorotic ringspots, and in *C. quinoa* large chlorotic local lesions, systemic mottling, leaf puckering and occasional epinasty. *Cucumis sativus* presented with large chlorotic local lesions and systemic chlorotic ringspots, *Phaseolus vulgaris* cv The Prince had occasional chlorotic local lesions that later became necrotic, not usually systemic.

Jones *et al.* (2006) comment that as BCRV is a relatively newly discovered virus the extent of its occurrence and the effect on fruit quality and plant growth are unknown, thus making it difficult to assess any potential risk.

3.1.2.2 Entry assessment

Rosa nursery stock entering New Zealand is likely to be arriving either as whole plants with leaves and roots, in a soil-less sterile rooting media; or as dormant cuttings consisting of stem only, possibly with buds but without roots or leaves; or as tissue cultures in sealed bags or containers. BCRV could be present in any plant part.

BCRV is widespread in the USA (Poudel 2011) and it is uncertain how prevalent it is in the UK (Jones *et al.* 2006).

It is expected that only healthy looking plants, budwood or tissue cultures would be exported to New Zealand. However, if BCRV behaves similarly in rose as it does in blackberry it is likely to be symptomless and therefore undetectable at export and upon entry.

The likelihood of entry of BRSV *is considered to be low to moderate, given the uncertainty about how geographically widespread it might be.*

6 BYVD includes but is not limited to *Blackberry yellow vein associated virus, Blackberry virus Y, Impatiens necrotic spot virus,* Rubus virus S and Blackberry virus E (Poudel 2011)

3.1.2.3 Exposure assessment

Rosa nursery stock is destined to be planted, grafted and propagated, and therefore BCRV will be transmitted by propagation or grafting and possibly by exposure to potential insect vectors if it is pollen transmissable.

The likelihood of exposure of BRSV *is considered to be high.*

3.1.2.4 Assessment of establishment and spread

Parts of New Zealand have similar ecoclimatic conditions to the United Kingdom and parts of the USA. Roses, *Rubus* species and apples are routinely grown commercially in New Zealand and in home gardens. Roses are a popular amenity plant. Additonally, blackberry and rose both grow wild in many areas of New Zealand, and occasionally wild apple trees can also be found. Many ilarviruses are transmitted through seed via the ovule and/or pollen (Jones *et al.* 2006). These wild populations of rose, blackberry and apple have the potential to act as reservoirs of BCRV, enabling continual dissemination of the virus through seed and/or possibly by pollen. If BCRV can be transmitted by pollen then it is likely spread would occur by insects distributing pollen amongst wild plants and into nearby orchards and/or nurseries. Two examples of such insects would be *Apis mellifera*, the honey bee which visits blackberry flowers and roses, and some flower thrips species, *e.g. Thrips obscuratus,* which are common in roses (pers. obs.). This type of spread is almost impossible to control once the virus is in the natural environment. The movement of whole plants and cuttings throughout New Zealand would also assist spread of BCRV.

There are no apparent natural barriers to this virus establishing and spreading within New Zealand.

The likelihood of establishment and spread of BRSV *is considered to be moderate to high.*

3.1.2.5 Consequence assessment

The following sections assess the potential impacts that the establishment of BCRV may have within New Zealand.

Economic consequences

The effect of BCRV on plant growth and fruit/flower quality in *Rubus, Malus* (apple) and *Rosa* is not yet known; nor is it yet known if it might have a synergistic effect in combination with other viruses.

A current value of the domestic rose industry (as whole plants for sale or as whole plants providing cutflowers) is not available. If BCRV is symptomless in rose, then it seems unlikely it would have any impact on roses or upon the rose industry. Roses are the main contribution to the domestic cutflower industry in New Zealand.

A number of *Rubus* species are grown commercially in New Zealand for their berries. The combined value of boyensberry, raspberry and other brambles as fresh and processed berries for domestic and export markets (excluding jams) was $13.4 million in the year 2010-2011 (Plant and Food Research 2011).

Apples were determined to be a natural host by Poudel (2011) but there is no description given of symptoms. It is possible that apple may be unaffected by the virus. However, if BCRV is detrimental to apples, there would be significant economic consequences, as apples are the third largest horticultural export earner for New Zealand.

New Zealand exports fresh apples to 74 countries. This was worth $363.3 m (fob) to New Zealand in 2011, and earnings from apple juice and apple preparations were $19.6m and $9.2m respectively (Plant and Food Research 2011).

The potential economic consequences of BCRV are *considered to range from negligible (no disease in Rubus, Rosa and Malus) to moderate (serious impacts on plant growth and fruit production in Malus in particular, also Rosa and Rubus).*

Environmental consequences

This virus is relatively new to science and there is much still unknown about its potential host range and affects on potential hosts.

Poudel (2011) remarks that as the virus infects four Rosaceous hosts there is the possibility it could infect other members of the *Rosa*ceae. There are 26 endemic species in the Rosaceae including *Rubus cissoides* (bush lawyer), and *Acaena anserinifolia* (bidibidi); others such as *Potentilla* spp. and *Geum* spp. are less common. If BCRV is like many ilarviruses and can be pollen transmissible then it is possible it may eventually reach endemic Rosaceae species. The effect on other Rosaceous plants is unknown and difficult to assess.

The potential environmental consequences of BCRV *are uncertain.*

Human health consequences

There are no known human health consequences associated with BCRV.

Socio-cultural consequences

If there is no discernable effect of the virus upon home grown roses, apples and berries then the consequences are likely to be negligible. If there is an effect on growth or fruit production the consequences from a national perspective are likely to be low.

The potential socio-cultural consequences of BCRV *are considered to be low to negligible.*

Risk estimation

The likelihood of entry for BCRV is considered to be low-moderate; the likelihood of exposure is considered to be high; and the likelihood of establishment and spread is considered to be moderate to high. The economic consequences are dependent on disease expression and affected host, thus range from negligible to moderate. The environmental consequences are uncertain, socio-cultural consequences are dependent on disease expression and affected host, thus range from low to negligible. There are no known consequences to human health.

As a result the risk estimate for BCRV *is non-negligible and it is classified as a risk in the commodity. The risk is worth considering and further analysis may be undertaken to decide if additional measures are warranted.*

Risk management for this virus is discussed in the Risk Management Proposal document.

3.2 Rose rosette virus and Rose rosette disease

Scientific name: Rose rosette virus (provisional name);
Family: genus (Unassigned family: *Emaravirus*)
Disease name: rose rosette disease; "witches broom"
Acronyms: RRV; RRD

3.2.1 Hazard identification

3.2.1.1 Pathogen synopsis

Rose rosette virus is a negative-sense RNA virus of the genus *Emaravirus.* It is the putative causal agent of 'rose rosette disease' in roses. The disease is transmitted by an Eriophyid mite and by graft.

3.2.2.1. Taxonomy

The genus *Emaravirus* has not yet been assigned to a family and order (ICTVdb 2012). The name 'Rose rosette virus' has been provisionally given (Laney *et al.* 2011).

In this risk analysis the acronym 'RRV' will be used in reference to the virus considered the putative causal agent and 'RRD' in reference to the disease. There is a long history (about 70 years) associated with the search for the identity of the causal agent of rose rosette disease. This is discussed in the biology section

3.2.1.2 New Zealand status

Not recorded in: PPIN (2012); Pearson *et al.* (2006).

3.2.1.3 Exporting country status

All countries of the world are considered exporting countries for the purposes of this risk analysis.

3.2.1.4 Geographic distribution

RRV has been reported from the USA (Laney *et al.* 2011).
RRD has been reported from the USA and from Canada (Epstein and Hill 1999).

3.2.1.5 Commodity associations

RRV has been detected in cultivated *Rosa* species. (Laney *et al.* 2011) and as such RRV may potentially be associated with all parts of the rose plant imported into New Zealand.
Within the *Rosa* genus rose rosette disease has differing impacts on different species and cultivars. Wild roses and many cultivars are affected by this virus, a few are included here: *Rosa multiflora, R. woodsii, R. bracteata, R. eglanteria* (*R.rubiginosa*), *R. rugosa* x *R. odorata* cvs. Peace, Chrysler, Imperial and Bonica (Epstein and Hill 1999). *Rosa multiflora* has been used for breeding purposes and as a rootstock for ornamental roses (Epstein and Hill 1999) and is still used as such in New Zealand.

3.2.1.6 Plant associations

RRV does not appear to be found in species outside the *Rosa* genus. Laney *et al*. (2011) surveyed 34 different plant species located around symptomatic roses in different states but found no evidence of alternative hosts.

RRD does not appear to affect other members of the Rosaceae or other families (Epstein and Hill 1999).

3.2.1.7 Potential for establishment and impacts

This virus has been reported from parts of the USA that are ecoclimatically similar to parts of New Zealand. There are *Rosa* hosts in New Zealand in cultivation and in the wild. RRV is potentially able to establish and have unwanted impacts on the rose industry, amenity and domestic plantings.

3.2.1.8 Hazard identification conclusion

Given that RRV

- is reported from *Rosa* spp.;
- is present in the USA;
- but is not reported from New Zealand;
- is potentially able to establish in New Zealand and have unwanted impacts;

it is considered a hazard on *Rosa* spp. nursery stock from USA in this risk analysis.

3.2.2 Risk assessment

3.2.2.1 Biology

History
Rose rosette disease was first reported in the early 1940's (Connor 1941, *cited in* Laney *et al*.. 2011) and became one of the most devastating diseases of roses, widespread in the USA by the late 1970's. Some of the symptoms exhibited are similar to those presented by phytoplasma infections. Tetracycline treatments did not cure infected plants indicating the disease was not caused by bacteria (Epstein and Hill 1999). Gergerich and Kim (1983) discovered double membrane-bound particles associated with RRD, Amrine *et al.* (1988) identified an eriophyid mite, *Phyllocoptes fructiphilus*, as a vector of RRD and with the isolation of dsRNA from infected material (Di *et al.* 1990 cited in Laney *et al*.. 2011), it was suggested that the causal agent of the disease was likely to be a virus. However, conclusive proof remained elusive and there are publications where the disease is still considered to be of phytoplasma origin (Horst and Cloyd 2007; Cloyd 2011) although phytoplasmas are known to be phloem limited and the insect vectors are phloem feeders (Bertaccini 2007).

Recently Laney *et al.* 2011 investigated 22 different isolates collected from different states separated by 1300km. Subsequently a virus was identified, but Kochs postulates could not be fulfilled for it as there were no local lesion alternative hosts identified, and virus purifications were unsuccessful. Therefore Laney *et al.* (2011) collected symptomatic tissue from 84 cultivated and *R. multiflora* roses from 9 states to run through PCR. Thirty asymptomatic

roses were used as negative controls. RRV was detected in all the symptomatic roses from all 9 states. Results showed a very strong correlation between presence of virus and disease and the absence of virus in asymptomatic roses collected from areas of extreme disease incidence. Therefore Laney *et al.* 2011 state it is most probable that RRV is the causal agent of rose rosette disease.

RRD has been investigated in the USA as a possible biocontrol agent for the rampant *Rosa multiflora.* The information in this section is for RRD in *Rosa multiflora*, and is mostly taken from Epstein and Hill (1999) unless otherwise stated.

Disease transmission:
RRD is transmitted in the field by the woolly mite, *Phyllocoptes fructiphilus* (Acari: Eriophyidae) (Amrine *et al.* 1988) and also by grafting (Doudrik *et al.* 1986).

Bud and shield grafts successfully transmitted RRD in greenhouse tests and in the field, whereas budless shield grafts were less effective in the field. After grafting, some plants showed reddening of veins on terminal leaflets and budbreak prior to visible growth of the graft. Others show symptoms of systemic infection once the graft has developed a 10-20cm long shoot.

Amrine *et al.* (1988) successfully transmitted RRD by root graft and state this "indicates that the agent for RRD resides in the roots of *R. multiflora*". Graft success in the field appeared to depend on timing (early summer was more successful) and reasonable irrigation (grafts in areas affected by drought failed) (Epstein and Hill1995).

Experiments showed that one mite was capable of transmitting RRD; it was also shown that the mites appeared to lose much of their ability to transmit the disease after 10 days; (Amrine *et al.* 1988).

There has been no detection of soil mediated transmission, nor have seedlings derived from the seed of infected plants become symptomatic. Attempts to transmit the disease by dodder were not successful (Epstein and Hill 1999).

Disease symptoms and progression:
The symptoms of RRD are complex, and are broken into stages.
<u>Stage 1.</u>
Earliest symptoms include deep red to magenta coloration on the underside of the leaf blades. Shoots of affected canes are vigorous, light pink becoming magenta and elongate rapidly. Affected shoots are noticeably more succulent and thorny, especially in cultivated roses, than is usual. Affected leaves tend to be elongated, deformed, crinkled, rugose and have varying degrees of yellow and green mosaic with red pigmentation. Starch reserves are greatly reduced. Flowering is reduced and individual blooms on symptomatic canes are often distorted. Temporary reversion to normal appearing growth has been observed in a few plants, with canes showing a mosaic of symptomatic and normal-appearing leaves, however this is largely due to the "normal" leaves failing to develop the red pigmentation and they remain symptomatic in texture and configuration.
<u>Stage 2</u>
In the early rosette stage, leaves of infected plants display a pattern of mosaic with intense red coloration and tend to be elongated, distorted and rugose. Many lateral buds break dormancy and start growing. Petioles are shortened giving the rosette appearance of the

symptomatic shoots. Growth rate of shoots on non-symptomatic portions of the plant may be greatly reduced and flowers rarely form on canes at this stage of infection.
Stage 3.
In the late stage of RRD rosetting is intense, leaves are greatly reduced, almost hair-like and intensely red; petioles are very short, most or all lateral buds break dormancy, begin to grow and are intensely red in colour. Apical growth is weak, internodes are shorter and canes are chlorotic. Plants in advanced stages of symptom expression produce very few rootlets and seldom survive Iowa winters. Smaller plants progress more quickly through disease stages than large, multicrowned plants. Infected seedlings seldom survive past 1 year, single crowned plants usually die within 2-3 years and some multicrowned plants have parts that may survive up to 5 years.

Epstein and Hill (1995) state that many ornamental roses are susceptible to RRD, but they observed incidence of infection has been low in the Iowa area; they considered this may be related to findings made by Crowe (1983) who noted eriophyid mites were not consistently found on hybrid roses.

Symptoms in ornamental cultivars are very similar but may include a more dramatic bud distortion and thorn proliferation. Epstein (unpublished data) 'noted graft transmission and development of RRD symptoms occurred on sweetbriar – *R. eglanteria* (*R. rubiginosa*) from New Zealand' (Epstein and Hill 1999). It is uncertain whether Epstein received infected samples from New Zealand or if he obtained plants from New Zealand that subsequently he infected with the disease in the US. Currently RRD and RRV are not reported from New Zealand (PPIN 2013).

Disease Latency:
Amrine *et al.* (1988) reported that grafting of rooted cuttings showed low transmission rates and a slow development of the disease, taking 41 days to 6 months for symptoms to appear. In graft transmission to large plants symptoms occurred in 60-75 days. Expression of disease in mite transmission experiments varied considerably between17-160 days in the laboratory and 30-279 days in the field.

It appears that some ornamental cultivars took a year to express RRD symptoms (Epstein and Hill 1995) whereas symptom expression seems to occur more rapidly in the highly susceptible *R. multiflora*.

3.2.2.2 Entry assessment

Rosa nursery stock entering New Zealand is likely to be arriving either as whole plants with leaves and roots, in a soil-less sterile rooting media; or as dormant cuttings consisting of stem only, possibly with buds but without roots or leaves; or as tissue cultures in sealed bags or containers.

Epstein and Hill (1995) state that many ornamental roses are susceptible to RRD and some may take a year to express symptoms. A mature plant may at some point become infected with RRD due to a single or multiple *P. fructiphilus* mites. If this were to occur just prior to export then it is unlikely symptoms would have had time to present.

It is expected that only healthy looking *Rosa* nursery stock would be exported to New Zealand. However, it is possible an early stage infection might not be immediately obvious in whole plants, or in plants that budwood and tissue cultures have been sourced from, and therefore RRV/RRD be exported along with healthy nursery stock.

The likelihood of entry of RRV/RRD *is considered to be low to moderate depending on the cultivar.*

3.2.2.3 Exposure assessment

Rosa nursery stock is destined to be planted outdoors, grafted and propagated from, and therefore RRV/RRD may be transmitted by propagation or grafting and exposed to potential mite vectors.

It is uncertain if the virus/disease could remain latent in certain cultivars and only express symptoms if grafted to different stock plants.

The likelihood of exposure of RRV/RRD *is considered to be high.*

3.2.2.4 Assessment of establishment and spread

RRV/RRD is reported from parts of the USA which are climatically similar to New Zealand, and therefore climatic conditions are unlikely to be a barrier to establishment.

Imported whole plants arriving are likely to be grown on for a period of time prior to cuttings or buds being taken from them. Some may be sold on, and some infected plants may die within a year or so. If disease expression occurred later than this, it is possible there would be numerous potential carrier plants, some of which may have been distributed.

Rosa nursery stock is for propagation and sale. As propagation is frequently by graft it is likely that the disease would be detected in susceptible cultivars as the graft developed and new shoots and leaves appeared with the symptoms mentioned in the section 6.2.2.1 (biology). Most nursery owners would cull suspect plants, and some might send samples for testing. It is less likely plants with RRD would be sold to the general public, as it would appear that by the time the plants are sufficiently developed for general sale, symptoms should be detectable. However, if an infected cultivar was weakly symptomatic or asymptomatic then it could be sold as ususal. Wild *R. multiflora* infected with RRD is reported to die of the disease within 1-5 years (Hill and Epstein 1999)

The disease is naturally transmitted by the Eriophyid mite *Phyllocoptes fructiphilus.* This mite is not reported to be present in New Zealand, although there are 4 species of *Phyllocoptes* that are here, 1 adventive and 3 endemic (Sirvid *et al.* 2010). It is not known if any of these *Phyllocoptes* species would be capable of transmitting RRD, although the adventive gall mite, *Phyllocoptes abaena* is reported from *Prunus* species (Rosaceae) in New Zealand. The other 3 *Phyllocoptes* species (*P. copromae, P. hazelae* and *P. metrosideri*) do not appear to have an association with *Rosa* species or Rosaceae (PlantSyNZ™ 2012; BUGZ 2012)

Given that:

- Transmission is solely dependent on grafting and/or the mite *Phyllocoptes fructiphilus*;
- *P. fructiphilus* is not present in New Zealand;
- It is uncertain if *Phyllocoptes* species present in New Zealand would be able to vector RRV/RRD
- Symptoms of RRV/RRD should be apparent within a year;

- Symptomatic plants are likely to be culled;
- Infected roses not culled may well die within 1-5 years;

The likelihood of establishment and spread if vectors in New Zealand can transmit RRV/RRD *is moderate*

The likelihood of permanent establishment of RRV/RRD *is considered to be very low in the absence of natural vectors.*

3.2.2.5 Consequence assessment

Economic consequences

RRD is a destructive disease, which will kill most host plants within 1-5 years, and has been investigated as a possible biocontrol for *R. multiflora* in the USA.

There are no figures available to determine the economic value of the rose growing industry in New Zealand, but it is the most popular flower grown, both as a nursery plant, amenity plant, garden plant and as a cut-flower. Although it appears unlikely that RRV/RRD would establish permanently (because of the absence of a natural vector) a temporary establishment would cause harm and economic losses.

The potential economic consequences of RRV/RRD *establishment are considered to be low to moderate*

Environmental consequences

There are 26 species in the *Rosa*ceae that are native to New Zealand, but none in the genus *Rosa*. As this virus only infects plant in the genus *Rosa* it is highly unlikely it would have any effect on plants species endemic to New Zealand.

The potential environmental consequences of RRV/RRD *establishment are negligible*

Human health consequences

There is no known human health consequence associated with RRV/RRD

Socio-cultural consequences

Roses are a very popular garden plant, and can be found throughout New Zealand. It is not unusual for roses to be planted as memorials to loved ones, or to commemorate significant events.

The potential socio-cultural consequences of RRV/RRD *are considered to be low when assessed at a national level.*

Risk estimation

The likelihood of entry for Rose rosette virus and/or rose rosette disease is considered low-moderate, exposure is high and establishment is vector dependent therefore could range from very low to moderate. Economic consequences are vector dependent therefore are considered low-moderate (as discussed in 3.2.2.5), environmental and human health consequences are negligible and socio-cultural consequences are low.

As a result the risk estimate for RRV/RRD *is non-negligible and it is classified as a risk in the commodity. The risk is worth considering and further analysis may be undertaken to decide id additional measures are warranted.*

Risk management for this virus is discussed in the Risk Management Proposal document.

3.3 References for Chapter 3

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4 Hazard organisms of unknown risk status

There are a number of viruses, phytoplasmas and uncharacterised causal agents affecting *Rosa* spp. for which there is insufficient information about the relationship with *Rosa* spp. (*e.g*. viruses that are new to science) or insufficient evidence of association with *Rosa* spp. (*e.g*. phytoplasmas, *Xylella*) to complete a full risk analysis. However they are considered significant enough to discuss in this chapter. The little that is known of these organisms or of their association with *Rosa* is described below.

Many of the rose rootstocks, species and cultivars known to host these pathogenic organisms are present in New Zealand. There is a possibility that some or all of these organisms may already be present in the country. However, a recent (Dec 2011-Mar 2012) survey of viruses affecting roses, conducted by the Plant Health and Entomology Laboratory (MPI Investigation and Diagnostic Centre), did not find any new viruses apart from *Rose spring dwarf associated virus* and Rose cryptic virus-1 (synonyms are Rose multiflora cryptic virus –RMCV, Rose transient mosaic virus -RoTMV) (Milleza *et al.* 2013; PPIN 2012). While this does not provide conclusive proof of absence, it does provide some evidence on which to base a freedom case. As suggested by Milleza *et al.* (2013), many diseases may have disappeared with changes in cultivation practices, virus indexing, gradual loss of old cultivars, development of new cultivars and new molecular techniques which have allowed detection of previously unknown organisms.

The hazard organisms discussed in this chapter are:

Rose chlorotic ringspot virus
Rose necrotic mosaic virus
Rosa rugosa leaf distortion virus
Rose yellow leaf virus
Rose yellow mosaic virus
Rose colour break (virus)
Tomato Varamin virus (syn: Tomato fruit yellow ring virus)
'*Candidatus* Phytoplasma prunorum'
Rubus stunt phytoplasma
Xylella fastidiosa
Rose bud proliferation
Rose cowl forming disease
Rose leaf curl
Rose ring pattern
Rose streak (virus)
Rose stunt
Tobacco streak virus

4.1 Hazard organisms not known from New Zealand

The following organisms and diseases are considered to be hazard organisms on *Rosa* nursery stock imported into New Zealand on the basis that:

- they are not known from New Zealand;
- they can potentially establish in New Zealand, and;
- they cause undesirable symptoms in *Rosa* species and cultivars, thus have the potential to cause an unwanted impact in New Zealand.

Six of the following are new to science and as such have not been fully characterised (Lockhart *et al.* 2011) or assigned to a family and genus. Three are phytoplasmas which have the potential to have a significant impact on other horticultural species of economic importance in New Zealand. If further information becomes available about any one of the following organisms discussed in this chapter then it may be necessary to conduct further risk assessment, which may alter the current status of the organism, *i.e.* a hazard organism may become a risk organism.

Rose chlorotic ringspot virus (RoCRSV)

RoCRSV is not reported from New Zealand (Pearson et al 2006; PPIN 2012) Symptoms of this caulimo-like virus are of mosaic and chlorotic ringspots on leaves Lockhart *et al.* (2011) found spherical particles of 45-50nm diameter containing a dsDNA genome similar in size and electrophoretic migration pattern to those of caulimoviruses. However, sequence of RoCRSV did not match any known caulimovirus. Attempts to transmit this virus mechanically and by the aphid *Macrosiphum euphorbiae* were unsuccessful. The virus has been isolated from several rose cultivars in the USA. The affected cultivars included the hybrid musks 'Mozart' and 'Prosperity', the Bourbon 'Mm Pierre Oger, and the rugosas 'Schneezwerg' and 'Belle Poitevine' (Lockhart *et al.* 2011).

Rose necrotic mosaic virus (RoNMV)

RoNMV has not been reported from New Zealand (Pearson *et al.* 2006; PPIN 2012). This virus shows symptoms of mosaic, necrotic streaking and leaf distortion. It was isolated from the cultivar 'Sweet Fragrance'in the USA and has filamentous particles750-800nm long, with a tendency to both aggregate and fragment. It has no serological relationship or sequence identity to any known virus (Lockhart *et al.* 2011).

***Rosa rugosa* leaf distortion virus (RRLDV)**

RRLDV is a carmovirus in the Tombusviridae family (Mollow, D. pers comm.). Spherical virions are 30-32nm spheres containing a 4.4kb ssRNA genome.Symptoms of the virus include stunting and leaf distortion. RRLDV was identified from the rugosa cultivars 'Charles Albanel', 'Belle Poitevine', 'Blanc double de Coubert', 'Grüss an Aachen' and 'FJ Grootendorst' in the USA (Lockhart *et al.* 2011). RRLDV was tested for in several cultivars and not found in New Zealand (Perez-Egusquiza *et al,* 2012; Milleza *et al.* 2013).

Rose yellow leaf virus (RoYLV)

RoYLV is also a Carmovirus. It was identified from cultivars 'Fiesta' and 'Softee' in the USA, with symptoms of blotchy yellow mosaic, premature leaf yellowing and senescence. The virus has spherical virions 30-32nm in diameter, containing a ssRNA of about 4.2kb in size (Lockhart *et al.* 2011). RoYLV is similar to RRLDVat the amino acid level, but can still be differentiated by molecular techniques (Mollow, D. pers. comm.). RoYLV was tested for in several cultivars and not found in New Zealand (Perez-Egusquiza *et al,* 2012; Milleza *et al.* 2013)

Rose yellow mosaic virus (RoYMV)
RoYMV virions are flexuous filaments measuring 11-12 x 790-800nm containing an ssRNA genome about 9.0kb in size. A partial sequence of 1.7kb had no significant nucleotide sequence homology to any known virus. RoYMV infection produces symptoms of yellow mosaic, ring mosaic, premature leaf senescence and dark brown rings on canes. RoYMV was not transmitted mechanically, nor by aphid (*M. euphorbiae*), but was successfully graft transmitted from infected 'June Bride' to virus free 'Ballerina', 'George Vancouver', 'Love and Peace' and 'Tropicana'. This virus is reported from USA (Lockhart *et al.* 2011). RoYMV was tested for in several cultivars and not found in New Zealand (Perez-Egusquiza *et al*, 2012; Milleza *et al.* 2013)

Rose colour break (virus) (RCBV)
This tentative- tobamovirus is thought to be the causal agent of rose colour break disease (synonym: Rose flower break) (Hicks and Frost 1984) and is possibly rose virus 00.071.0.91.003 (ICTVdb 2009). The disease has previously been reported from roses in New Zealand (Horst and Cloyd 2007), however, no tobamovirus was detected in the recent rose survey (Milleza *et al.* 2013). Rose colour break symptoms were observed in some of the samples collected during the survey. It is possible the symptom has a different origin (Perez-Egusquiza, Z. pers comm.). If the virus was present in New Zealand previously, it may have been eliminated through more stringent cultivation and plant management practices. It has an impact on roses grown for cut flowers as it severely reduces the flower quality, distorting petal margins and intensifying colour in petal veins (Horst and Cloyd 2007). It therefore remains a hazard on the rose nursery stock pathway.

Tomato Varamin virus (ToVV) (syn: Tomato fruit yellow ring virus) [Bunyaviridae: Tospovirus]
ToVV (syn. Tomato fruit yellow ring virus "TFYRV" and Tomato yellow ring virus "TYRV" is a Tospovirus not known from New Zealand (Pearson *et al.* 2006; PPIN 2012; Milleza *et al.* 2013). It has been reported from Iran on rose, tomato and various ornamentals and weeds (Ghotbi *et al.* 2005), and has just been reported (asTYRV) from Kenya on tomato (Birithia *et al.* 2012) which indicates the virus may spread to other countires and potentially to roses also.

It appears from other records, such as Rasoulpour and Izadpanah (2007) (cineraria) and Hassani-Mehraban *et al.* (2007) (soybean, potato) that there are different strains of the virus. ToVV is graft transmissible and is also transmitted by thrips; *Microcephalothrips abdominalis* and *Thrips tabaci* are implicated as possible vectors. Both thrips species are present in New Zealand.

As ToVV is a relatively new virus and currently reported on rose only from Iran, there is insufficient information upon which to base a full risk assessment. However, it is considered a hazard on rose nursery stock given that the vectors, already in New Zealand, would be capable of transmitting the virus to other hosts including tomato.

***'Candidatus* Phytoplasma prunorum' (16SrX-B) - European stonefruit yellows (ESFY) [Mollicutes];**
and
Rubus stunt phytoplasma [Mollicutes]
'*Candidatus* Phytoplasma prunorum' (group16SrX-B) and Rubus stunt phytoplasma have not been reported from New Zealand (Pearson *et al.* 2006; PPIN 2012). *Ca*. P. prunorum is present in 15 of the 27 EU countries (Steffek *et al.* 2012), also Turkey and Azerbajdzhan (*In*:

Marcone *et al.* 2010). It is prevalent in the important stonefruit production areas (Central and Southern Europe) where it causes substantial impacts in apricots, Japanese plums, and peaches. It is occasionally found in plums (which tolerate the infection) in Northern Europe (Steffek *et al.* 2012). Marcone *et al.* (2010) state that '*Ca*. P. prunorum' includes strains that differ greatly in aggressiveness, from avirulent to highly virulent. '*Ca*. P. prunorum' is vectored by the psyllid, *Cacopsylla pruni.*

Rubus stunt phytoplasma, as reported by Jarausch *et al.* (2001) is possibly the phytoplasma that is reported as belonging to the the Elm yellows phytoplasma group 16SrV (Malembic-Maher *et al.* 2011); Rubus stunt phytoplasma in the Elm yellows group has been proposed as a "novel putative taxon: '*Candidatus* Phytoplasma rubi' " (Malembic-Maher *et al.* 2011). There is little information given by Jarausch *et al.* (2001) about this phytoplasma in *Rosa* canina, although they suggest the vector of Rubus stunt phytoplasma, the leafhopper *Macropsis fuscula*, may be responsible for transmitting the disease to *Rosa canina* and great mallow. Rubus stunt phytoplasma causes proliferation disease in *Rubus* species (Jarausch *et al.* 2001) and may potentially have unwanted impacts on native *Rubus* spp., the berry industry and roses.

'Ca. P. prunorum' and Rubus stunt phytoplasma have been reported from *Rosa canina* (dog rose) in France (Jarausch *et al.* 2001). There do not appear to be any other reports in the literature of either of these organisms infecting other *Rosa* species. The report from Jarausch *et al.* (2001), state that these phytoplasmas are symptomless in *R. canina*. It should be noted that forms of *Rosa canina* have been used as a rootstock in the past. These organisms are regarded as hazards. If further information becomes available regarding '*Ca*. P. prunorum' and/or Rubus stunt phytoplasma in roses then they may warrant full risk analyses.

***Xylella fastidiosa* (Bacteria: Gracilicutes)**
X. fastidiosa is a xylem limited bacteria vectored by several sharpshooters (Heteroptera: Cercopidae) and is also graft transmissible. *X. fastidiosa* has not been reported from New Zealand (NZFungi 2012; PPIN 2012; Young *et al.* 2012). *X. fastidiosa* has been cultured from *Rosa californica* (Purcell and Saunders 1999) http://nature.berkeley.edu/xylella/

There is insufficient information on *Rosa* species as a host for *X. fastidiosa* to conduct a risk analysis on this bacteria in *Rosa* NS. However, it is included as a hazard organism as it is considered the potential impacts associated with this bacteria (Pierce's disease especially) warrant a precautionary approach. The sharpshooter *Graphocephala atropunctata* (blue-green sharpshooter) is reported on rose, is known to vector Pierce's disease, and is found from Central America to British Colombia http://nature.berkeley.edu/xylella/

X. fastidiosa is an organism that could have a devastating impact on New Zealand's horticultural industries, in particular grapes for wine which earns over one billion dollars a year in exports.

Xylella fastidiosa is reported from parts of North, Central and South America, India and Taiwan (EPPO data sheet). *Xylella fastidiosa* causes four important crop diseases in California: Pierce's disease of grapevines, almond leaf scorch, alfalfa dwarf, and oleander leaf scorch. Oleander leaf scorch, is suspected to be caused by a strain of *Xylella fastidiosa*. Diseases have also been reported in some weed species such as umbrella sedge, poison hemlock, and Dallis grass. In Brazil it causes Citrus variegated chlorosis; in Taiwan it is suspected to cause leaf scorch disease in pear.

4.1.1 Diseases of unknown ætiology

Rose bud proliferation
Rose bud proliferation has not been reported from New Zealand (PPIN 2012; Pearson *et al.* 2006). Under this name the disorder has only been reported from the Netherlands (Bos and Perquin 1975). There was no other information found and the symptoms are consistent with those of some phytoplasmas. In terms of the disorder by this name, there is insufficient information to consider it a hazard on roses. However, two phytoplasmas in rose have been assessed as risk organisms.

Rose cowl forming disease
This disorder has not been reported from New Zealand (PPIN 2012; Pearson *et al.* 2006). Rose cowl-forming disease was mentioned in Cooper (1993) as a disorder in rose. Klastersky (1951) reported it as graft transmissible and wrote it was found in lime (*Tilia* sp.), elm and rose. Válová *et al.* (2004) mention cowl formation in 3 species of *Tilia* in the Czech Republic, attributable to aster yellows phytoplasma. Navrátil *et al.* (2009) found cowl formation in elm trees in the Czech Republic, and identified a phytoplasma that sits within the Elm yellows group 16Sr-V. It seems likely that the cowl formation mentioned in rose may be a symptom of a phytoplasma presence. There is insufficient information about the disorder under this name to pursue it. However, at least 2 phytoplasmas in rose have been assessed as risk organisms.

Rose leaf curl disease
The disease is widely distributed in the USA, especially near the old rose varieties. Characteristic symptoms resembling rose wilt occur on hybrid teas but not on rootstock cultivars. Symptoms first seen in the spring are reduced leaf size, easily detached leaves, leaf epinasty, necrosis of shoot tips, yellow flecking of veins, which may progress into necrosis. Shoots are characteristically pointed with a broad base. Plants may recover during summer but symptoms reappear in the autumn, usually as leaf epinasty and as cracking, internal necrosis, longitudinal corky areas and xylem pitting in mature canes. Good indicator plants are the cultivars 'Queen Elizabeth' and 'Madame Butterfly' (Horst & Cloyd 2007). The causal agent of rose leaf curl has not been determined, however, a begomovirus named Rose leaf curl virus has recently been associated to the disease (Khatri *et al.* 2011). Begomoviruses were tested for and were not found in a limited survey of roses in New Zealand (Milleza *et al.* 2013)

Rose ring pattern
This disease occurs in commercially grown roses in Oregon and California, USA. It was first found in *Rosa multiflora* 'Burr' which is a reliable indicator for the causal agent. The symptoms have been readily transmitted by graft to numerous cultivars, to *R. rugosa* and major rootstocks. Infection produces rings, fine line patterns and chlorotic flecking of leaves in most cultivars. Symptoms may resemble those caused by *Rose mosaic virus* but rose ring pattern does not cause the characteristic necrotic reaction in *Prunus serrulata* 'Shirofugen'. The rose cultivar Queen Anne develops yellow blotches on the leaves and colour breaking in ring patterns on petals. 'Madame Butterfly also exhibits colour break symptoms. Some rootstocks do not exhibit symptoms when infected, though *R. manetti*, *R. odorata* Sweet cv. Sweet and 'Dr. Huey' develop faint ring patterns or line patterns (Horst and Cloyd 2007). The virus or virus-like causal agent for rose ring pattern has not been identified, appears to be disseminated through propagative plant material (i.e. grafting) and there is no evidence for natural transmission in greenhouse or field grown roses. The causal agent is sensitive to

thermal therapy. Remission of symptoms has also been observed in *R. multiflora* after treatments with the antiviral compound ribavirin (Horst and Cloyd 2007).

Rose streak disease (Rose streak virus, RSV)
This disease occurs in Europe and the USA the causal agent is suspected to be a virus, Rose streak virus (RSV). It has not been reported from New Zealand (PPIN 2012; Pearson *et al.* 2006). The virus is graft transmitted and appears to only affect roses. Characteristic symptoms of rose streak are brownish-green rings and veinbanding in expanded leaves, premature leaf drop, ring patterns on stems and sometimes on fruits (Hosrt and Cloyd 2007). Inoculation of rose streak infected buds by graft causes necrosis and blackening around the inserted bud soon after the union has been established (Secor *et al.* 1977). Cultivars 'Ophelia', 'Madame Butterfly', 'Briarcliff' and 'Rapture' are sensitive indicators of RSV. Infections may occur in tea roses, hybrid teas, hybrid perpetual, hybrid multifloras, hybrid wichuraianas, hybrid rugosas, hybrid Bengals, noisettes, Chinas and polyanthas. Rugosas may have mild or undetectable symptoms compared to wichuraianas and hybrid multifloras which exhibit severe symptoms.

Rose stunt
Under this name the disorder has only been reported from the UK. Similar disorders are reported from Netherlands, USA, Italy, Czechoslovakia, Bulgaria and New Zealand (Kaminska *et al.* 2001). There is insufficient information to carry out a risk analysis on this disorder. It is possible 'rose stunt' is a symptom of a phytoplasma infection. At least 2 phytoplasmas in rose have been assessed as risk organisms.

4.2 Hazard organisms with strains not known from New Zealand

***Tobacco streak virus* (TSV) (Bromoviridae: *Ilarvirus*)**
Tobacco streak virus has been reported from *Dahlia* sp. in New Zealand but it has not been reported from *Rosa* spp. here (Pearson *et al.* 2006). It is believed an old report of TSV in *Rubus ursinus* (Pearson et al 2006) was in fact *Strawberry necrotic shock virus* (Perez, Z. pers. comm.). TSV is considered a hazard as the type strain of this virus is not known from New Zealand. According to Horst & Cloyd (2007) TSV is found in *Rosa setigera* and wild roses in Oregon. The incidence is low in cultivars; symptoms are more severe than those exhibited from rose mosaic. Symptoms of TSV include irregular chlorotic areas, vein chlorosis and twisted leaves. TSV is reported on rose in China (Lu *et al.* 2001 in Gao *et al.* 2008), in the USA (Fulton 1970). TSV is also reported from Canada, Sth America, Africa, Europe, Asia and Australia and has a reasonably wide host range (EPPO 2009). Transmission can be by seed in many plant species, by pollen, and some species of thrips may be vectors.

4.3 Invertebrate hazards that are known or putative vectors of assessed organisms

The invertebrates listed in the following table are the known or putative vectors of the phytoplasmas, viruses and bacteria that have been assessed in Chapters 2, 3 and 4. It is not in the scope of this risk analysis to assess these invertebrates, but they are recorded here for reference. It must be noted that this is by no means a complete list, as there are vectors not yet identified or confirmed. Putative vectors have an asterisk next to their name.

Table 3. Some of the known and putative (*) invertebrate vectors of the pathogens assessed in this Import Risk Analysis

Invertebrate vectors	Family	Organism/disease vectored	Reference
Macrosteles spp.	Hemiptera: Cicadellidae	*'Candidatus* Phytoplasma asteris'	Lee *et al.* 2004
Euscelis spp.	Hemiptera: Cicadellidae	*'Ca.* P. asteris'	Lee *et al.* 2004
Scaphytopius spp.	Hemiptera: Cicadellidae	*'Ca.* P. asteris'	Lee *et al.* 2004
Aphrodes spp.	Hemiptera: Cicadellidae	*'Ca.* P. asteris'	Lee *et al.* 2004
Halyomorpha halys (brown marmorated stinkbug)	Hemiptera: Pentatomidae	*'Ca.* P. asteris'	Weintraub and Beanland 2006
Hishimonus phycitis	Hemiptera: Cicadellidae	*'Candidatus* Phytoplasma aurantifolia'	Salehi *et al.* 2007
*Empoasca papayae**	Hemiptera: Cicadellidae	*'Ca.* P. aurantifolia'	Arocha *et al.*.2007
*Orosius orientalis**	Hemiptera: Cicadellidae	*'Ca.* P. aurantifolia'	Naito *et al.* 2007
Cacopsylla melanoneura	Hemiptera: Psyllidae	*'Candidatus* Phytoplasma mali'	Tedeschi and Alma 2006
Cacopsylla picta (syn*: C. costalis)*	Hemiptera: Psyllidae	*'Ca.* P. mali'	Tedeschi and Alma 2006
Fieberiella florii (privet leafhopper)	Hemiptera: Cicadellidae	*'Ca.* P. mali'	Tedeschi and Alma 2006
*Philaenus spumarius** (froghopper/spittlebug)	Hemiptera: Aphrophoridae	*'Ca.* P. mali'	Hegab and El-Zohairy 1986
Cacopsylla pruni	Hemiptera: Psyllidae	*'Candidatus* Phytoplasma prunorum'	Marcone *et al.* 2010
Macropsis fuscula	Hemiptera: Cicadellidae	Rubus stunt phytoplasma	van der Meer 1987 *in*: Jarausch *et al.* 2001
Phyllocoptes fructiphilus	Acari: Eriophyidae	Rose rosette disease (virus)	Amrine *et al.* 1988
Microcephalothrips abdominalis	Thysanoptera:Thripidae	Tomato Varamin virus	Ghotbi *et al.* 2005
Thrips tabaci	Thysanoptera:Thripidae	Tomato Varamin virus	Ghotbi *et al.* 2005
Graphocephala atropunctata	Hemiptera: Cicadellidae	*Xylella fastidiosa*	Alexander Purcell http://nature.berkeley.edu/xylella/

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Appendix 1 List of potential hazard organisms (excluding fungi and invertebrates)

The following table lists graft transmitted potential hazard organisms (excluding fungi) for *Rosa* nursery stock. Invertebrates were not looked at as they are beyond the scope of this IRA. Fungi will be addressed as a second stage to this IRA. This list of organisms was established from the comprehensive (but not necessarily complete) list developed for *Rosa* cut flowers. The hazard identification process identified the following organisms potentially associated with *Rosa* plants. Organisms were classed as a potential hazard if they were not known to be present in New Zealand. Organisms were also classed as potential hazards if they are present in New Zealand and the organisms have strains that do not occur in New Zealand; if the organism is of restricted distribution in New Zealand, if the organism is under official control in New Zealand, or if the organism is listed on the unwanted organisms register (UOR) as a notifiable organism. Invertebrate vectors of potential hazard organisms are not listed in this table as they are not included in the scope of this IRA. However, the known and putative vectors of organisms assessed as hazard and risk organisms in this IRA are documented in Chapter 4.

Organism	Associated with *Rosa*	Countries reported from	Present in NZ	Continue?	Potential to establish and have unwanted impacts	Hazard conclusion	Consider further
Bacteria							
Bacillus pumilis [Bacilli: Bacilliaceae]	Y: intercepted on *Rosa multiflora* NS	N/A	Y: Young 2000	N		N	Appendix 2
Erwinia amylovora - fireblight [Enterobacteriaceae]	Y: Bradbury 1986	N/A	Y: PPIN 2010	N		N	Appendix 2
Pseudomonas marginalis [Pseudomonadaceae]	Y: Pennycook 1989	N/A	Y: NZFungi 2009; PPIN 2010	N		N	Appendix 2
Pseudomonas syringae (at the species level) [Pseudomonadaceae]	Y: PPIN 2010	N/A	Y: NZFungi 2009; PPIN 2010	N		N	Appendix 2
Pseudomonas syringae pv. *syringae* [Pseudomonadaceae]	Y: Bradbury 1986	N/A	Y: NZFungi 2009; PPIN 2010	N		N	Appendix 2

Organism	Associated with *Rosa*	Countries reported from	Present in NZ	Continue?	Potential to establish and have unwanted impacts	Hazard conclusion	Consider further
Pseudomonas viridiflava [Pseudomonadaceae]	Y: Pennycook 1989	N/A	Y: NZFungi 2009; PPIN 2010	N		N	Appendix 2
Rhizobium radiobacter (Ri plasmid, rhizogenic) [Rhizobiaceae]	Y: Horst 1983	N/A	Y: NZFungi 2009	N		N	Appendix 2
Rhizobium radiobacter (Ti plasmid, tumour forming) [Rhizobiaceae]	Y: Horst 1983	N/A	Y: NZFungi 2009	N		N	Appendix 2
Xylella fastidiotus [Xanthomonadaceae]	Y: Purcell and Saunders 1999	USA	N: NZFungi 2009	Y	Could establish in NZ, although vector is not here, could be vectored by similar species. Would have very severe impact on wine industry- causes Pierces disease in grapes- warrants further work.	Y	Chapter 4
Phytoplasmas							
'*Candidatus* Phytoplasma asteris'	Y: Kamińska *et al.* 2001	Europe, Asia, Africa, South America	N: Liefting *et al.* 2007; PPIN 2012	Y	Could establish in NZ and impacts would be serious across several horticultural industries.	Y	Chapter 2
'*Candidatus* Phytoplasma aurantifolia'	Y: Arocha *et al.* 2010	Europe, Asia, South America, Australia, some Pacific Islands	N: Liefting *et al.* 2007; PPIN 2012	Y	Could establish in NZ and would affect Citrus industry	Y	Chapter 2
'*Candidatus* Phytoplasma mali'	Y: Kamińska and Śliwa 2004	Europe, Turkey, Syria.	N: Liefting *et al.* 2007; PPIN 2012	Y	Could establish in NZ and would have serious impacts on apple industry	Y	Chapter 2
'*Candidatus* Phytoplasma prunorum'	Y: Jarausch *et al.* 2001	Europe, Turkey, Azerbajdzhan	N: Liefting *et al.* 2007; PPIN 2012	Y	Could establish in NZ and would have serious impact on stonefruit	Y	Chapter 4

Organism	Associated with *Rosa*	Countries reported from	Present in NZ	Continue?	Potential to establish and have unwanted impacts	Hazard conclusion	Consider further
Rubus stunt phytoplasma	Y: Jarausch *et al.* 2001	Europe	N: Liefting *et al.* 2007; PPIN 2012	Y	Could establish in NZ and would impact *Rubus* species, potentially native spp.also	Y	Chapter 4
Viruses							
Alfalfa mosaic virus 00.010.0.01.001	Y: Pearson *et al.* 2006		Y: Pearson *et al.* 2006	N		N	Appendix 2
Apple mosaic virus 00.010.0.02.003 [Bromoviridae: Ilarvirus]	ICTVdb 2009		Y: Pearson *et al.* 2006	N		N	Appendix 2
Arabis mosaic virus 00.018.0.03.002 [Comoviridae: Nepovirus]	ICTVdb 2009		Y: Pearson *et al.* 2006	N		N	Appendix 2
Blackberry chlorotic ringspot virus	Y: Tzanetakis *et al*. 2006	USA, Scotland	N: Milleza *et al.* inpress; PPIN 2012	Y	Could establish, potential to affect *Rosa* and *Rubus* species	Y	Chapter 3
Citrus enation-woody gall virus 00.039.0.91.001 [Luteoviridae: Luteovirus]	Y: ICTVdb Association with rose is thought to be tenuous		Y: Pennycook 1989;	N		N	Appendix 2
Impatiens necrotic spot virus 00.011.0.05.002 [Bunyaviridae: Tospovirus]	Y: Ghotbi *et al.* 2005; Shahreen *et al.* 2002	Iran	Y: Pearson *et al.* 2006	N		N	Appendix 2
Iris yellow spot virus [Bunyaviridae: Tospovirus]	Y: Ghotbi *et al.* 2005	Iran (Roses)	Y: PPIN 2012 (PHA :20450)	N		N	Appendix 2
Prunus necrotic ringspot virus 00.010.0.02.015 [Bromoviridae: Ilarvirus]	Y: ICTVdb 2009; Pennycook 1989		Y: Pearson *et al.* 2006	N		N	Appendix 2
Rose chlorotic ringspot virus	Y: Lockhart *et al.* 2012	USA	N: Pearson *et al.* 2006; PPIN 2012	Y	Could establish in NZ and impact upon rose nursery and cutflower industry	Y	Chapter 4

Organism	Associated with *Rosa*	Countries reported from	Present in NZ	Continue?	Potential to establish and have unwanted impacts	Hazard conclusion	Consider further
Rose colour break 'virus' [This is thought to be a Tobamovirus]	Y: Szyndel 2004		N: IDC rose survey 2011; Milleza *et al.* 2013	Y	previously established in NZ and could do so again -impact upon rose nursery and cutflower industry	Y	Chapter 4
Rose cryptic virus-1 [synonyms: *Rosa multiflora cryptic virus;* Rose transient mosaic]	Y: Lockhart *et al.* 2012; Martin and Tzanetakis 2008	USA	Y: IDC rose survey 2011; PPIN 2012	N		N	Appendix 2
Rose necrotic mosaic virus	Y: Lockhart *et al.* 2012	USA	N: Pearson *et al.* 2006; PPIN 2012	Y	Could establish in NZ and impact nursery and cutflower industries	Y	Chapter 4
Rose rosette disease (virus)	Y: Horst 1983	USA, Canada: Epstein & Hill 1999	N: Pearson *et al.* 2006	Y	Could establish in NZ and impact nursery and cutflower industries	Y	Chapter 3
Rosa rugosa leaf distortion virus	Y: Lockhart *et al.* 2012	USA	N: Pearson *et al.* 2006; PPIN 2012	Y	Could establish in NZ and impact nursery and cutflower industries	Y	Chapter 4
Rose spring dwarf-associated virus [Luteoviridae: Luteovirus]	Y: Salem *et al.* 2008		Y: IDC rose survey 2011; PPIN 2012	N		N	Appendix 2
Rose yellow leaf virus	Y: Lockhart *et al.* 2012	USA	N: Pearson *et al.* 2006; PPIN 2012	Y	Could establish in NZ and impact nursery and cutflower industries	Y	Chapter 4
Rose yellow mosaic virus	Y: Lockhart *et al.* 2012	USA	N: Pearson *et al.* 2006; PPIN 2012	N		Y	Chapter 4
Strawberry latent ringspot virus 00.112.0.01.002 [unassigned: Sadwavirus]	Y: Horst & Cloyd 2007	ICTVdb 2009: "The virus is found, but with no evidence of proliferation, in Canada and New Zealand."	Y: Pearson *et al.* 2006.	N		N	Appendix 2

Organism	Associated with *Rosa*	Countries reported from	Present in NZ	Continue?	Potential to establish and have unwanted impacts	Hazard conclusion	Consider further
Tobacco mosaic virus 00.071.0.01.001 [Unassigned: Tobamovirus]	See Appendix 2		Y: Pearson *et al.* 2006	N		N	Appendix 2
Tobacco ringspot virus 00.018.0.03.001 [Comoviridae: Nepovirus]	Y: McDaniel *et al.* 1971		Y: Pearson *et al.* 2006.	N		N	Appendix 2
Tobacco streak virus 00.010.0.02.017 [Bromoviridae: Ilarvirus]	Y: Lu *et al.* 2001 in Gao *et al.*. 2008, Converse and Bartlett 1979		Y: Pappu *et al.* 2008 (strains) N:The type strain is **not** known from NZ	Y	Type strain could establish in NZ and have unwanted impacts on several species of economic importance to NZ	Y	Chapter 4
Tomato ringspot virus 00.018.0.03.029 [Comoviridae: Ilarvirus]	Y: Halliwell and Milbraith 1962		Y: Pearson *et al.* 2006; regulated strains	N		N	Appendix 2
Tomato spotted wilt virus 00.011.0.05.001 [Bunyaviridae: Tospovirus]	Y: Ghotbi *et al.* 2005		Y: Pearson *et al.* 2006	N		N	Appendix 2
Tomato Varamin virus (ToVV) [Bunyaviridae: Tospovirus]	Y: Ghotbi *et al.* 2005	Only reported from Iran-Ghotbi *et al.* 2005	N: PPIN 2012	Y	Could establish in NZ and have serious impacts on tomato industry- vectors are in NZ	Y	Chapt er 4
Rose yellow vein virus	Y: Lockhart *et al.* 2012		Y: IDC rose survey 2011; PPIN 2012	N		N	Appendix 2

Organism	Associated with *Rosa*	Countries reported from	Present in NZ	Continue?	Potential to establish and have unwanted impacts	Hazard conclusion	Consider further
Diseases of unknown aetiology							
Rose bud proliferation	Y: Ikin and Frost 1974	Italy	N: Milleza *et al*. 2013	Y		UNC	Chapter 4
Rose cowl forming disease	Y: Cooper 1993	Czechoslovakia	N: Pearson *et al.* 2006;	Y		UNC	Chapter 4
Rose "frisure"	Y: Devergne & Coujon 1975	France	N: Pennycook 1989; Pearson et al 2006; Milleza et al 2013	N		N	Appendix 2
Rose leaf curl Thought to be a Begomovirus	Y: Horst & Cloyd 2007	USA	N: Milleza *et al*. 2013	Y	Could establish in NZ and impact upon rose nursery and cutflower industry	Y	Chapter 4
Rose little leaf	Y: Szyndel 2004	Sth Africa (Meyer 1960)	N: Pearson *et al.* 2006	N		N	Appendix 2
Rose petal fleck	Y: Rosa pest list archive		Y: Pennycook 1989 (see Appendix 2)	N		N	Appendix 2
Rose ring pattern	Y: Horst 1983	USA	N: Pearson *et al.* 2006	Y	Could establish in NZ and impact upon rose nursery and cutflower industry	Y	Chapter 4
Rose streak (virus?)	Y: Horst 1983	USA	N: Pearson *et al.* 2006	Y	Could establish in NZ and impact upon rose nursery and cutflower industry	Y	Chapter 4
Rose stunt	Y: Ikin & Frost 1974	USA	N: Pearson *et al.* 2006; PPIN 2012	Y		UNC	Chapter 4
Rose wilt	Y: Horst 1983		Y: Pearson *et al.* 2006	N		N	Appendix 2
Rose yellow mosaic	See RoYMV		See Appendix 2	N		N	Appendix 2

UNC= uncertain

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Appendix 2 Excluded organisms

The following organisms have been excluded from the list of hazard organisms. They do not meet some of the criteria that would classify them as hazard organisms. The rationale for exclusion is stated. Should new information become apparent for any of these organisms then the organism/s may need to be reassessed and this may result in a change of conclusion.

Organism	Reason for exclusion
Bacillus pumilis	This organism had been intercepted from Australia in the past on *Rosa multiflora* nursery stock. There is limited information on this species in NZ, but it is a widespread species (e.g. found in soil) and is largely non-pathogenic. There is no information of it in association with roses therefore cannot justify considering it as a hazard.
Erwinia amylovora	We have investigated the possibility of strains and associations with rose, and this organism is not considered a hazard on *Rosa* nursery stock.
Pseudomonas marginalis	The type pathovar is reported from rose in NZ.
Pseudomonas syringae (at the species level)	Present in NZ, widespread, wide host range, numerous pathovars and the two that are associated with rose will be listed separately
Pseudomonas syringae pv. *syringae*	Reported on rose in New Zealand
Pseudomonas viridiflava	Reported on rose in New Zealand
Rhizobium radiobacter (Ri plasmid, rhizogenic)	Present in New Zealand
Rhizobium radiobacter (Ti plasmid, tumour forming)	Present in New Zealand
Alfalfa mosaic virus 00.010.0.01.001	It has been reported on roses in New Zealand, but not on roses overseas.
Apple mosaic virus 00.010.0.02.003	Reported on roses in NZ in the past, was not found in recent survey. There do not appear to be recognised strains of it (ICTVdb 2009) therefore it cannot be considered a hazard on roses from overseas.
Arabis mosaic virus 00.018.0.03.002	Present on rose in New Zealand
Citrus enation-woody gall virus 00.039.0.91.001	Although there has been some uncertainty in the past as to whether citrus enation virus is present in new Zealand (Pearson *et al.*. 2006) it is now known to be present (PPIN 2011). There is one report of it associated with rose (Fraser 1979 in ICTVdb) which is loose and there is no other evidence in the literature searched to support Frasers (1979) comment. Additionally, the virus is considered of minor importance.
Impatiens necrotic spot virus 00.011.0.05.002	Reported from Rose overseas. Present in NZ, although was not found on rose in recent survey. There are no recognised strains mentioned (ICTVdb 2009) so it is not considered a hazard on rose.
Iris yellow spot virus	This virus is reported from rose in Iran (but is not an approved exporter of roses to NZ) and is said to have a narrow host range. It does not appear to be on rose elsewhere, nor does there appear to be mention of strains. It has been reported from onion in New Zealand, but not from rose. It is not considered a hazard on rose.
Prunus necrotic ringspot virus 00.010.0.02.015	This virus is reported from roses in New Zealand (Melliza *et al.* in press)
Rose cryptic virus-1 [synonyms: *Rosa multiflora cryptic virus;* Rose transient mosaic virus]	Confirmed as present in New Zealand by Investigation & Diagnostic Centre (MPI) in Aug 2012.
Rose spring dwarf-associated virus	Confirmed as present in New Zealand by Investigation & Diagnostic Centre (MPI) in Aug 2012.

Organism	Reason for exclusion
Strawberry latent ringspot virus 00.112.0.01.002 [unassigned: Sadwavirus]	Reported from New Zealand, but no evidence of proliferation. ICTVdb (2009) do not mention strains although CAB Abstracts has numerous references to strains but host range and pathogenicity is unclear. However none associated with roses therefore is not considered a hazard on rose.
Tobacco mosaic virus 00.071.0.01.001	Rose is listed as a host of TMV in CPC and listed in Lisa 1998. However CPC listing is unreferenced. Lisa 1998 refers to Hicks and Frost 1984. This paper described the isolation of a virus from the tobamovirus group from rose but did not state that it was TMV and it is now described as separate virus. No other references to this virus on rose have been found. Therefore it is not considered in this document to occur on roses.
Tobacco ringspot virus 00.018.0.03.001 [Comoviridae: Nepovirus]	Reported from New Zealand. There are strains, but we are uncertain of what is present and what is absent from NZ. There is insufficient evidence of separate strains associated with roses to consider this virus a hazard on roses.
Tomato ringspot virus 00.018.0.03.029	This virus is reported from New Zealand. There are recognised, named strains but none are reported as associated with roses. There are 3 references citing this virus has been found in rose, first Halliwell and Milbraith (1962), they are cited in McDaniel *et al.* 1979 and both these 2 are cited in Moury *et al.* 2001. Added to this Gardiner 1983 thinks the Halliwell & Milbraith paper is suspect. There does not appear to be any significant new information and therefore this cannot be taken further.
Tomato spotted wilt virus 00.011.0.05.001	This virus is present in New Zealand. There is a report of it on rose in Iran, and the virus is found in numerous countries. There is plenty of evidence of strains (including resistance–breaking strains in *Chrysanthemum*, tomato, capsicum etc.), but CAB Abstract searches have not produced evidence of which specific strain is associated with rose.
Rose yellow vein virus	This virus has been detected on rose in Zealand (PPIN 2012)
Rose "frisure"	Not reported from New Zealand. There is one report by this name from France, all other references quote the one original reference. There is insufficient information to pursue this or to consider it a hazard on rose.
Rose little leaf	Not reported as present in New Zealand. In various plants including rose it appears to be associated with phytoplasma infections. In some plants, *e.g.* coconut and oil palm, 'little leaf' symptoms occur in combination with a nematode infestation, and in some pines it is a symptom of *Phytophthora cinnamomi* infection. It is sufficiently inconclusive to make it difficult to pursue and so it is assumed in this analysis that it is a component of a phytoplasma infection and is dealt with under the assessments for phytoplasmas.
Rose petal fleck	This disorder is present in New Zealand. It may be of viral origin but this hasn't been confirmed. It is likely to occur overseas but probably under a different name. It is not considered a hazard on imported roses.
Rose wilt	This disease is present in New Zealand, the causal agent has not been confirmed although Gardner 1983 suggested it was associated with PNRSV (also present in NZ) in mature rose plants.
Rose yellow mosaic- (as distinct from the virus characterised by Lockhart *et al.* 2011)	This is described by Cooper 1993 as a foliar symptom of rose viruses, and he doesn't treat it as a separate symptom from rose mosaic, it is possibly a symptom of PNRSV which is present in New Zealand. A lack of clarity makes it difficult to meaningfully pursue.

Appendix 3 *Rosa* nursery stock import pathway

Overview

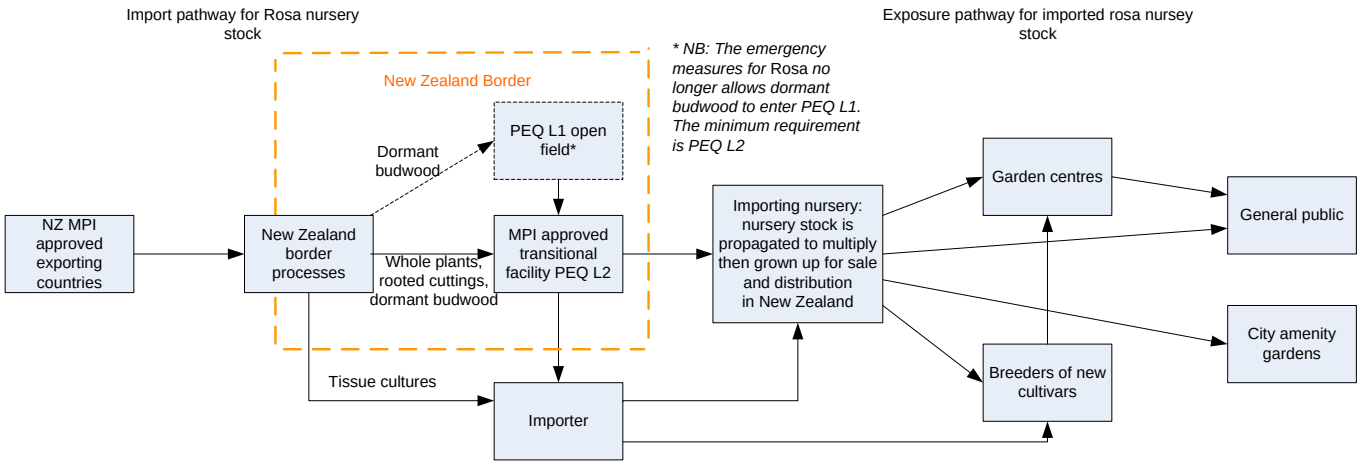

Figure 1. Overview of Rosa nursery stock import pathway

Entry to New Zealand

Rosa nursery stock arriving in New Zealand is inspected at the border. Whole plants, rooted cuttings and dormant cuttings are sent into a Level 2 post entry quarantine (L2PEQ) transitional facility for a minimum of 6 months during the growing period (see Basic conditions p. 62-63). Level 2 PEQ transitional facilities are MPI approved growing facilities that are expected to prevent the exit or entry of invertebrates and pathogens. If organisms, lesions or symptoms are found, samples are sent for identification. Tissue cultures are inspected and when cleared are released to the importer (see Basic conditions p 63).

Importers often bring nursery stock in to New Zealand to propagate from, and grow the new plants up to a point where they can be sold on to other breeders, or nurseries or garden centres. The following is a general description of how this may happen. For *Rosa* budwood, this is likely to begin with grafting the buds onto a number of pest and disease-free rootstocks (*e.g*. *Rosa multiflora* or similar) within L2PEQ. When the grafted buds are sufficiently developed, the rootstock foliage and stems are cut back to allow further growth of the new cultivar. After 6 months or longer, when the 'new' plants appear to be clear of disease they are likely to be planted into the open field and grown up to a point where budwood can be harvested from them. The new 'crop' of buds is grafted onto rootstock in the fields for further propagation. Plants that are ready for sale are usually about two years old, but often the grafting and propagation process may have taken up to 5-6 years. Therefore, in some cases it may take a few years before the plants leave the original importer. Nurseries and garden centres may then sell the rose plants to the general public, or city amenity nurseries may plant out the roses into city spaces, *e.g* traffic islands, road verges, city parks.

In figure 2 the basic conditions for entry to New Zealand and the biosecurity processes are outlined.

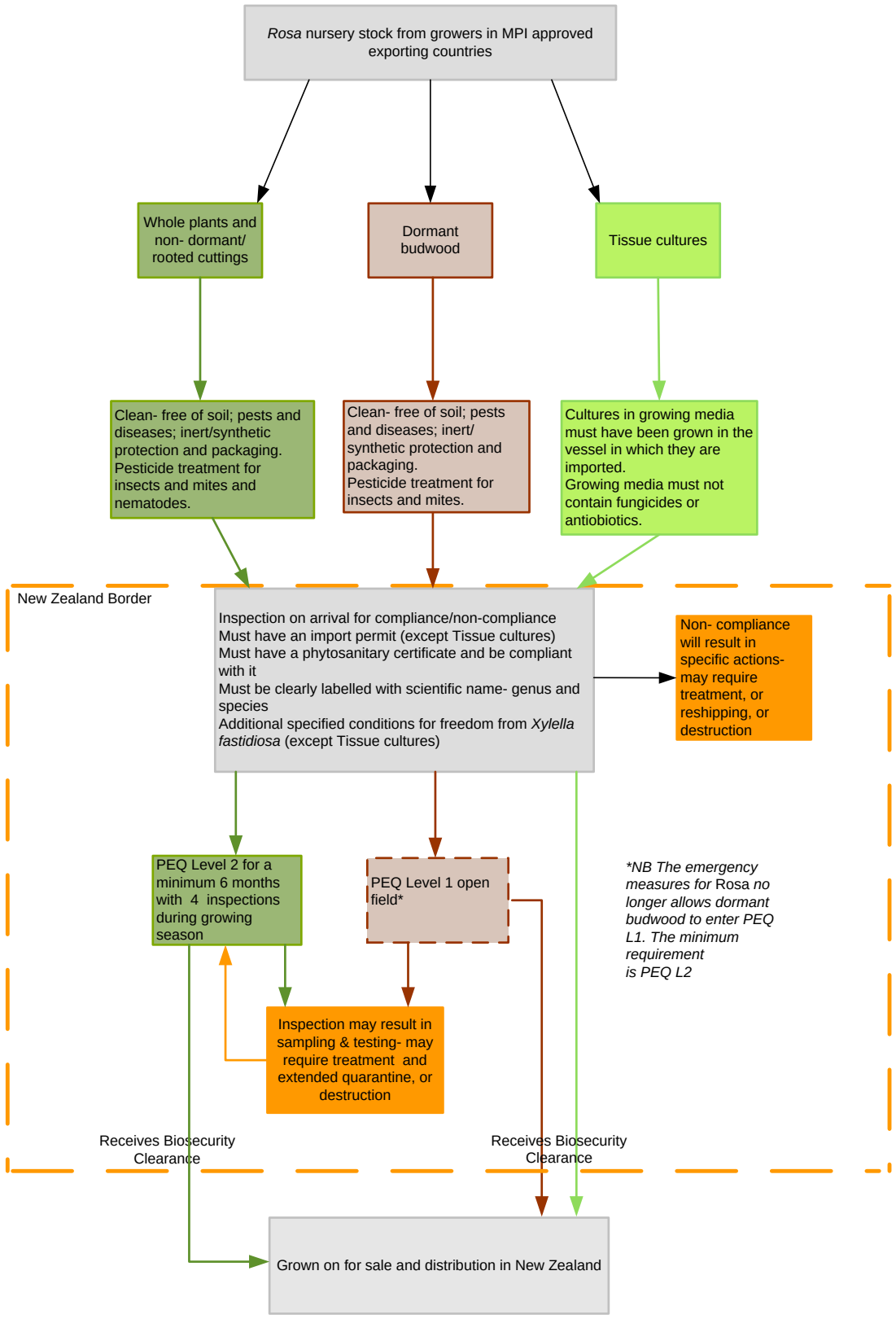

Figure 2. Overview of the border biosecurity process for the entry of *Rosa* nursery stock to New Zealand as at 2012

Basic[7] Conditions of Entry

The following is a summary of the conditions in the Import Health Standard for Nursery Stock and is given for a general understanding in the context of this risk assessment. For the specifics conditions for importation the reader is directed to the MPI Biosecurity website, and the Import Health Standard 155-02-06 Importing Nursery Stock
http://www.biosecurity.govt.nz/ihs/search

All nursery stock imported into New Zealand must comply with the Basic Conditions in section 2.2 of the import health standard. The Basic Conditions section is split into three parts to identify the mandatory requirements for each commodity type:

- 2.2.1 Whole plants (includes rooted cuttings), cuttings (dormant and non-dormant) and dormant bulbs (and tubers)
- 2.2.2 Plants in tissue culture (plants in-vitro)
- 2.2.3 Pollen

Plants that are eligible for import into New Zealand as nursery stock are listed in the Plant Biosecurity Index. Plants with a nursery stock import specification of 'L2 (Basic)'[8] must meet the Basic Conditions as summarised below. There are schedules for various genera that have additional requirements, such as *Rosa* species.

Import requirements for 'L2 (Basic)' species imported as whole plants, cuttings or dormant bulbs

- 'L2 (Basic)' species are eligible for import from any country[9] and must comply with the requirements of section 2.2.1 of the import health standard when being imported as whole plants, cuttings, or dormant bulbs.
- A permit to import issued by MPI is required.
- The nursery stock must be clearly identified with the scientific name (genus and species). The scientific name may be given on the phytosanitary certificate, the invoice, or a written declaration by the importer or exporter.
- The nursery stock must be free from soil, pests, disease, extraneous plant material, and other contamination.
- A phytosanitary certificate issued by the exporting National Plant Protection is required, which verifies that the consignment complies with New Zealand's import requirements and is free from visually detectable pests.
- Pesticide treatments are required:
    - Whole plants (and rooted cuttings) must be either raised in soil-less growing media or the roots must be treated with fenamiphos.
    - Whole plants, cuttings and bulbs must be treated for insects and mites. The importer has the option to treat with methyl bromide or chemical treatments.
- Requirements for fungi may be required, depending on the country of origin. These measures are required regardless of the species being imported:
    - For *Helicobasidium mompa* (Violet root rot), all whole plants, cuttings, and dormant bulbs from the specified countries (in Asia and the Middle East) must

7 Referred to as "L2(Basic)" in the Plants Biosecurity Index
8 L2 denotes the level of post-entry quarantine required, i.e. post-entry quarantine level 2 which is screened to contain and exclude movement of invertebrates.
9 Rosa nursery stock is imported from MPI approved countries

meet specified requirements, e.g. pest free declarations endorsed on the phytosanitary certificate, and treatments may be required in some cases.
    - For *Phymatotrichopsis omnivora* (Texas root rot)' all whole plants (and 'L2(Basic)' dormant bulbs) from the specified countries (in Central America) must meet specific requirements, e,g, pest free declarations endorsed on the phytosanitary certificate.
- Requirements for *Phytophthora ramorum* (Sudden oak death) are required for named host species. This section allows importation of host species from only those countries recognised by MPI as being free from *P. ramorum*.
- Requirements for *Xylella fastidiosa* (Peirce's disease) are required for named host species. This section allows importation of host species from only those countries recognised by MPI as being free from *X. fastidiosa;* or if the country is not free it can be from a pest-free place of production and must be tested while in post entry quarantine.
- All consignments are inspected on arrival to verify that the documentation is compliant and the nursery stock is free from visually detectable pests. Inspection requirements are specified in Section 2.1 of the import health standard.
- Nursery stock must be grown in a Level 2 post-entry quarantine (PEQ) facility for a minimum active growth period of three months[10], during which time the plants undergo regular inspections for visually detectable pests and disease by the operator of the PEQ facility and the MPI Inspector.
- If symptoms or signs of pests or disease are observed on arrival in New Zealand or while in post-entry quarantine, samples are collected and submitted for identification. Where regulated organisms are identified the importer is given a list of appropriate options for the management of regulated organisms, including treatments (if appropriate), reshipment or destruction of the consignment.

Import requirements for 'L2(Basic)' species imported as tissue culture

- 'L2(Basic)' species (as specified in the Plant Biosecurity Index) are eligible for import from any country and must comply with the requirements of section 2.2.2 of the import health standard when being imported as tissue culture.
- A permit to import is not required.
- The tissue cultures must be clearly identified with the scientific name (genus and species). The scientific name may be given on the phytosanitary certificate, the invoice, or a written declaration by the importer or exporter.
- The nursery stock must be free from soil, pests, disease, extraneous plant material, and other contamination.
- A phytosanitary certificate issued by the exporting National Plant Protection Organisation is required, which verifies that the consignment complies with New Zealand's import requirements and is free from visually detectable pests.
- All consignments are inspected on arrival to verify that the documentation is compliant and the tissue cultures are free from visually detectable pests. Inspection requirements are specified in Section 2.1 of the import health standard.
- If symptoms or signs of pests or disease are observed on arrival in New Zealand the importer has the option to reship or destroy the tissue cultures, or samples are collected and submitted for identification. Where regulated organisms are identified the importer is given a list of appropriate options for the management of regulated

10 This can alter for specific schedules, *e.g.* for Rosa nursery stock the requirement is 6 months minimum

organisms, including treatments (if appropriate), reshipment or destruction of the consignment.

- A period in post-entry quarantine is not required, and the tissue cultures may be given biosecurity clearance on arrival in New Zealand if all requirements have been met.

Import requirements for 'L2(Basic)' species imported as pollen

The importation of pollen can only occur when pollen is listed as an approved commodity type on a specific schedule for that species. As 'L2(Basic)' species are not imported under a specific schedule, the importer would need to request the development of import requirements for pollen.

Appendix 4 *Rosa* and Rosaceae in New Zealand

Description of *Rosa*

Rose plants (in the genus *Rosa*) belong to the family Rosaceae. The last complete account of the genus *Rosa* was made in 1820 and problems of classification and naming are rife, with many species being cultivated and hybridized for centuries and some species being highly polymorphic. When documenting pest-host associations many authors will subsequently avoid identifying rose plants to species level (Huxley and Griffiths, 1999). In the context of this risk analysis a rose plant may therefore refer to any plant species in the genus *Rosa*.

Leaves of *Rosa* species are alternate, usually odd-pinnate, and toothed. Small stipules (leafy outgrowths) are usually present at the base of the leaf stalks and the stems usually have thorns and/or bristles. Flowers of *Rosa* species can be solitary or in corymbs (clusters) and they are borne at the end of short branches, singly or paired. The bases of the sepals, petals and stamens are characteristically fused together into a structure called a hypathium which is globose to urn-shaped. Cultivated varieties have scores of scented petals but generally there are four or five sepals and four or five petals. Petals are usually obovate, coloured white, cream, pink, red, purple-pink, orange or yellow. Almost all species of *Rosa* are summer-flowering in temperate and sub-tropical zones (Huxley and Griffiths, 1999).

The genus *Rosa* includes 100 to 150 species of deciduous, or sometimes evergreen, shrubs with erect, arching, scrambling or occasionally trailing stems. In the ancient world the plants were grown commercially for the production of scented oils, and also for medicinal use through the distillation of rose hips, leaves, flowers and roots. Today, however, they are grown primarily as decorative plants for their flowers (Huxley and Griffiths, 1999).

Rosaceae in New Zealand

Other members of the Rosaceae in New Zealand that are of importance to the country include *Acaena* (NZ native), *Fragaria*, *Malus*, *Prunus*, *Pyrus*, and *Rubus* (exotic and NZ native) species.

There are a number of endemic taxa in the genus *Acaena*. Two are listed as threatened with *A. buchananii* has a status of gradual decline and *A. rorida* is reported to be Nationally Critical (NZPCN 2013). In the genus *Rubus* there are 6 endemic species, all reported at this time to be Non Threatened (NZPCN 2013).

The remaining genera listed above are of economic importance to New Zealand for either the domestic market or the export market or both. *Malus*, for instance, was the third largest earner of export dollars in the horticultural sector for 2011 (Fresh Facts 2012)

The New Zealand rose industry

There is little information regarding the rose industry in New Zealand and the economic value of the industry to New Zealand is not known. It provides plants and cut flowers to the public and to businesses. Roses are frequently used in public garden plantings, reflecting their popularity. Carpet roses are commonly used in roadside or traffic island plantings in some cities throughout the country, (*e.g.* Palmerston North). Parts of New Zealand have Historical collections of roses which date back to the arrival of the European settlers (*e.g.* Pauatahanui Burial Ground, Porirua City Council). New Zealand is noted for some exceptional roses bred by internationally recognised rose breeders such as Sam McGredy.

References for Appendix 4

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