Australian Government

Biosecurity Australia

Revised Draft Import Risk Analysis Report for Apples from New Zealand

Part C

December 2005

Please note that this is a draft document for comment only. It has been issued to give all interested parties an opportunity to comment and to draw attention to any errors, misinterpretations, typographical errors and gaps in the data. Any comments should be submitted to Biosecurity Australia within the comment period allowed (usually 60 days). The draft will then be revised to take account of the comments received and will be released as a final document at a later date.

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Cover image: Apple orchard in New Zealand.

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Appendix 1A – Pathogen categorisation

Scientific name	Common name/s	Reference for presence in New Zealand	Presence in Australia Reference	Potential for being on mature apple fruit Comments if applicable	Potential for establishment or spread	Potential for consequences Comments if applicable	Consider species further?
Bacteria							
Erwinia amylovora (Burrill 1882) Winslow et al. (1920) (Syn. = *Micrococcus amylovorus* (Burrill 1882); *Bacillus amylovorus* (Burrill 1882) Trevisan 1889; *Bacterium amylovorus* (*sic*) (Burrill 1882) Chester (1897)) [Enterobacteriaceae: Enterobacteriales]	Fire blight	MAFNZ (2000b); MAFNZ (2002b)	No *E. amylovora* was detected in the Melbourne Royal Botanic Garden in 1996 and its eradication was confirmed by a survey in 1997 (Jock et al., 2000)	Likely Fire blight is endemic in New Zealand. Fruit sourced from infected orchards have the potential to carry epiphytic bacteria (Hale et al., 1987) but endophytic infections in fruit are rare (van der Zwet et al., 1990)	Feasible	Significant (Bonn, 1999); (Vanneste, 2000)	Yes
Pseudomonas syringae pv. *syringae* van Hall (1902) [Pseudomonadaceae: Pseudomonadales]	Bacterial canker; blast; blister spot	MAFNZ (2000b); MAFNZ (2002b)	Yes (Shivas, 1989); (Washington and Nancarrow, 1983); (Cook and Dubé, 1989); (Letham, 1995)	-	-	-	No
Rhizobium radiobacter (Beijerinck & van Delden 1902) Young et al. (2001) (Basionym *Agrobacterium radiobacter* (Beijerinck & van Delden (1902) Conn (1942)) (Syn. = *Agrobacterium tumefaciens* (E.F. Smith & Townsend) Conn (1907) as in list (MAFNZ, 1999a)) [Rhizobiaceae: Rhizobiales]	Crown gall	MAFNZ (1999a)	Yes (Shivas, 1989); (Washington and Nancarrow, 1983); (Cook and Dubé, 1989); (Letham, 1995); (Simmonds, 1966); (Sampson and Walker, 1982); (APPD, 2005) as *A. tumefaciens*	-	-	-	No

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Fungi							
Alternaria alternata (Fr.: Fr.) Keissl. (1912) (Basionym *Torula alternata* Fr. (1832)) (Syn. = *Alternaria tenuis* Nees (1822), *Alternaria mali* Roberts (1924); *Alternaria fasciculata* (Cooke & Ellis) L.R. Jones & Grout (1897)) [Anamorphic *Lewia*]	Alternaria brown spot; black rot	MAFNZ (2000b); MAFNZ (2002b)	Yes (Shivas, 1989); (Pitkethley, 1998); (Washington and Nancarrow, 1983); (Cook and Dubé, 1989); (Letham, 1995); (Sampson and Walker, 1982); (APPD, 2005)	-	-	-	No
Antrodia serialis (Fr.: Fr.) Donk (1966) (Basionym *Polyporus serialis* Fr. (1821)) (Syn. = *Boletus serialis* (Fr.) Spreng. (1827); *Trametes serialis* (Fr.) Fr. (1874); *Coriolellus serialis* (Fr.) Murrill (1907)) [Polyporales: Meripilaceae]	None	MAFNZ (1999a)	Yes (APPD, 2005)	-	-	-	No
Armillaria (Fr.) Staude (1857) sp. [Agaricales: Marasmiaceae]	Armillaria root rot	MAFNZ (1999a)	Uncertain (APPD, 2005)	Not likely It is a root pathogen (MAFNZ, 2002b)	-	-	No
Athelia rolfsii (Curzi) C. C. Tu & Kimbr. (1978) (Basionym *Corticium rolfsii* Curzi (1931)) (Syn. = *Sclerotium rolfsii* Sacc. (1911)) [Polyporales: Atheliaceae]	Southern blight	MAFNZ (1999a)	Yes (Shivas, 1989); (Pitkethley, 1998); (Washington and Nancarrow, 1983); (Letham, 1995); (Simmonds, 1966); as *Sclerotium rolfsii* (APPD, 2005)	-	-	-	No
Auriculariopsis ampla (Lév.) Maire (1902) (Basionym *Cyphella ampla* Lév. (1848)) (Syn. = *Chaetocypha ampla* (Lév.) Kuntze (1891); *Schizophyllum amplum* (Lév.) Nakasone (1996)) [Agaricales: Schizophyllaceae]	None	MAFNZ (1999a)	Yes (Cook and Dubé, 1989)	-	-	-	No

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Botryosphaeria Ces. & De Not. (1863) sp. [Dothideales: Botryosphaeriaceae]	Fruit rot	MAFNZ (2000b); MAFNZ (2002b)	Uncertain (APPD, 2005)	Likely It causes primary fruit rot (MAFNZ, 2002b)	Feasible	Not significant There are several species belonging to this genus already in Australia (APPD, 2005) but no reports of economic damage in the literature	No
Botryosphaeria dothidea (Moug.: Fr.) Ces. & De Not. (1863) (Basionym *Sphaeria dothidea* Moug. (1823)) (Syn. = *Dothiorella mali* var. *fructans* Dearn. (1941)) [Dothideales: Botryosphaeriaceae]	Ripe spot; white rot	MAFNZ (2000b); MAFNZ (2002b)	Yes (Letham, 1995); (APPD, 2005)	-	-	-	No
Botryosphaeria lutea A. J. L. Phillips (2002) (Anamorph *Fusicoccum luteum* Pennycook & Samuels (1985) as in list (MAFNZ, 1999a)) [Dothideales: Botryosphaeriaceae]	Fusicoccum rot; ripe spot	MAFNZ (2000b); MAFNZ (2002b)	Yes*[1] (Denman et al., 2003) But not recorded in Western Australia	Likely Recorded on fruit in New Zealand as *Fusicoccum luteum* (Tyson, 2003)	Feasible	Not significant See appendix 1B	No
Botryosphaeria obtusa (Schwein.) Shoemaker (1964) (Basionym *Sphaeria obtusa* Schwein. (1832)) (Syn. = *Physalospora obtusa* (Schwein.) Cooke (1892)) [Dothideales: Botryosphaeriaceae]	Black rot	MAFNZ (2000b); MAFNZ (2002b)	Yes (Shivas, 1989); (Cook and Dubé, 1989); (Letham, 1995); (Sampson and Walker, 1982); (APPD, 2005)	-	-	-	No
Botryosphaeria parva Pennycook & Samuels (1985) (Anamorph: *Fusicoccum parvum* Pennycook & Samuels (1985)) [Dothideales: Botryosphaeriaceae]	Fruit rot; ripe spot	MAFNZ (2000b); MAFNZ (2002b)	Yes* (APPD, 2005) Recorded only from Queensland	Likely Detected on twigs of apple but may appear on fruit. See appendix 1B	Feasible	Not significant See appendix 1B	No

[1] 'Yes*' indicates that this species is present but not widely distributed and being officially controlled or where regional freedoms exist within Australia.

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Botryosphaeria ribis Grossenb. & Duggar (1911) (Syn. = *Botryosphaeria berengeriana* De Not. (1863); *Dothiorella ribis* (Fuckel) Sacc. (1884)) [Dothideales: Botryosphaeriaceae]	Stem canker; limb canker	CABI (2005)	Yes (Shivas, 1989); (Washington and Nancarrow, 1983); (Letham, 1995); (Simmonds, 1966); (APPD, 2005)	-	-	-	No
Botryosphaeria stevensii Shoemaker (1964) [Dothideales: Botryosphaeriaceae]	Black rot; diplodia canker	MAFNZ (2000b); MAFNZ (2002b)	Yes (Shivas, 1989); (Washington and Nancarrow, 1983); (APPD, 2005)	-	-	-	No
Botryotinia fuckeliana (de Bary) Whetzel (1945) (Basionym *Peziza fuckeliana* de Bary (18??)[2]) (Syn. = *Sclerotinia fuckeliana* (de Bary) Fuckel (1870); *Botrytis fuckeliana* N. F. Buchw. (1949)) [Helotiales: Sclerotiniaceae]	Dry eye rot; ghost spot; grey mould	MAFNZ (2000b); MAFNZ (2002b)	Yes (Shivas, 1989; Pitkethley, 1998); (Washington and Nancarrow, 1983); (Letham, 1995); (Cook and Dubé, 1989); (Simmonds, 1966); (Sampson and Walker, 1982); (APPD, 2005)	-	-	-	No
Calonectria kyotensis Terash. (1968) (Syn. = *Cylindrocladium floridanum* Sobers & C. P. Seym. (1967); *Calonectria uniseptata* Gerlach (1968)) [Hypocreales: Nectriaceae]	Root rot	MAFNZ (1999a)	Yes (APPD, 2005)	-	-	-	No
Calosphaeria Tul. & C. Tul. (1863) sp. [Calosphaeriales: Calosphaeriaceae]	None	MAFNZ (1999a)	Uncertain (APPD, 2005)	Not likely It occurs on bark (MAFNZ, 2002b)	-	-	No
Chondrostereum purpureum (Pers.: Fr.) Pouzar (1959) (Basionym *Stereum purpureum* Pers. (1794)) (Syn. = *Thelephora purpurea* (Pers.) Pers. (1801)) [Polyporales: Meruliaceae]	Silver leaf	MAFNZ (1999a)	Yes (Washington and Nancarrow, 1983); (Cook and Dubé, 1989); (Letham, 1995); (APPD, 2005)		-	-	No

[2] (?) = Publication date unknown

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Cladosporium herbarum (Pers.: Fr.) Link (1816) (Basionym *Dematium herbarum* Pers. (1794)) (Syn. = *Byssus herbarum* (Pers.) DC. (1815)) [Anamorphic *Mycosphaerella*]	Cladosporium rot	MAFNZ (2002b)	Yes (APPD, 2005)		-	-	No
Corticium salmonicolor Berk. & Broome (1873) (Syn. = *Erythricium salmonicolor* (Berk. & Broome) Burds. (1985); *Phanerochaete salmonicolor* (Berk. & Broome) Jülich (1975) as in list (MAFNZ, 1999a)) [Polyporales: Corticiaceae]	Root rot	MAFNZ (1999a)	Yes (Cook and Dubé, 1989); (Simmonds, 1966); as *Corticium salmonicolor* (APPD, 2005)		-	-	No
Corticium utriculicum G. Cunn. (1954) [Polyporales: Corticiaceae]	Root rot	MAFNZ (1999a)	No (APPD, 2005)	Not likely It occurs on roots (MAFNZ, 1999a)	-	-	No
Cytospora Ehrenb. (1818) sp. [Anamorphic *Valsa*]	None	MAFNZ (1999a)	Uncertain (Shivas, 1989) (Washington and Nancarrow, 1983); (Letham, 1995); (Simmonds, 1966); (APPD, 2005)	Not likely It occurs on wood (MAFNZ, 2002b)	-	-	No
Diaporthe Nitschke (1870) sp. [Diaporthales: Valsaceae]	Phomopsis rot; fruit rot	MAFNZ (2000b); MAFNZ (2002b)	Uncertain (APPD, 2005)	Likely It occurs on fruit (MAFNZ, 2002b)	Feasible	Not significant It causes secondary rot on fruit (MAFNZ, 2002b). Also see appendix 1B	No
Diaporthe actinidiae N. F. Sommer & Beraha (1975) [Diaporthales: Valsaceae]	Phomopsis rot; stem-end rot	MAFNZ (2000b); MAFNZ (2002b)	Yes* (APPD, 2005) Recorded only from New South Wales	Not likely No reports of association with apple fruit. See appendix 1B	-	-	No
Diaporthe eres Nitschke (1870) (Syn. = *Diaporthe conorum* (Desm.) Niessl (1876)) [Diaporthales: Valsaceae]	Phomopsis rot; stem-end rot	MAFNZ (2000b)	Yes (Shivas, 1989); (Letham, 1995); (APPD, 2005)	-	-	-	No

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Diplocarpon mespili (Sorauer) B. Sutton (1980) (Basionym *Stigmatea mespili* Sorauer (1878)) (Syn. = *Xyloma mespili* DC. ex Duby (1830); *Entomosporium maculatum* Lév. (1857); *Entomosporium mespili* (DC.) Sacc. (1880)) [Helotiales: Dermateaceae]	Fabraea leaf spot; fabraea spot; fruit spot	MAFNZ (2000b); MAFNZ (2002b)	Yes (Shivas, 1989); as *Entomosporium mespili* and *Entomosporium maculatum* (APPD, 2005)	-	-	-	No
Diplodia Fr. in Mont. (1834) sp. [Anamorphic *Botryosphaeria*]	None	MAFNZ (1999a)	Uncertain (Shivas, 1989); (Washington and Nancarrow, 1983); (APPD, 2005)	Not likely It occurs on twigs (MAFNZ, 2002b)	-	-	No
Discostroma corticola (Fuckel) Brockm. (1976) (Basionym *Sphaeria corticola* Fuckel (1870)) (Syn. = *Clethridium corticola* (Fuckel) Shoemaker & E. Müller [as *Clathridium*] (1964) as in list (MAFNZ, 1999a); *Griphosphaeria corticola* (Fuckel) Höhn. (1918); *Seimatosporium lichenicola* (Corda) Shoemaker & E. Müller(1964)) [Xylariales: Amphisphaeriaceae]	Postharvest rot; mouldy core	MAFNZ (1999a); MAFNZ (2002b)	Yes* As *Griphosphaeria corticola* and *Seimatosporium lichenicola* (APPD, 2005) Not recorded in Western Australia	Likely Can occur on fruit as *Clethridium corticola* (Rosenberger, 1990b)	Feasible	Not significant Not an economically significant disease. See appendix 1B	No
Elsinoë pyri (Woron.) Jenkins [as '*piri*'] (1932) (Basionym *Plectodiscella piri* Woron. (1914)) [Myriangiales: Elsinoaceae]	Anthracnose; scab	MAFNZ (2000b); MAFNZ (2002b)	Yes* As *Elsinoe piri*. (Letham, 1995; APPD, 2005) Recorded only from New South Wales and Queensland	Likely It can occur on fruit (Atkinson, 1971)	Feasible	Not significant Currently not considered an economically significant pest[3] See appendix 1B	No

[3] The term 'pest' used throughout this report is the collective term used for insect pests, plant diseases, viruses, bacteria and fungi that could harm plants. The formal definition used is the one provided in the International Plant Protection Convention (IPPC): any species, strain, or biotype of plant, animal or pathogenic agent injurious to plants or plant products

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Eutypa lata (Pers.: Fr.) Tul. & C. Tul. (1863) (Basionym *Sphaeria lata* Pers. (1796)) (Syn. = *Libertella blepharis* A. L. Sm. (1900)) [Xylariales: Diatrypaceae]	Eutypa canker; fruit rot; mouldy rot	MAFNZ (2000b); MAFNZ (2002b)	Yes (Cook and Dubé, 1989); (Letham, 1995); (CABI, 2005); (APPD, 2005)	-	-	-	No
Fusarium Link (1809) sp. [Anamorphic *Gibberella*]	None	MAFNZ (1999a)	Uncertain (APPD, 2005)	Not likely It occurs on twigs (MAFNZ, 2002b)	-	-	No
Fusarium culmorum (W. G. Sm.) Sacc. (1895) (Basionym *Fusisporium culmorum* W. G. Sm. (1884)) [Anamorphic *Gibberella*]	Storage rot	MAFNZ (2002c)	Yes (APPD, 2005)	-	-	-	No
Fusarium oxysporum Schltdl.: Fr. (1824) (Syn. = *Fusarium bulbigenum* (1887)) [Anamorphic *Gibberella*]	Root rot	MAFNZ (1999a)	Yes (Shivas, 1989); (Pitkethley, 1998); (Cook and Dubé, 1989); (Letham, 1995); (Simmonds, 1966); (Sampson and Walker, 1982); (APPD, 2005)	-	-	-	No
Geotrichum candidum Link: Fr. (1809) [Saccharomycetales: Dipodascaceae]	Storage rot	MAFNZ (2000b)	Yes (APPD, 2005)	-	-	-	No
Gibberella acuminata C. Booth (1971) (Syn. = *Fusarium acuminatum* Ellis & Everh. (1895)) [Hypocreales: Nectriaceae]	Fruit rot	MAFNZ (1999a)	Yes (APPD, 2005)	-	-	-	No
Gibberella avenacea R.J. Cook (1967) (Syn. = *Fusarium avenaceum* (Corda) Sacc. (1886)) [Hypocreales: Nectriaceae]	Fruit rot; fusarium mould	MAFNZ (2000b); MAFNZ (2002b)	Yes As *Fusarium avenaceum* (APPD, 2005)	-	-	-	No
Gibberella baccata (Wallr.) Sacc. (1878) (Basionym *Sphaeria baccata* Wallr. (1833)) (Syn. = *Fusarium lateritium* Nees (1817)) [Hypocreales: Nectriaceae]	Fruit rot; fusarium rot	MAFNZ (2000b); MAFNZ (2002b)	Yes (APPD, 2005)	-	-	-	No
Gibberella intricans Wollenw. (1930) (Syn. = *Fusarium equiseti* (Corda) Sacc. (1886)) [Hypocreales: Nectriaceae]	Fruit rot	MAFNZ (2000b); MAFNZ (2002b)	Yes (APPD, 2005)	-	-	-	No

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Glomerella cingulata (Stoneman) Spauld. & H. Schrenk (1903) (Basionym *Gnomoniopsis cingulata* Stoneman (1898)) (Syn. = *Colletotrichum acutatum* J.H. Simmonds (1965) as in list (MAFNZ, 1999a); *Colletotrichum gloeosporioides* (Penz.) Penz. & Sacc. (1884)) [*Incertae sedis*: Glomerellaceae]	Anthracnose; bitter rot	MAFNZ (2000b); MAFNZ (2002b)	Yes (Shivas, 1989); (Pitkethley, 1998); (Washington and Nancarrow, 1983); (Letham, 1995); (Simmonds, 1966); (Sampson and Walker, 1982); (APPD, 2005)	-	-	-	No
Leptosphaeria coniothyrium (Fuckel) Sacc. (1875) (Basionym *Sphaeria coniothyrium* Fuckel (1870)) (Syn. = *Coniothyrium fuckelii* Sacc. (1878)) [Pleosporales: Leptosphaeriaceae]	Stem canker	MAFNZ (1999a)	Yes (Letham, 1995); (Simmonds, 1966); (Sampson and Walker, 1982); (APPD, 2005)	-	-	-	No
Leucostoma persoonii (Nitschke) Höhn. (1928) (Basionym *Valsa persoonii* Nitschke (1870)) (Syn. = *Sphaeria leucostoma* Pers. (1801); *Valsa leucostoma* (Pers.) Fr. (1849) as in list (MAFNZ, 1999a)) [Diaporthales: Valsaceae]	Valsa canker	MAFNZ (2000b)	Yes (APPD, 2005)	-	-	-	No
Monilinia fructicola (G. Winter) Honey (1928) (Basionym *Ciboria fructicola* G. Winter (1883)) (Syn. = *Sclerotinia fructicola* (G. Winter) Rehm (1906); *Monilia fructicola* L.R. Batra (1991)) [Helotiales: Sclerotiniaceae]	Brown rot	MAFNZ (2000b); MAFNZ (2002b)	Yes (Washington and Nancarrow, 1983); (Cook and Dubé, 1989); (Letham, 1995); (Simmonds, 1966); (Sampson and Walker, 1982); (APPD, 2005)	-	-	-	No
Monilinia laxa (Aderh. & Ruhland) Honey (1945) (Basionym *Sclerotinia laxa* Aderh. & Ruhland (1905)) (Syn. = *Sclerotinia cinerea* Wormald (1921)) [Helotiales: Sclerotiniaceae]	Blossom blight	MAFNZ (2000b) MAFNZ (2002b)	Yes (Washington and Nancarrow, 1983); (Cook and Dubé, 1989); (Letham, 1995); (APPD, 2005)	-	-	-	No

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Mycosphaerella pomi (Pass.) Lindau (1897) (Basionym *Sphaerella pomi* Pass. (1878)) (Syn. = *Cylindrosporium pomi* C. Brooks (?)) [Mycosphaerellales: Mycosphaerellaceae]	Brooks fruit spot	MAFNZ (2000b); MAFNZ (2002b)	Yes* (Letham, 1995); As *Cylindrosporium pomi* (APPD, 2005) Recorded only from New South Wales	Likely Affects apple fruit See appendix 1B	Feasible	Not significant Does not appear to be an economically significant disease in the Southern Hemisphere including New Zealand and the State of New South Wales of Australia where it has been detected. See appendix 1B	No
Mycosphaerella tassiana (De Not.) Johanson (1884) (Basionym *Sphaerella tassiana* De Not. (?)) (Syn. = *Cladosporium graminum* Corda (1824); *Mycosphaerella schoenoprasi* Rabenh. (1894)) [Mycosphaerellales: Mycosphaerellaceae]	Cladosporium rot	MAFNZ (1999a)	Yes (APPD, 2005)	-	-	-	No
Nectria cinnabarina (Tode) Fr. (1849) (Basionym *Sphaeria cinnabarina* Tode (1791)) (Syn. = *Tubercularia vulgaris* Tode (1790)) [Hypocreales: Nectriaceae]	Nectria twig blight	MAFNZ (1999a)	Yes (Washington and Nancarrow, 1983); (Sampson and Walker, 1982); (APPD, 2005)	-	-	-	No
Nectria discophora Mont. (1854) [Hypocreales:Nectriaceae]	None	MAFNZ (1999a)	No (APPD, 2005)	Not likely It is recorded on wood (MAFNZ, 2002b)	-	-	No

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Neonectria galligena (Bres.) Rossman & Samuels (1999) (Syn. = *Nectria galligena* Bres. (1901); *Fusarium heteronemum* Berk. & Broome (1865); *Cylindrocarpon heteronema* (Berk. & Broome) Wollenw. [as '*heteronemum*'] (1926); *Cylindrocarpon mali* (Allesch.) Wollenw. (1928)) [Hypocreales: Nectriaceae]	European canker; eye rot; cylindrocarpon fruit rot	MAFNZ (2000b); MAFNZ (2002b)	No (APPD, 2005) Has been eradicated from Tasmania (Ransom, 1997)	Likely It causes a primary fruit spot. Latent fruit infections may occur (Swinburne, 1971a)	Feasible	Significant (Swinburne, 1970a)	Yes
Nectria haematococca Berk. & Broome (1873) (Syn. = *Fusarium solani* (Mart.) Sacc. (1881); *Haematonectria haematococca* (Berk. & Broome) Samuels & Nirenberg (1999)) [Hypocreales: Nectriaceae]	Storage rot	MAFNZ (2002c)	Yes (APPD, 2005)	-	-	-	No
Nectria radicicola Gerlach & L. Nilsson (1963) (Syn. = *Cylindrocarpon destructans* (Zinssm.) Scholten (1964); *Neonectria radicola* (Gerlach & L. Nilsson) Mantiri & Samuels (2001)) [Hypocreales: Nectriaceae]	Storage rot	MAFNZ (1999a)	Yes as *Cylindrocarpon destructans* (APPD, 2005)	-	-	-	No
Neofabraea alba (E. J. Guthrie) Verkley (1999) (Basionym. *Pezicula alba* E. J. Guthrie (1959) as in list (MAFNZ, 1999a)) (Syn. = *Gloeosporium album* Osterw. (1907); *Phlyctema vagabunda* Desm. (1847)) [Helotiales: Dermateaceae]	Ripe spot	MAFNZ (1999a)	Yes (Shivas, 1989); (Washington and Nancarrow, 1983); (Simmonds, 1966); (APPD, 2005)	-	-	-	No
Neofabraea corticola C. A. Jørg. (1930) (Syn. = *Pezicula corticola* (C. A. Jörg.) Nannf. (1932) as in list (MAFNZ, 1999a)) [Helotiales: Dermateaceae]	Bark canker	MAFNZ (1999a)	No (APPD, 2005)	Not likely It is recorded on bark (MAFNZ, 2002b)	-	-	No

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Neofabraea malicorticis H. S. Jacks. (1913) (Syn. = *Pezicula malicorticis* (H.S. Jacks.) Nannf. (1932) as in list (MAFNZ, 1999a)) [Helotiales: Dermateaceae]	Bull's-eye rot; anthracnose canker; gleoesporium rot; ripe spot	Pennycook (1989); Snowdon (1990b); Grove (1990b); MAFNZ (2000b) Note: *N. malicorticis* isolates in New Zealand have not been characterised by molecular techniques	No (APPD, 2005) All Australian herbarium specimens of *Neofabraea* species *were re-examined*. Of these, isolates from Victoria have been identified as *Neofabraea perennans* and two New South Wales collections and a Western Australian collection were an undescribed species of *Neofabraea* previously known from Portugal and Canada (Cunnington, 2004)	Likely	Feasible	Not significant See appendix 1C	No
Peniophora sacrata G. Cunn. (1955) (Syn. = *Amylostereum sacratum* (G. Cunn.) Burds. (1985) as in list (MAFNZ, 1999a); *Phanerochaete sacrata* (G. Cunn.) J. B. Taylor (1981); *Gloeocystidiellum sacratum* (G. Cunn.) Stalpers & P. K. Buchanan (1991)) [Russulales: Stereaceae]	Peniophora root canker	MAFNZ (1999a)	Yes (APPD, 2005)	-	-	-	No
Pestalotiopsis maculans (Corda) Nag Raj (1985) (Basionym *Sporocadus maculans* Corda (1839)) (Syn. = *Pestalotia maculans* (Corda) S. Hughes 1958); *Pestalotiopsis guepinii* Desmazières (1840) [as '*guepini*']) [Anamorphic *Pestalosphaeria*]	Twig dieback	MAFNZ (2000b); MAFNZ (2002b)	Yes As *Pestalotiopsis guepinii* (Shivas, 1989; APPD, 2005)	-	-	-	No

Scientific name	**Common name/s**	**Reference for presence in New Zealand**	**Presence in Australia Reference**	**Potential for being on mature apple fruit Comments if applicable**	**Potential for establishment or spread**	**Potential for consequences Comments if applicable**	**Consider species further?**
Phoma cava Schulzer (1871) (Syn. = *Phoma aposphaerioides* Briard & Har. (1890); *Pleurophoma cava* (Schulzer) Boerema, Loerakker & Hamers (1996)) [Anamorphic *Leptosphaeria*]	Mouldy core rot	MAFNZ (2000b); MAFNZ (2002b)	No (APPD, 2005)	Likely Fungus is associated with fruit (MAFNZ, 2002b)	Feasible	Not significant It is a secondary pathogen associated with apple fruit and rarely found in New Zealand (Tyson, 2003). See appendix 1B	No
Phoma exigua f. sp. *exigua* Malc. & E. G. Gray (?) [Anamorphic *Leptosphaeria*]	Phoma fruit spot; mouldy core rot; storage rot	MAFNZ (2000b); MAFNZ (2002b)	Yes (Shivas, 1989); (Cook and Dubé, 1989); (Letham, 1995); (Sampson and Walker, 1982)	-	-	-	No
Phoma glomerata (Corda) Wollenw. & Hochapfel (1936) (Basionym *Coniothyrium glomeratum* Corda (1840)) (Syn. = *Phoma alternariaceum* F. T. Brooks & Searle (1921)) [Anamorphic *Leptosphaeria*]	Phoma leaf and fruit spot; storage rot	MAFNZ (2000b); MAFNZ (2002b)	Yes (Shivas, 1989); (Letham, 1995); (Sampson and Walker, 1982); (APPD, 2005)	-	-	-	No
Phoma macrostoma f. sp. *macrostoma* Mont. (1849) (Syn. = *Polyopeus purpureus* A. S. Horne (1920)) [Anamorphic *Leptosphaeria*]	Phoma fruit spot; storage rot	MAFNZ (2000b); MAFNZ (2002b)	Yes (Washington and Nancarrow, 1983)	-	-	-	No
Phoma pomorum Thüm. (1879) (Syn. = *Phoma prunicola* (Opiz ex Sacc.) Wollenw. & Hochapfel (1936); *Phyllosticta pyrina* Sacc. (1878)) [Anamorphic *Leptosphaeria*]	Phoma fruit spot	MAFNZ (2000b)	Yes (Shivas, 1989); (Washington and Nancarrow, 1983); (Cook and Dubé, 1989); (Letham, 1995); (APPD, 2005)	-	-	-	No

Scientific name	Common name/s	Reference for presence in New Zealand	Presence in Australia Reference	Potential for being on mature apple fruit Comments if applicable	Potential for establishment or spread	Potential for consequences Comments if applicable	Consider species further?
Phomopsis (Sacc.) Bubák (1905) sp. [Anamorphic *Diaporthe*]	Phomopsis rot	MAFNZ (2000b)	Uncertain (APPD, 2005)	Likely It causes fruit rot (MAFNZ, 2002b)	Feasible	Not significant It causes secondary fruit rot in New Zealand (MAFNZ, 2002b). There are many records of this genus in Australia (APPD, 2005) but no reports of economic damage in the literature. See appendix 1B	No
Phyllachora pomigena (Schwein.) Sacc. (1883) (Basionym *Dothidea pomigena* Schwein. (1832)) (Syn. = *Gloeodes pomigena* (Schwein.) Colby (1920) as in list (MAFNZ, 1999a) [Phyllachorales: Phyllachoraceae]	Sooty blotch	MAFNZ (2000b); MAFNZ (2002b)	Yes (Shivas, 1989); (Letham, 1995); (Simmonds, 1966); (Sampson and Walker, 1982); (APPD, 2005) As *Gloeodes pomigena*	-	-	-	No
Phytophthora cactorum (Lebert & Cohn) J. Schröt. (1886) (Basionym *Peronospora cactorum* Lebert & Cohn (1870)) [Pythiales: Pythiaceae]	Phytophthora fruit rot	MAFNZ (2000b); MAFNZ (2002b)	Yes (Shivas, 1989); (Washington and Nancarrow, 1983); (Cook and Dubé, 1989); (Letham, 1995); (Sampson and Walker, 1982); (APPD, 2005)	-	-	-	No
Phytophthora cambivora (Petri) Buisman (1927) (Basionym *Blepharospora cambivora* Petri (1917)) [Pythiales: Pythiaceae]	Phytophthora root rot	MAFNZ (1999a)	Yes (Shivas, 1989); (Cook and Dubé, 1989); (Letham, 1995); (APPD, 2005)	-	-	-	No

Scientific name	Common name/s	Reference for presence in New Zealand	Presence in Australia Reference	Potential for being on mature apple fruit Comments if applicable	Potential for establishment or spread	Potential for consequences Comments if applicable	Consider species further?
Phytophthora citricola Sawada (1927) (Syn. = *Phytophthora cactorum* var. *applanata* Chester (1932)) [Pythiales: Pythiaceae]	Phytophthora root rot	MAFNZ (1999a)	Yes (Shivas, 1989); (Washington and Nancarrow, 1983); (Cook and Dubé, 1989); (APPD, 2005)	-	-	-	No
Phytophthora cryptogea Pethybr. & Laff. (1919) [Pythiales: Pythiaceae]	Phytophthora root rot	MAFNZ (1999a)	Yes (Shivas, 1989); (Cook and Dubé, 1989); (Letham, 1995); (Sampson and Walker, 1982); (APPD, 2005)	-	-	-	No
Phytophthora drechsleri Tucker (1931) (Syn. = *Phytophthora erythroseptica* var. *drechsleri* (Tucker) Sarej. (?)) [Pythiales: Pythiaceae]	Crown rot, collar and root rot	MAFNZ (1999a)	Yes (Shivas, 1989); (Pitkethley, 1998); (Washington and Nancarrow, 1983); (Cook and Dubé, 1989); (Simmonds, 1966); (Sampson and Walker, 1982); (APPD, 2005)	-	-	-	No
Phytophthora gonapodyides (H. E. Petersen) Buisman (1927) (Basionym *Pythiomorpha gonapodyoides* H. E. Petersen [as '*gonapodyides*'] (1909)) [Pythiales: Pythiaceae]	Phytophthora root rot	MAFNZ (1999a)	Yes (APPD, 2005)	-	-	-	No
Phytophthora megasperma Drechsler (1931) (Syn. = *Pythiomorpha miyabeana* S. Ito & Nagai (?)) [Pythiales: Pythiaceae]	Phytophthora root rot	MAFNZ (1999a)	Yes (Shivas, 1989); (Cook and Dubé, 1989); (Sampson and Walker, 1982); (APPD, 2005)	-	-	-	No

Scientific name	Common name/s	Reference for presence in New Zealand	Presence in Australia Reference	Potential for being on mature apple fruit Comments if applicable	Potential for establishment or spread	Potential for consequences Comments if applicable	Consider species further?
Phytophthora syringae (Kleb.) Kleb. (1909) (Basionym *Phloeophthora syringae* Kleb. (1906)) [Pythiales: Pythiaceae]	Phytophthora fruit rot	MAFNZ (2000b)	Yes* (Washington and Nancarrow, 1983); (Cook and Dubé, 1989); (APPD, 2005) Not recorded in Western Australia	Likely Soil fungus affecting mostly roots and collar but rarely fruit that is close to soil can be affected See appendix 1B	Feasible	Not significant It is of extremely low prevalence in New Zealand and they have removed it from the 2002 pest list (see appendix 1B). In States of Australia where it is present it is of minor economic significance	No
Pleospora herbarum Cavara & Mollica: Fr. {?} (1863) (Syn. = *Sphaeria herbarum* Pers. (1801); *Macrosporium parasiticum* Thüm.(?)) [Pleosporales: Pleosporaceae]	Pleospora rot	MAFNZ (2002b)	Yes (APPD, 2005)	-	-	-	No
Podosphaera leucotricha (Ellis & Everh.) E.S. Salmon (1900) (Basionym *Sphaerotheca leucotricha* Ellis & Everh. (1888)) (Syn. = *Sphaerotheca leucotricha* Ellis & Everh. (1888); *Oidium farinosum* Cooke (1887)) [Erysiphales: Erysiphaceae]	Powdery mildew	MAFNZ (2000b); MAFNZ (2002b)	Yes (Shivas, 1989); (Washington and Nancarrow, 1983); (Cook and Dubé, 1989); (Letham, 1995); (Simmonds, 1966); (Sampson and Walker, 1982); (APPD, 2005)	-	-	-	No
Polyporus arcularius (Batsch: Fr.) Fr. (1821) (Basionym *Boletus arcularius* Batsch (1783)) (Syn. = *Leucoporus arcularius* (Batsch: Fr.) Quél. (1888)) [Polyporales: Polyporaceae]	Stem rot	MAFNZ (1999a)	Yes (APPD, 2005)	-	-	-	No

Scientific name	**Common name/s**	**Reference for presence in New Zealand**	**Presence in Australia Reference**	**Potential for being on mature apple fruit Comments if applicable**	**Potential for establishment or spread**	**Potential for consequences Comments if applicable**	**Consider species further?**
Pythium Pringsh [nom. cons.] (1858) sp. [Pythiales: Pythiaceae]	Pythium root rot	MAFNZ (1999a)	Uncertain (Shivas, 1989) (Pitkethley, 1998); (Washington and Nancarrow, 1983); (Cook and Dubé, 1989); (Sampson and Walker, 1982); (APPD, 2005)	Not likely It is a root pathogen (MAFNZ, 2002b)	-	-	No
Pythium arrhenomanes Drechsler (1928) (Syn. = *Nematosporangium arrhenomanes* (Drechsler) Sideris (?)) [Pythiales: Pythiaceae]	Pythium root rot	MAFNZ (1999a)	Yes (Letham, 1995); (Simmonds, 1966); (APPD, 2005)	-	-	-	No
Pythium debaryanum R. Hesse [as '*de-baryanum*'] (1874) (Syn. = *Eupythium debaryanum* (R. Hesse) Nieuwl. (1916)) [Pythiales: Pythiaceae]	Pythium root rot; damping-off	MAFNZ (1999a)	Yes (Shivas, 1989); (Cook and Dubé, 1989); (Simmonds, 1966); (Sampson and Walker, 1982); (APPD, 2005)	-	-	-	No
Pythium echinulatum V. D. Matthews (1931) [Pythiales: Pythiaceae]	Pythium root rot; damping-off	MAFNZ (1999a)	Yes (Shivas, 1989); (Cook and Dubé, 1989); (Sampson and Walker, 1982); (APPD, 2005)	-	-	-	No
Pythium irregulare Buisman (1927) [Pythiales: Pythiaceae]	Pythium root rot; damping-off	MAFNZ (1999a)	Yes (Shivas, 1989); (Cook and Dubé, 1989); (Letham, 1995); (Simmonds, 1966); (Sampson and Walker, 1982); (APPD, 2005)	-	-	-	No
Pythium paroecandrum Drechsler (1930) [Pythiales: Pythiaceae]	Pythium root rot	MAFNZ (1999a)	Yes (Cook and Dubé, 1989); (APPD, 2005)	-	-	-	No
Pythium rostratum E. J. Butler (1907) [Pythiales: Pythiaceae]	Pythium root rot	MAFNZ (1999a)	Yes (Cook and Dubé, 1989); (Letham, 1995); (APPD, 2005)	-	-	-	No

Scientific name	**Common name/s**	**Reference for presence in New Zealand**	**Presence in Australia Reference**	**Potential for being on mature apple fruit Comments if applicable**	**Potential for establishment or spread**	**Potential for consequences Comments if applicable**	**Consider species further?**
Pythium ultimum Trow (1901) [Pythiales: Pythiaceae]	Pythium root rot	MAFNZ (1999a)	Yes (Shivas, 1989); (Pitkethley, 1998); (Cook and Dubé, 1989); (Letham, 1995); (Simmonds, 1966); (Sampson and Walker, 1982); (APPD, 2005)	-	-	-	No
Pythium vexans de Bary (1876) [Pythiales: Pythiaceae]	Pythium root rot	MAFNZ (1999a)	Yes (Shivas, 1989); (Pitkethley, 1998); (Cook and Dubé, 1989); (Letham, 1995); (Simmonds, 1966); (APPD, 2005)	-	-	-	No
Rhinocladiella Nannf. (1934) sp. [Anamorphic *Capronia*]	None	MAFNZ (2000b); MAFNZ (2002b)	Uncertain (APPD, 2005)	Likely It is recorded from fruit (MAFNZ, 2002b)	Feasible	Not significant No reports of economic damage in the literature. See appendix 1B	No
Rosellinia De Not. (1844) sp. [Xylariales: Xylariaceae]	Root rot	MAFNZ (1999a)	Uncertain (APPD, 2005)	Not likely It is a root pathogen (MAFNZ, 2002b)	-	-	No
Rosellinia necatrix Berl. ex Prill. (1904) (Syn. = *Dematophora necatrix* R. Hartig (1883)) [Xylariales: Xylariaceae]	Rosellinia root rot	MAFNZ (1999a)	Yes (Shivas, 1989); (Washington and Nancarrow, 1983); (APPD, 2005)	-	-	-	No
Schizothyrium pomi (Mont. & Fr.) Arx (1959) (Basionym *Labrella pomi* Mont. (?)) (Syn. = *Leptothyrium pomi* (Montagne and Fries) Saccardo (1880) as in list (MAFNZ, 1999a); *Zygophiala jamaicensis* E. W. Mason (1945)) [Microthyriales: Schizothyriaceae]	Fly speck	MAFNZ (2000b); MAFNZ (2002b)	Yes (Shivas, 1989); (Letham, 1995); (Simmonds, 1966); (APPD, 2005)	-	-	-	No

Scientific name	Common name/s	Reference for presence in New Zealand	Presence in Australia Reference	Potential for being on mature apple fruit Comments if applicable	Potential for establishment or spread	Potential for consequences Comments if applicable	Consider species further?
Sclerotinia sclerotiorum (Lib.) de Bary (1884) (Basionym *Peziza sclerotiorum* Lib. (1837) (Syn. = *Sclerotinia libertiana* Fuckel (1869)) [Helotiales: Sclerotiniaceae]	Calyx end rot; sclerotinia rot; white mould	MAFNZ (2000b); MAFNZ (2002b)	Yes (Shivas, 1989); (Cook and Dubé, 1989); (Letham, 1995); (Simmonds, 1966); (Sampson and Walker, 1982); (APPD, 2005)	-	-	-	No
Sphaerotheca pannosa (Wallr: Fr.) Lév. (1851) (Basionym *Alphitomorpha pannosa* Wallr. (1819)) [Erysiphales: Erysiphaceae]	Powdery mildew	MAFNZ (2000b); MAFNZ (2002b)	Yes (Pitkethley, 1998); (Cook and Dubé, 1989); (Sampson and Walker, 1982); (APPD, 2005)	-	-	-	No
Sporotrichum malorum Kidd & Beaumont (1924) (Syn. = *Phialophora malorum* (Kidd & Beaumont) McColloch (1944); *Cadophora malorum* (Kidd & Beaumont) W. Gams (2000)) [Anamorphic *Laetiporus*]	Side rot	MAFNZ (2002b)	Yes (APPD, 2005) As *Phialophora malorum*	-	-	-	No
Trametes ochracea (Pers.) Gilb. & Ryvarden (1987) (Basionym *Boletus ochraceus* Pers. (1794)) (Syn. = *Boletus zonatus* Nees (1817); *Trametes zonata* (Nees) Pilát (1939)) [Polyporales: Polyporaceae]	Wood rot	MAFNZ (1999a)	Yes (APPD, 2005) As *Trametes zonata*	-	-	-	No
Trametes pubescens (Schumach.: Fr.) Pilát (1939) (Basionym *Boletus pubescens* Schumach (1803)) (Syn. = *Polyporus pubescens* Schumach.: Fr. (1821)) [Polyporales: Polyporaceae]	Wood rot	MAFNZ (1999a)	No (APPD, 2005)	Not likely It is a wood rotting pathogen (MAFNZ, 1999a)	-	-	No
Trametes versicolor (L.: Fr.) Lloyd (1921) (Basionym *Boletus versicolor* L. (1753)) (Syn. = *Polyporus versicolor* (L.: Fr.) Fr. (1821); *Polystictus versicolor* (L.: Fr.) Fr. (1851)) [Polyporales: Polyporaceae]	Wood rot	MAFNZ (1999a)	Yes (Washington and Nancarrow, 1983); (Letham, 1995); (Sampson and Walker, 1982); (APPD, 2005)	-	-	-	No

Scientific name	Common name/s	Reference for presence in New Zealand	Presence in Australia Reference	Potential for being on mature apple fruit Comments if applicable	Potential for establishment or spread	Potential for consequences Comments if applicable	Consider species further?
Trichothecium roseum (Pers.: Fr.) Link (1809) (Basionym *Trichoderma roseum* Pers. (1797)) (Syn. = *Cephalothecium roseum* Corda (1838)) [Anamorphic Ascomycetes]	Mould; pink rot	MAFNZ (2000b); MAFNZ (2002b)	Yes (Shivas, 1989); (Washington and Nancarrow, 1983); (Letham, 1995); (Sampson and Walker, 1982); (APPD, 2005)	-	-	-	No
Venturia inaequalis (Cooke) G. Winter (1875) (Basionym *Sphaerella inaequalis* Cooke (1866)) (Syn. = *Spilocaea pomi* Fr.: Fr. (1825); *Fusicladium dendriticum* (Wallr.) Fuckel (1870)) [Pleosporales: Venturiaceae]	Apple scab; black spot	MAFNZ (2000b); MAFNZ (2002b)	Yes* (Washington and Nancarrow, 1983); (Cook and Dubé, 1989); (Letham, 1995); (Simmonds, 1966) (Sampson and Walker, 1982); (APPD, 2005). Under official control in Western Australia (Kumar, 2002)	Likely It causes primary fruit spot (MAFNZ, 2002b) See Appendix 1B	Feasible	Significant (Biggs, 1990)	Yes*
Verticillium dahliae Kleb. (1913) (Syn. = *Verticillium albo-atrum* var. *dahliae* (Kleb.) R. Nelson (1950)) [Anamorphic *Hypomyces*]	Verticillium wilt	MAFNZ (1999a)	Yes (Shivas, 1989); (Washington and Nancarrow, 1983); (Cook and Dubé, 1989); (Letham, 1995); (Sampson and Walker, 1982); (APPD, 2005)	-	-	-	No
Zetiasplozna thuemenii (Speg.) Nag Raj (1993) (Basionym *Pestalotia thuemenii* Speg. (1878)) (Syn. = *Pestalozzina thuemenii* (Speg.). Guba (1961)) [Anamorphic Ascomycetes]	None	MAFNZ (1999a)	Yes (APPD, 2005)	-	-	-	No
Nematodes							
Helicotylenchus labiatus Roman (1965) [Tylenchida: Hopolaimidae]	Spiral nematode	MAFNZ (1999a)	Yes (McLeod et al., 1994)	-	-	-	No
Longidorus elongatus (de Man) Thorne & Swanger (1936) [Dorylaimida: Longidoridae]	Needle nematode	Hooper (1973)	Yes (McLeod et al., 1994)	-	-	-	No

Scientific name	Common name/s	Reference for presence in New Zealand	Presence in Australia Reference	Potential for being on mature apple fruit Comments if applicable	Potential for establishment or spread	Potential for consequences Comments if applicable	Consider species further?
Paratrichodorus minor (Colbran, 1956) Siddiqi, 1974 (Syn. = *Nanidorus minor* (Colbran) Siddiqi (?)) [Dorylaimida: Trichodoridae]	Stubby root nematode	MAFNZ (1999a)	Yes (McLeod et al., 1994); (APPD, 2005)	-	-	-	No
Pratylenchus Filipjev (1936) spp. [Tylenchida: Pratylenchidae]	Root lesion nematode	MAFNZ (1999a)	Yes (APPD, 2005)	-	-	-	No
Pratylenchus penetrans (Cobb (1917)) Chitwood & Oteifa (1952) [Tylenchida: Pratylenchidae]	Root lesion nematode	MAFNZ (1999a)	Yes (McLeod et al., 1994); (APPD, 2005)	-	-	-	No
Pratylenchus vulnus Allen & Jensen (1951) [Tylenchida: Pratylenchidae]	Root lesion nematode	MAFNZ (1999a)	Yes (McLeod et al., 1994); (APPD, 2005)	-	-	-	No
Xiphinema Cobb (1913) sp. [Dorylaimida: Longidoridae]	Dagger nematode	MAFNZ (1999a)	Yes (APPD, 2005)	-	-	-	No
Xiphinema diversicaudatum (Micoletzky) Thorne (1927) [Dorylaimida: Longidoridae]	Dagger nematode	MAFNZ (1999a)	Yes (APPD, 2005)	-	-	-	No
Viruses							
Apple chlorotic leaf spot *trichovirus* Cadman (1963); Cropley (1963; 1964) and Lister et al. (1965)	Apple chlorotic leaf spot virus	MAFNZ (1999a)	Yes (Washington and Nancarrow, 1983) (Letham, 1995); (Sampson and Walker, 1982)	-	-	-	No
Apple green crinkle virus Atkinson and Robins (1951)	Apple green crinkle	MAFNZ (1999a)	Yes (Goodman, 1983); (Letham, 1995); (Simmonds, 1966); (Sampson and Walker, 1982)	-	-	-	No
Apple leaf pucker virus	Apple leaf pucker	MAFNZ (1999a)	Yes (Letham, 1995)	-	-	-	No

Scientific name	Common name/s	Reference for presence in New Zealand	Presence in Australia Reference	Potential for being on mature apple fruit Comments if applicable	Potential for establishment or spread	Potential for consequences Comments if applicable	Consider species further?
Apple mosaic *ilarvirus* Bradford & Joley (1933); Christoff (1934) and White (1928)	Apple mosaic virus	MAFNZ (1999a)	Yes (Washington and Nancarrow, 1983); (Letham, 1995); (Simmonds, 1966); (Sampson and Walker, 1982); (McLean and Price, 1984)	-	-	-	No
Apple platycarpa scaly bark virus	Apple platycarpa scaly bark	MAFNZ (1999a)	Yes (Nemeth, 1986)	Not likely It is transmitted by grafting and budding (MAFNZ, 1999a)	-	-	No
Apple ring spot virus Atkinson et al. (1954)	Apple ring spot virus	MAFNZ (1999a)	Yes (Letham, 1995); (Sampson and Walker, 1982); (Simmonds, 1966)	-	-	-	No
Apple russet ring and associated disorders	Apple russet ring; leaf pucker and fruit russet; leaf fleck; bark blister and fruit distortion	MAFNZ (1999a)	Yes (Letham, 1995); (Pares, 1970)	-	-	-	No
Apple stem grooving *capillovirus* Lister et al. (1965)	Apple stem grooving virus.	MAFNZ (1999a)	Yes (Washington and Nancarrow, 1983); (Letham, 1995); (Sampson and Walker, 1982)	-	-	-	No
Apple stem pitting *foveavirus* Smith (1954)	Apple stem pitting virus	MAFNZ (1999a)	Yes (Washington and Nancarrow, 1983); (Cook and Dubé, 1989); (Letham, 1995); (Simmonds, 1966); (Sampson and Walker, 1982)	-	-	-	No
Unknown etiology							
Apple scaly bark	Scaly bark	MAFNZ (1999a)	Uncertain	Not likely It is transmitted by grafting (MAFNZ, 1999a)	-	-	No

Scientific name	Common name/s	Reference for presence in New Zealand	Presence in Australia Reference	Potential for being on mature apple fruit Comments if applicable	Potential for establishment or spread	Potential for consequences Comments if applicable	Consider species further?
Apple chat fruit phytoplasma	Apple chat fruit; apple small fruit	MAFNZ (1999a)	Uncertain	Not likely It is transmitted by grafting; budding; contact between roots and vector (MAFNZ, 1999a)	-	-	No
Apple rubbery wood phytoplasma	Rubbery wood; flat limb	MAFNZ (1999a)	Yes (Washington and Nancarrow, 1983); (Letham, 1995); (Sampson and Walker, 1982)	-	-	-	No

Appendix 1B – Pathogen categorisation – Pest issues of regional importance

Information used to decide the potential quarantine status of some pests identified by Western Australia as of concern to them, on pages 49-51 of their submission to the *Draft import risk analysis on the importation of apples (*Malus x domestica *Borkh.) from New Zealand* (BA, 2000)[4], are presented below. The discussion has also considered further comments provided by Western Australia on this issue through their submission to the *Draft import risk analysis on the importation of apples from New Zealand* (BA, 2004).[4]

Western Australia has commented that some points given for each pest in this section may not be relevant to the determination of the quarantine pest status. However, Biosecurity Australia felt they are relevant to the elements in the categorisation of a pest given on page 14 of Part B.

Botryosphaeria lutea A. J. L. Phillips (2002) anamorph: *Fusicoccum luteum* Pennycook & Samuels (1985)

Three cultural types of *Fusicoccum* Corda fall within the anamorph of *Botryosphaeria dothidea* (Mougeot: Fries) Cesati & de Notaris. These are *Fusicoccum aesculi* Corda; *F. parvum* Pennycook and Samuel and *F. luteum* Pennycook and Samuel (Pennycook and Samuel, 1985).

Differentiation of *Botryosphaeria* species with *Fusicoccum* anamorphs has depended on recognition of the anamorphs. This has resulted in some confusion in the taxonomy because these anamorphs are very similar morphologically and the characters used for differentiation can be influenced by the substrate (Smith and Stanosz, 2001).

Cluster analyses of random amplified polymorphic DNA (RAPD) marker data were done for 89 isolates identified as *B. dothidea* (*F. aesculi*); *B. ribis* (*Fusicoccum* sp.); *B. parva* (*F. parvum*) or *B. lutea* (*F. luteum*). These were categorised into three distinct groups; which have been designated Bd (probable *B. dothidea*); Br (probable *B. ribis*; but including isolates of *B. parva*) and F1 (probable *F. luteum*) (Smith and Stanosz, 2001).

Nucleotide sequence of the nuclear rDNA internal transcribed spacer ITS2 distinguished isolates of *F. luteum* from others in the *B. dothidea* complex. The teleomorph is *Botryosphaeria lutea* A.J.L. Phillips. It is morphologically indistinguishable from other teleomorphs in the *B. dothidea* complex (Phillips et al., 2002).

More recently however, Slippers et al. (2004) using morphological, cultural and multi-allelic DNA sequence data sheets from the rDNA (ITS 1, 5.8S and ITS 2), β-tubulin and EFI-α genes, concluded *B. dothidea*, *B. ribis*, *B. parva* and *B. lutea* to be separate species.

Earlier identification of this pathogen may have been as *B. dothidea* (Pennycook and Samuel, 1985).

F. luteum was isolated from kiwifruit (*Actinidia deliciosa*); apple (*Malus x domestica*); and pear (*Pyrus communis*) (Pennycook and Samuel, 1985).

There are nine records (all from Auckland in 1982 and 1983) of this pathogen affecting apple fruit in New Zealand (Tyson, 2003).

Available literature suggests that this pathogen affects kiwifruit (Pennycook and Samuel, 1985) and olive (Taylor et al., 2001).

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[4]Available at http://www.daff.gov.au

Australia imports kiwifruit from New Zealand and a pathway already exists for this pathogen to enter Australia.

The fungus has not been intercepted in Australia on kiwifruit or other plant products imported from New Zealand between June 1988 and January 2003.

There are seven records in the Australian Plant Pest Database (APPD, 2005), for *Fusicoccum luteum* but there are 160 records of *Fusicoccum* sp. including 11 from Western Australia.

However Shivas has informed Biosecurity Australia that *Fusicoccum luteum* is recorded on kiwifruit, mango and avocado in Queensland (Shivas, 2003).

Avocado fruit are being sent from Queensland to Western Australia and therefore a pathway exists for this pathogen to gain entry into Western Australia.

Fusicoccum luteum is widely distributed in Australian Proteaceae (Denman et al., 2003).

Botryosphaeria lutea (anamorph: *Fusicoccum luteum*) is recorded on kiwifruit in New Zealand. It is also recorded on kiwifruit and avocado in Queensland and Australian Proteaceae. A pathway already exists for this pathogen to enter Western Australia via kiwifruit imported from New Zealand and avocado from Queensland.

Botryosphaeria species are currently considered minor pathogens (Merwin et al., 1994). MacHardy (1996) and Merwin et al. (1994) speculated whether *Botryosphaeria* species could take on greater economic significance with the development and use of scab resistant cultivars. However, in a project undertaken by the Sustainable Agriculture Research and Education program of the USDA to evaluate the extent to which minor diseases might become a problem in orchards with scab resistant cultivars, only sooty blotch and flyspeck were identified as diseases that may increase and not those caused by *Botryosphaeria* species (Merwin et al., 1994). Hence, at present *Botryosphaeria lutea* does not appear to be a pest of significant economic importance and therefore is not considered a potential quarantine pest for Western Australia.

Botryosphaeria parva Pennycook & Samuels (1985) anamorph: *Fusicoccum parvum* Pennycook & Samuels (1985)

Currently there are two records of this pathogen in Australia, one from New South Wales and the other from Queensland (APPD, 2005).

It is not recorded in Western Australia. But 89 records of *Botryosphaeria* sp. including seven from Western Australia have been reported (APPD, 2005).

Shivas (1989) reported the presence of two *Botryosphaeria* sp. in Western Australia.

There are four records of this pathogen on apples in New Zealand between 1975-1991 (Tyson, 2003).

In New Zealand, this pathogen is associated with kiwifruit, avocado fruit and wood/twigs of apple and poplar (*Populus niger*) (Pennycook and Samuel, 1985; Pennycook, 1989; Hartill, 1991; McKenzie et al., 1992; Everett, 1996; Hartill and Everett, 2002).

This fungus has not been intercepted in Australia on plant products imported from New Zealand from June 1988 to January 2003.

Three cultural types of *Fusicoccum* Corda, one being the anamorph of *B. dothidea* (*F. aesculi*) recorded in Australia (New South Wales and Victoria) were repeatedly isolated from ripe kiwifruit in New Zealand. They differ in their cultural characteristics (including conidial size and shape) in the stage of fruit ripeness at which their lesions first developed and their sensitivity to benzimidazole fungicide (Pennycook and Samuel, 1985).

Cultures of conidial and single ascospore isolates from *Fusicoccum* and *Botryosphaeria* fructifications found abundantly in kiwifruit orchards were identical with two of the culture types from fruit rots. These two culture types corresponded to small but consistent differences in ascospore size. The fungi are described as *Botryosphaeria dothidea* (*Fusicoccum aesculi* Corda); *B. parva* (*F. parvum*); and *B. lutea* (*F. luteum*) (Pennycook and Samuel, 1985).

Most types of affected fruit will develop rots during ripening. This is caused by latent infections established in the orchard during the growing season. Affected samples of fruit yielded at least two, and usually all three of the culture types. *F. parvum* was present in a small proportion of lesions that developed early, but this fungus was frequently isolated from the later small lesions on ripe and over-ripe fruit. However, *F. aesculi* was isolated invariably from early lesions but less frequently from smaller later developing lesions and rarely on over-ripe fruit (Pennycook and Samuel, 1985).

There is considerable uncertainty about the nomenclature of *B. dothidea*, *B. ribis* and *B. parva*.

- Cluster analysis of RAPD marker data for 89 isolates identified by collectors as *B. dothidea* (*F. aesculi*), *B. ribis* (*Fusicoccum* sp.), *B. parva* (*F. parvum*) or *B. lutea* (*F. luteum*) identified three distinct groups. They have been designated Bd (probable *B. dothidea*); Br (probable *B. ribis* but including isolates of *B. parva*) and F1 (probable *B. lutea* (*F. luteum*) (Smith and Stanosz, 2001). This indicates that *B. ribis* and *B. parva* are the same or very closely similar.
- There are 17 records of *B. ribis* in Western Australia (Shivas, 1989).
- *Botryosphaeria ribis* and *B. parva* are related but separable, whereas *B. dothidea* and *B. ribis* are distinct (Smith et al., 2001).
- The data sheet on *B. dothidea* and *B. ribis* (CABI, 2005) states *B. dothidea* has been considered by some as synonymous with *B. ribis* while others consider it as a distinct species [with several references given for each group]. Most descriptions of the reported anamorphic stages of *B. dothidea* and *B. ribis* overlap. This controversy in *B. ribis* taxonomy appears mainly due to the variable mycelial and conidial morphology in different growth conditions and stages, rareness of sexual stages, pantropic distribution and ability to cause disease on many plant species.
- Most of the earlier records of *Botryosphaeria dothidea* on several hosts including apple and pear spp. may have included records of recently segregated taxa such as *B. parva* and *F. luteum* (Pennycook, 1989).
- More recently however, Slippers et al. (2004) using morphological, cultural and multi-allelic DNA sequence data sheets from the rDNA (ITS 1, 5.8S and ITS 2), β-tubulin and EFI-α genes, concluded *B. dothidea*, *B. ribis*, *B. parva* and *B. lutea* to be separate species.

Australia has been importing kiwifruit and avocado from New Zealand for some years. A pathway already exists for the pathogen to gain entry should these pathogens occur as latent infection. All three fungal species are likely to be present on fruit as latent infections.

Western Australia has been sourcing avocado fruit from Queensland, where *B. parva* is known to infect avocado fruit (Shivas, 2003).

There is a paucity of information about this pathogen on apple in New Zealand but *F. parvum* (teleomorph: *B. parva*) has been isolated from pycnidia found on apple twigs (Pennycook and Samuel, 1985).

Although New Zealand has recorded *B. parva* as a primary pathogen, scanning of available literature did not reveal any published technical information on this pathogen (except for one paper on the taxonomy of *Botryosphaeria* and *Fusicoccum* species in New Zealand (Pennycook and Samuel, 1985). It could be assumed that it is not a major problem causing economic losses.

As discussed under *B. lutea* above, *Botryosphaeria* species currently are considered minor pathogens (Merwin et al., 1994).

Based on the above information *B. parva* appears to be a pest of no economic significance and therefore is not considered a potential quarantine pest for Western Australia.

Diaporthe Nitschke (1870) spp.

There are several species of *Diaporthe* affecting many plant species (Farr et al., 1995).

D. decorticans (Libert) Saccardon & Roumeguere, *D. pruni* Ellis & Everhart, *D. pennsylvanica* (Bèrkeley and M. A. Curtis) Wenmeyer, *D. prunicola* (Peck) Wenmeyer and *D. tuberculosa* (Ellis) Saccardo affect *Prunus* spp.; and *D. eres* Nitsche affects *Prunus, Pyrus* and *Malus* spp. (Farr et al., 1995).

D. tanakae T. Kobayashi & Sakuma (anamorph *Phomospsis* tanakae T. Kobayashi & Sakuma) is only recorded on apple and pear in Japan (Nakatani and Fujita, 1990).

The pathogen primarily affects stems, twigs and flowers (Nakatani and Fujita, 1990).

D. perniciosa is considered a synonym of *D. eres* by Farr et al. (1995), Rosenberger (1990a) and CABI (2005).

D. eres (syn. *D. perniciosa*) is present in Western Australia (Shivas, 1989).

There is an unidentified *Diaporthe* sp. in Western Australia on the host *Kennedia coccinea* Ventenat (Shivas, 1989). There are two records of *Diaporthe* sp. in Western Australia, one on lupin stem and the other on chestnut stem (APPD, 2005).

The genus has not been intercepted in Australia on plant products imported from New Zealand between June 1988 and January 2003.

In New Zealand this pest is recorded as causing secondary rot in apple fruit (MAFNZ, 2002b).

Based on the above information *Diaporthe* sp. does not appear to be a pest of economic significance and hence is not considered a potential quarantine pest.

Diaporthe actinidiae N. F. Sommer & Beraha (1975)

There is one record of *D. actinidiae* in New South Wales and 13 records of *Diaporthe* sp. including two from Western Australia (APPD, 2005).

It is a postharvest pathogen of kiwifruit causing stem-end rot (Sommer and Beraha, 1975; Palma and Piontelli, 2000; Lee et al., 2001) and it also causes damage during storage, transportation, and marketing (Pratella, 1995). A study in Spain (Pintos-Varela et al., 2000) claims that it can affect many other parts of kiwifruit plants.

This pathogen has been isolated from apple trees in New Zealand but was most common on kiwifruit (Hawthorne et al., 1982; Pennycook, 1989).

There are two reports of its occurrence in 1975 on apples in New Zealand (Tyson, 2003).

New Zealand has listed it as a secondary pathogen of apple; however, there are no reports of it associated with apple fruit in the databases searched.

New Zealand kiwifruit have been imported into Australia for many years. Therefore, a pathway already exists for it to gain entry into Western Australia.

The fungus has not been intercepted in Australia on plant products imported from New Zealand between June 1988 and January 2003.

As there are no reports of association of this pest with apple fruit it is unlikely to be associated with the pathway. Further it is only a secondary pathogen of kiwifruit and apple with no significant economic consequences. Hence it is not considered a potential quarantine pest for Western Australia.

Discostroma corticola **(Fuckel) Brockmann (1976) anamorph:** ***Seimatosporium lichenicola*** **(Corda) Shoemaker & E. Müller**

This pathogen is recorded as *Griphosphaeria corticola* (Fuckel) Höhnel (Syn. *Clethridium corticola* (Fuckel) Shoemaker & E. Müller. [as '*Clathridium*'] (1964) in New South Wales and as *Seimatosporium lichenicola* (Corda) Shoemaker & E. Müller (1964) (APPD, 2005). There are no records for Western Australia.

There is some confusion in the manner in which the genus part of this pathogen is spelt in literature; some spelling it as *Clethridium* while others as *Clathridium*.

Rosenberger uses the spelling *Clethridium corticola* (Rosenberger, 1990b) New Zealand pest list also spelt it as *Clethridium corticola.*

> Bibliographic searches (WebSPIRS5, 2005) show 24 records for *Clathridium corticola* and 9 records for *Clethridium corticola*. The former group, as *Clathridium corticola,* are mostly research papers from India on apple rot, but with one Scottish and one Australian group also using this spelling. In the latter group, as *Clethridium corticola,* 7 are on roses, two on raspberry and one on apple rot but claiming it is not of economic importance.

For *Griphosphaeria corticola* databases return eight records giving mostly roses and raspberry as hosts (WebSPIRS5, 2005).

For *Discostroma corticola* databases give 35 records with roses, raspberries and apples as hosts but in general considering the diseases to be of no economic importance (WebSPIRS5, 2005).

In New Zealand's updated disease list this is considered a secondary pathogen (MAFNZ, 2002b).

There is only one record of its occurrence in New Zealand in 1981 but no published literature is available (Tyson, 2003).

The fungus has not been intercepted in Australia on plant products imported from New Zealand between June 1988 and January 2003.

Indian literature on *Clethridium corticola* indicates it to be causing fruit rot of apples there.

Rosenburger considers *Clethridium corticola* to be rarely found in apples from commercially tended orchards if the fruit is stored under modern cold storage conditions (Rosenberger, 1990b).

Absence of technical information suggests that it is an unimportant pathogen.

Although there are no records of *Discostroma corticola* in Western Australia lack of technical information on this pathogen indicates that it is not an economically significant disease. Hence it is not considered a potential quarantine pest for Western Australia.

Elsinoë pyri (Woronichin) Jenkins [as 'piri'] (1932) anamorph: *Sphaceloma pyrinum* (Peglion) Jenkins (1946) [as '*pirinum*']

It is recorded as *E. piri* affecting quince (*Cydonia* spp.), apple and pear (Farr et al., 1995).

There are seven records *E. piri* on apple fruit; six in New South Wales and one in Queensland (APPD, 2005) where it is not considered a major pathogen (Heaton et al., 1991; Dullahide, 2003; Hetherington, 2003). It is not recorded in Western Australia.

Symptoms occur on the leaves and fruit of both apple and pear in New Zealand (Atkinson, 1971).

It is relatively common in New Zealand apple fruit (62 records from 1921-1993) (Tyson, 2003). The number of specimens collected has been increasing and may become more important in the future (Atkinson, 1971) but there is little published literature on this pathogen.

It is of secondary importance but on the increase (Lemoine, 1998).

Only the anamorph has been found in New Zealand (Dingley, 1969).

Fungicides applied to control *V. inaequalis* (apple scab) are also effective in controlling *E. pyri* (Dingley, 1969).

It is generally not considered to be of economic importance. Little work has been done on this disease and information about it is scanty (Atkinson, 1971).

The disease causes damage to the epidermis leaving the fruit unfit for sale (Lemoine, 1998). Infected fruit are likely to be detected at pre-clearance inspection.

Between June 1988 and January 2003 there has been only one interception (in December 2000) of *Elsinoë* sp. on fruit (type not specified) from New Zealand.

WebSPIRS databases returned only one published paper (Lemoine, 1998) from France for *E. pyri* but eight records for *E. piri* (WebSPIRS5, 2005) with one from report from Argentina stating that *E. piri* on apple and pear to be quite unimportant.

It is not reported in the Compendium of Apple and Pear Diseases published by the American Plant Pathological Society (Jones and Aldwinckle, 1990).

There is no data sheet on this pathogen in the CABI Compendium (CABI, 2005).

The evidence above indicates *Elsinoë pyri* to be a pathogen of no economic significance. Hence it is not considered a potential quarantine pest for Western Australia.

Mycosphaerella pomi (Passerini) Lindau (1897) anamorph: *Cylindrosporium pomi* C. Brooks (?)[5]

It is recorded in New South Wales (eight records) as *Cylindrosporium pomi* (APPD, 2005). It is not recorded in Western Australia.

Brooks fruit spot is caused by a minor disease in the north-eastern and mid-Atlantic apple-growing regions of the USA. It is also reported from Canada (Yoder, 1990).

[5] (?) = Publication date unknown.

While it is a minor disease in some parts of USA, it may cause severe losses in these areas when trees are not well pruned and sprayed .[6] However, in the Southern Hemisphere including New Zealand and the State of New South Wales of Australia where the pest is recorded there are no reports of significant economic losses.

This pathogen is found in most apple-growing areas of New Zealand but only occasionally. It is of no economic importance in New Zealand (Atkinson, 1971).

Although it is listed in New Zealand as a primary pathogen of apple fruit, literature searches revealed only scanty published information on the pathogen in New Zealand.

According to information provided recently (Tyson, 2003) there is only one record of this pathogen in New Zealand and it is only very rarely isolated from apple in Hawke's Bay (MAFNZ, 2003).

A search of the WebSPIRS5 databases returns 48 records for this fungus 32 from USA; eight from Japan; two from South Korea, two from China, one each from Lithuania, Australia and India but none from New Zealand (WebSPIRS5, 2005).

The fungus has not been intercepted in Australia on plant products imported from New Zealand between June 1988 and January 2003.

The disease first appears on immature fruit. As the fruit mature, lesions change colour and dark specks appear. Severe infection may result in pitting and cracking of fruit (Yoder, 1990).

Infected fruit may have colourless conidia (*Cylindrosporium* stage), colourless spores from pycnidia (*Phoma pomi* Schulzer & Saccardo) or chlamydospores. Perithecia have not been found in New Zealand (Cunningham, 1925).

Field observations suggest that control measures for apple scab and powdery mildew would also be effective against this disease (Dingley, 1969).

Mycosphaerella pomi does not appear to be a pest of economic significance in the Southern Hemisphere including New Zealand and the State of New South Wales of Australia where it is reported. Based on this it is not considered a potential quarantine pest for Western Australia.

***Pestalotiopsis maculans* (Corda) Nag Jaj (1985) Syn. *Pestalotia guepinii* Desmazières ['as *guepini*'] (1840)**

This fungus with the synonym *Pestalotopsisa guepinii* Desmazières (1840) [as '*guepini*'] (Farr et al., 1995) is present in Australia (APPD, 2005).

New Zealand Landcare database considers both *Pestalotia guepinii* and *Pestalotiopsis guepinii* to be synonyms for *Pestalotiopsis maculans* but these synonyms are not indicated in the CABI Index Fungorum database.

Pennycook (1989) also has considered *Pestalotiopsis maculans* to be synonymous with *Pestalotia guepinii*.

Pestalotiopsis guepinii is recorded on *Camellia japonica* in Western Australia (Shivas, 1989).

APPD shows six records of *Pestalotiopsis guepinii,* five from Victoria and one from Queensland but none from Western Australia (APPD, 2005). The record in above (Shivas,

[6] http://postharvest.tfrec.wsu.edu/marketdiseases/fruitspot.html;
http://vm.cfsan.fda.gov/~dms/mpm-6.html;
http://ssfruit.cas.psu.edu/chapter4/chapter4i.htm

1989) has not gone into the APPD probably because there is no associated culture lodged with one of the participating culture collections.

Trapero et al. (2003) have also considered *Pestalotiopsis guepinii* to be a synonym for *Pestalotiopsis maculans.*

A company in Germany supplying actively growing cultures of filamentous fungi also consider *Pestalotia guepini* isolated from leaf spots on *Camellia japonica* in that country to be synonymous with *Pestalotiopsis maculans.*[7]

There appears to be considerable support for the synonymy between *Pestalotiopsis guepinii* and *Pestalotiopsis maculans.* Therefore this pathogen is rated as present in Western Australia and is not considered a potential quarantine pest.

Phoma cava **Schulzer (1871) Syn.** ***Pleurophoma cava*** **(Schulzer) Boerema, Loerakker & Hamers (1996)**

Phoma cava is not recorded in Australia. However, there are 512 records of *Phoma* sp., of which thirty six are from Western Australia (APPD, 2005).

According to (Shivas, 1989) *Phoma* sp. from nine hosts in Western Australia have not been identified to species level.

New Zealand considers it as a secondary pathogen in apple associated with mouldy core rot of fruit (MAFNZ, 2002b).

Of the 512 *Phoma* sp. recorded in the APPD database, one from Victoria is an isolation from symptomless apple core. There are twelve records on apple leaf, six on apple stem, two on apple twig and one on apple branch.

Eight records of this pathogen are reported from 1980-1998 on apples in New Zealand (Tyson, 2003) but little published information could be found on the pathogen.

The fungus has not been intercepted in Australia on plant products imported from New Zealand between June 1988 and January 2003.

In the databases examined there is no literature on this pathogen in apple.

The fungus is associated with the decomposition of sugar maple leaf (Kuter, 1986).

It is pathogenic to several species of oak (Manicone, 1991; Luisi et al., 1995).

One report claims that it causes aural dermatitis in deer (Gordon et al., 1975) and another connects the fungus to skin lesions in a human (Zaitz et al., 1997).

There are reports on toxin production by this fungus (Evidente, 1987; Evidente et al., 1985).

It is a secondary pathogen with limited distribution in New Zealand. There is little published information on the pathogen. The detections on oak, deer and humans and reports of toxin production do not appear to cause major economic losses. These indicate the pathogen to be of no potential economic significance and on this basis it is not considered a potential quarantine pest.

[7] http://www.dsmz.de/strains/no062882.htm

Phomopsis (Saccardo) Bubák (1905) spp.

According to (APPD, 2005) there are over 25 different species of *Phomopsis* and 397 records not identified to species (i.e. *Phomopsis* sp.) in Australia including Western Australia.

There are records of *Phomopsis* sp. on six host species in Western Australia including *Malus sylvestris* (Shivas, 1989).

Phomopsis canker and *Phomopsis* fruit rot are caused by *Diaporthe perniciosa* Em. Marchal (syn. *D. eres* Nitschke; anamorph *Phomopsis mali* Roberts) (Rosenberger, 1990a).

Fruit rot by *Phomopsis* sp. seldom occurs until late in storage and it is a minor disease and is not economically important in most orchards (Rosenberger, 1990a).

Between June 1988 and January 2003 there have been five interceptions of *Phomopsis castanea* on seeds and nuts from New Zealand.

Phomopsis sp. cause only secondary fruit rot in New Zealand (MAFNZ, 2002b). There are many records of this genus in Australia including Western Australia (APPD, 2005) but with no reports of significant economic damage in the literature. Therefore, it is not considered a potential quarantine pest.

Phytophthora syringae (Klebahn) Klebahn (1909)

New Zealand included this pest in their list (MAFNZ, 1999a) and it was therefore considered in the *Draft import risk analysis on the importation of apples (*Malux x domestica *Borkh.) from New Zealand* (BA, 2000). However, New Zealand has removed it from their 2002 pest list (MAFNZ, 2002b). A decision has been taken to consider all pests in New Zealand's 1999a, 2000b and 2002b pest lists in the *Draft import risk analysis on the importation of apples from New Zealand* (BA, 2004).

The pathogen has been recorded (one record) only in New South Wales (APPD, 2005). But according to (Washington and Nancarrow, 1983; Cook and Dubé, 1989) it is present in Victoria and South Australia.

There are 258 records of *Phytophthora* sp. in (APPD, 2005); which include New South Wales, Victoria., South Australia, Tasmania., Queensland, Northern Territory and Australian Capital Territory but not Western Australia. However, *Phytophthora* isolates from 11 hosts in Western Australia have not been identified to species level (Shivas, 1989).

There are three records (two from soil and root; one from an unknown source) of its occurrence from 1974 to 1997 in New Zealand (Tyson, 2003).

The fungus has not been intercepted in Australia on plant products imported from New Zealand between June 1988 and January 2003.

This pathogen caused collar rot and stem canker in apricot, cherries and peaches in orchards near Christchurch in New Zealand in 1955 (Dingley, 1969).

This pathogen is widespread in apple orchard soils in North America and commonly infects roots, fruits and leaves fallen on the orchard floor. Fruit (particularly on dwarf trees) close to the soil level are prone to infection from soil splash (Covey and Harris, 1990).

Fruit infected early in the season are unlikely to be harvested.

Fruit contaminated with the pathogen late in the season or at harvest might be infected during long-term storage and are likely to be discarded at pre-export inspection.

The pathogen is of low prevalence in New Zealand and they have removed it from their 2002 pest list. Even in USA and Canada where it is widespread in orchards soils it is of limited economic importance (Covey and Harris, 1990). In States of Australia where it is recorded it is of minor economic significance. On the basis of low economic significance this pathogen is not considered a potential quarantine pest.

Rhinocladiella Nannfeldt (1934) spp.

R. atrovirens Nannfeldt in Melin & Nannfeldt is recorded from *Pinus* sp. (Farr et al., 1995).

There is one record of this pathogen on apples in 1981 in New Zealand but no published information was found (Tyson, 2003).

The genus has not been intercepted in Australia on plant products imported from New Zealand between June 1988 and January 2003.

There is one record of *Rhinocladiella mansonii* (Castellani) Schol-Schwarz in Western Australia (APPD, 2005) on *Triticum aestivum* (collection date 1973) but Shivas does not list this (Shivas, 1989).

There are four records of *Rhinocladiella* sp in APPD one from Western Australia.

It is rarely found in New Zealand. There is no published technical information on this pathogen. This indicates that it has no potential economic significance and therefore is not considered a potential quarantine pest for Western Australia.

Venturia inaequalis (Cooke) G. Winter (1875)

Under the current State Regulations, there is a prohibition on apple fruit and plants importation from Countries, States and Territories that have known diseases that are exotic to Western Australia' (Kumar, 2002). This measure constitutes official control of the pathogen (FAO, 1996a).

Between June 1988 and January 2003, there was one interception of the pathogen (in June 2000) on fruit from New Zealand.

There is only one strain of this pathogen in New Zealand (Patterson et al., 2003) which is also present in Australia (Heaton et al., 1991).

A data sheet on *V. inaequalis* is in Appendix 3 in Part C.

On the basis that *V. inaequalis* is under official control in Western Australia, it is considered a potential quarantine pest.

Appendix 1C – Pathogen categorisation – Bull's-eye rot

Neofabraea malicorticis H.S. Jacks (1913) - Bull's-eye rot

Bull's-eye rot caused by a species of *Neofabraea* causes cankers on apple branches, but on pears only colonises injured and dead outer bark. Fruit can be infected at any time between petal fall and harvest. The susceptibility of fruit to infection increases as it matures. Bull's-eye rot is severe when rains occur during harvest, because rain-dispersed conidia can cause infection. Symptoms of fruit infection develop only after about five months in storage (Spotts, 1990).

The cankers are active for one year, but the fungus can live in dead canker tissues and produces large numbers of conidia. Over the years, the disease spreads outwards from the centre, leaving concentric rings of dead bark. Cankers are most abundant on smaller branches but may also occur on larger limbs.

Frequently the pathogen enters through lenticels but gains entry through wounds caused by pruning or uninjured bark in the autumn. Cankers however, will not appear until spring. The first sign of infection is the appearance of small circular, reddish brown spots on the bark, extending to the underlying tissue. Cankers grow in the spring and develop cracks delimiting the canker from the surrounding healthy tissue. The surface of the canker becomes shrunken and shrivelled as the surrounding tissue continues to grow during the summer. During summer, numerous fruiting bodies or pustules (acervuli) appear on the canker surface, first at the centre of the canker and later in the margins. Spores that mature at the end of summer or early autumn are disseminated by rain and wind.

Fruit become infected when they come in contact with spores at any time between petal-fall and harvest. Infection is most common in the spring and late autumn, with rots also occurring during storage. Infection initially appears as brown, depressed, circular spots in storage. As the disease spreads fruiting bodies are produced in its centre, often in concentric rings, which gives it the name Bull's-eye rot (Anonymous, 2004a).

The infection caused by *N. malicorticis* on stems may cause girdling and result in death of limbs, or may cause fruit rot in storage (Anonymous, 2004a).

Rapid cooling of fruit increases the likelihood of development of Bull's-eye rot. Controlled atmosphere storage especially with low oxygen (1%) reduces the incidence and severity of Bull's-eye rot (Spotts, 1990).

Sanitation methods, such as use of clean plant material free of visible symptoms and pruning infected tissue would provide long term control of the disease. Application of fungicides (For example, Bordeaux mixture, Mancozeb) before autumn would reduce the possibility of infection (Anonymous, 2004a).

Until recently the genus *Neofabraea* has been considered a synonym of *Pezicula*. *Pezicula malicorticis* is present in Australia (APPD, 2005). Three fungal species causing Bull's-eye rot in apples have been identified as members of the genus *Pezicula*. There has been considerable debate regarding the taxonomy of the fungi belonging to this genus. Verkley (1999) matched the morphological characters with molecular data (restriction fragment length polymorphisms of nuclear rDNA) and revalidated the genus *Neofabraea*.

Abeln et al. (2000) conducted a phylogenetic study of *Pezicula*, *Dermea*, and *Neofabraea* by partial sequencing of ribosomal RNA genes, and concluded that *Neofabraea* is a separate evolutionary lineage and should not be included among *Pezicula*.

Recently, de Jong et al. (2001) identified four species of *Neofabraea* associated with Bull's-eye rot and apple tree cankers, including *N. alba*, *N. malicorticis*, *N. perennans* and the putative new species. In Europe, both *N. malicorticis* and *N. perennans* have generally been considered a single species and grouped under *N. malicorticis* (Edney, 1983), but based on genetic differences de Jong et al. (2001) recognised them as two distinct taxa. In North America they have been considered two distinct species (Grove, 1990b; Dugan et al., 1993a; Dugan et al., 1993b). Bull's-eye rot caused by *N. alba* has been reported as a minor disease of apple in eastern North America, while *N. malicorticis* causes anthracnose canker of apple trees in humid climates in the Pacific North West (Spotts, 1990).

Phylogenetic relationships among *Neofabraea* species based on DNA sequencing of Internal Transcribed Spacer (ITS) nuclear rDNA, mitochondrial rDNA, and the β-tubulin gene provided evidence for the existence of distinct pathogens, including *N. malicorticis*, *N. perennans, N. alba*, and a putative new *Neofabraea* species. These pathogens associated with apple tree cankers and Bull's-eye rot were isolated in both Europe and eastern North America (de Jong et al., 2001). They also showed that the primary pathogens causing these diseases in North America are *N. malicorticis* and *N. perennans* in the west, and *N. alba* in eastern Canada. *N. perennans*, *N. alba* and an undescribed *Neofabraea* species were found in Europe but the presence of *N. malicorticis* was not confirmed.

In Australia, there are several records of occurrence of *N. alba* but reports on *N. malicorticis* and *N. perennans* are sporadic. These two species were considered to be conspecific (Sutton, 1980), but based on gene sequencing they were fond to be distinct species (de Jong et al., 2001). All Australian herbarium specimens belonging to the *N. malicorticis*-*N. perennans* group, were re-examined using β-tubulin sequences (Cunnington, 2004). This author found that Victorian collections were identical to *N. perennans*, while two New South Wales and a Western Australian specimen were neither *N. malicorticis* nor *N. perennans,* but an undescribed species of *Neofabraea* previously identified from Portugal and Canada by de Jong et al. (2001). Another specimen collected in Western Australia was identified as *N. alba*, but none of the three specimens from Tasmania were found to belong to *Neofabraea*. The taxonomic status of the latter is still uncertain.

A polymerase chain reaction (PCR) study of a collection of *Neofabraea* fungi isolated from pear, showed that *N. alba* was identified most frequently from samples in Oregon and California, while *N. perennans* was predominant in Washington (Henriquez et al., 2004). These authors also isolated Bull's-eye rot pathogens from fruit of nine different European pear cultivars, Asian pear and quince. These authors also found that *N. alba* was the most prevalent species in 2001, whereas *N. perennans* was more prevalent in 2002. An undescribed species of *Neofabraea* was also reported from Oregon corresponding to species previously found by others (Henriquez et al., 2004).

N. malicorticis is recorded from three locations in New Zealand, one in Auckland and two in Nelson.[8] Bull's-eye rot does not appear to be a serious problem in well managed orchards in New Zealand.

In Australia Bull's-eye rot is caused predominantly by *N. perennans, N. alba* and an undescribed species of *Neofabraea* (Cunnington, 2004). The APPD (2005) database shows five records of *Pezicula malicortis*. Although there are taxonomic differences among the pathogens of Bull's-eye rot, the damage caused by these organisms produce similar symptoms on affected plant parts, however severe economic losses have not been reported in Australia.

Bull's-eye rot also occurs on serviceberry (*Amelanchier* spp.), flowering quince (*Chaenomeles japonica*), hawthorn (*Crataegus* spp.), quince (*Cydonia oblonga*), peach (*Prunus persica*), apricot (*P. armeniaca*), rose (*Rosa* spp.) and mountain ash (*Sorbus* spp.)

[8] http://nzfungi.landcareresearch.co.nz/html. Accessed on 15 August 2005

(Anonymous, 2004b).[9] However, the identity of the species that cause infection on the above hosts in Australia is unknown.

Apple fruit infected by spores or incipient infections can remain latent for several months in storage before development of symptoms. The level of infection is related to the frequency of rains during harvest. Bull's-eye rot is caused by *N. alba*, *N. perennans* and an undescribed *Neofabraea* species in Australia, but no information is available regarding their pathogenicity on susceptible hosts. Species of *Neofabraea* produce similar symptoms and damage on hosts they infect, but there is no evidence of serious damage to major hosts of economic importance. New Zealand records indicate that *N. malicorticis* is not wide spread and there are no reports of severe economic losses caused by this pathogen. Factors contributing to inoculum build up such as unattended cankers and infected fruit left on the orchard floor are unlikely to occur in well managed orchards in New Zealand. *N. malicorticis* is not recorded in Australia but rots caused by other species of *Neofabraea* or *Pezicula* have not been reported to cause crop losses in Australia. Although this pathogen is absent in Australia but has the potential to be on the fruit, it is unlikely to cause more damage than those already known to cause fruit rots.

[9] 'CBS Fungi database' - http://www.cbs.knaw.nl/databases/index.htm. Accessed on 13 February 2004

Appendix 2 – Arthropod categorisation

Note:

A stakeholder states that the criteria provided in Table 8 of the 2004 revised draft IRA are not consistent and may result in a single pest being placed in either category under some conditions. Taking stakeholder's comments into consideration, Biosecurity Australia in consultation with the IRA team revised these pathway criteria. As a result, the following categorisations have been revised according to the revised criteria set out in the table in the method section.

It should be pointed out that some contaminants of apple fruit were assessed as being on pathway based on the criteria used in the *Draft import risk analysis on the importation of apples from New Zealand* (BA, 2004) but are now assessed as not likely being on pathway using the revised criteria because they are not pests of apple and do not live in or on mature apple fruit. Such species include burnt pine longhorn beetle *Arhopalus ferus* (Mulsant), click beetle *Conoderus exsul* Sharp, New Zealand flower thrips *Thrips obscuratus* (Crawford) and, wheat bug *Nysius huttoni* White. Current Biosecurity Australia and AQIS policy for the interception of pests not known to be pests of the imported commodity (contaminants) requires that the consignment is held until the quarantine status of the contaminants is determined. If the pests are determined to be a quarantine pest the importer is given the options of treatment of the consignment to remove the pest, re-export of the consignment or destruction of the consignment.

Scientific name	Common name/s	Reference for presence in New Zealand	Presence in Australia Reference	Potential for being on mature apple fruit Comments if applicable	Potential for establishment or spread	Potential for consequences Comments if applicable	Consider species further?
Insects - Blattodea							
Blattella germanica (L.) [Blattodea: Blattellidae]	German cockroach	MAFNZ (2000b)	Yes (CSIRO/DAFF, 2005)	-	-	-	No
Insects - Coleoptera							
Agonum spp. [Coleoptera: Carabidae]	Ground beetle	MAFNZ (2000b)	Uncertain	Not likely Adults are orchard or packing house contaminants, adults and larvae are predatory in soil (MAFNZ, 2000b)	-	-	No

Scientific name	Common name/s	Reference for presence in New Zealand	Presence in Australia Reference	Potential for being on mature apple fruit Comments if applicable	Potential for establishment or spread	Potential for consequences Comments if applicable	Consider species further?
Agrypnus variabilis (Candèze) [Coleoptera: Elateridae]	Variable wireworm, surgarcane wireworm	MAFNZ (2000b)	Yes*[10] (CSIRO/DAFF, 2005)	Not likely Adults are orchard or packing house contaminants, larvae feed in soil on herbaceous hosts (MAFNZ, 2000b)	-	-	No
Ahasverus advena (Walt.) [Coleoptera: Silvanidae]	Foreign grain beetle	MAFNZ (2000b)	Yes (CSIRO/DAFF, 2005)	-	-	-	No
Alticinae (Halticinae) [Coleoptera: Chrysomelidae]	Flea beetle	MAFNZ (2000b)	Uncertain	Not likely Larvae can be primary pests on foliage (MAFNZ, 1999a)	-	-	No
Anchomenus spp. [Coleoptera: Carabidae]	Ground beetle	MAFNZ (2000b)	Uncertain	Not likely Adults are orchard or packing house contaminants, adults and larvae are predatory in soil (MAFNZ, 2000b)	-	-	No
Anobium punctatum (de Geer) [Coleoptera: Anobiidae]	House borer	MAFNZ (2000b)	Yes (CSIRO/DAFF, 2005)	-	-	-	No
Anthicus floralis L. [Coleoptera: Anthicidae]	Narrownecked grain beetle	MAFNZ (2000b)	Yes* (CSIRO/DAFF, 2005)	Not likely Adults are orchard or packing house contaminants, larvae are secondary feeders on decaying plant material (MAFNZ, 2000b). This species was assessed as "Not likely" to have the potential for being on mature apple fruit in the present document based on the revised criteria set out in the methodology section. It is treated as contaminant and will be dealt with based on the approach described in the pest risk management section	-	-	No
Araecerus palmaris (Pascoe) (Syn. = *Doticus palmaris*) [Coleoptera: Anthribidae]	Fungus weevil, Dried apple beetle	MAFNZ (2000b)	Yes* (CSIRO/DAFF, 2005)	Not likely Larvae normally feed in mummified fruit only (MAFNZ, 2000b)	-	-	No

[10] 'Yes*' indicates that this species is present but not widely distributed and being officially controlled or where regional freedoms exist within Australia.

Scientific name	Common name/s	Reference for presence in New Zealand	Presence in Australia Reference	Potential for being on mature apple fruit Comments if applicable	Potential for establishment or spread	Potential for consequences Comments if applicable	Consider species further?
Arhopalus ferus (Mulsant) [Coleoptera: Cerambycidae]	Burnt pine longhorn beetle	MAFNZ (2000b)	No (Wang, 2002)	Not likely MAFNZ (2000b) stated that adults are orchard or packing house contaminants, larvae are woodboring plant feeders of pine trees. (MAFNZ, 2003a) clarified it as packing house contaminants. New Zealand timber exported to Australia requires fumigation for this pest. This species was assessed as "Not likely" to have the potential for being on mature apple fruit in the present document based on the revised criteria set out in the methodology section. It is treated as contaminant and will be dealt with based on the approach described in the pest risk management section	-	-	No (was yes in the last revised draft IRA but see the revised criteria for being on pathway)
Arhopalus tristis (F.) (A junior synonym of *A. rusticus* (L.) according to Wang (2002). all references to *A. tristis* in New Zealand should actually refer now to *A. ferus* (Wang, 2002) [Coleoptera: Cerambycidae]	Burnt pine longhorn beetle	MAFNZ (2000b) Actually not in New Zealand (Wang, 2002)	-	- All references to *A. tristis* in New Zealand should actually refer now to *A. ferus* above (Wang, 2002)	-	-	No
Aridius bifasciatus (Reitter) [Coleoptera:Corticariidae]	Minute brown scavenger beetle	MAFNZ (2000b)	Yes* (AQIS, 1998a)	Not likely Orchard or packing house contaminant (adult life stage), secondary feeder on decaying plant material (MAFNZ, 2000b). This species was assessed as "Not likely" to have the potential for being on mature apple fruit in the present document based on the revised criteria set out in the methodology section. It is treated as contaminant and will be dealt with based on the approach described in the pest risk management section	-	-	No
Aridius nodifer (Westwood) [Coleoptera: Corticariidae]	Minute brown scavenger beetle	MAFNZ (2000b)	Yes* (AQIS, 1998a)	Not likely Orchard or packing house contaminant (adult life stage), secondary feeder on decaying plant material (MAFNZ, 2000b). This species was assessed as "Not likely" to have the potential for being on mature apple fruit in the present document based on the revised criteria set out in the methodology section. It is treated as contaminant and will be dealt with based on the approach described in the pest risk management section	-	-.	No
Asynonychus cervinus (Boheman) [Coleoptera: Curculionidae]	Fuller's rose weevil	MAFNZ (2000b)	Yes (CSIRO/DAFF, 2005)	-	-	-	No

Scientific name	**Common name/s**	**Reference for presence in New Zealand**	**Presence in Australia Reference**	**Potential for being on mature apple fruit Comments if applicable**	**Potential for establishment or spread**	**Potential for consequences Comments if applicable**	**Consider species further?**
Carabid beetle [Coleoptera: Carabidae]	Ground beetle	HortResearch (1999b)	Uncertain	Not likely Carabid beetles are primarily ground beetles that are predators that feed on a wide variety of insects (CSIRO, 1991)	-	-	No
Carpophilus davidsoni (Dobson) [Coleoptera: Nitidulidae]	Dried fruit beetle	MAFNZ (2000b)	Yes (CSIRO/DAFF, 2005)	-	-	-	No
Carpophilus gaveni Dobson [Coleoptera: Nitidulidae]	Dried fruit beetle	MAFNZ (2000b)	Yes* (AQIS, 1998a), (James et al., 1995)	Not likely Adults are contaminants/secondarily on fruit. Adult and larvae of *Carpophilus* species are attracted to ripe and fermenting fruit (Kuschel, 1990; MAFNZ, 2000b). The damaged ripe and fermenting fruit would be removed from the quality control process	-	-	No
Carpophilus humeralis (Fabricius) (as *Urophorus humeralis* in (MAFNZ, 2000b) Coleoptera: Nitidulidae]	Fruit beetle	MAFNZ (2000b)	Yes (CSIRO/DAFF, 2005)	-	-	-	No

Scientific name	Common name/s	Reference for presence in New Zealand	Presence in Australia Reference	Potential for being on mature apple fruit Comments if applicable	Potential for establishment or spread	Potential for consequences Comments if applicable	Consider species further?
Carpophilus spp. [Coleoptera: Nitidulidae]	Dried fruit beetle	MAFNZ (2000b)	Uncertain 12 species known in New Zealand (Leschen, 2000), six of these are not in Australia see next column for details	Not likely In the *Draft import risk analysis on the importation of apples (*Malus x domestica *Borkh.) from New Zealand* (BA, 2000), '*Carpophilus* spp. ' were considered further and a full risk assessment was undertaken. However, based on further information provided by New Zealand, it is now accepted that the potential for importation of '*Carpophilus* spp.' would be unlikely as explained below. Altogether, 12 species of *Carpophilus* are reported from New Zealand (MAFNZ, 2001; Leschen, 2000). Among the species, six of them (*C. davidsoni* Dobson, *C. gaveni* Dobson (not in WA), *C. hemipterus* (L.), *C. marginellus* Motschulsky *C. mutilatus* (Erichson) and *C. dimidiatus* (Fabricius)) are recorded from Australia (James et al., 1995; CABI, 2005; CABI , 2001). Specimens fo six other species *C. ligneus* Murray, *C. maculatus, C. obsoletus, C. oculatus, C. oculatus gilloglyi, C. pilosellus* Motschulsky) are present in the New Zealand Arthropod Collections (Leschen, 2000) but none of them are recorded on fresh apple fruit. The single identified specimen of *C. sexpustulatus* (Fabricius) in New Zealand Arthropod Collection is actually an incomplete specimen of a misidentified *Nitidula carnaria*. Based on the above information, it is highly likely that '*Carpophilus* spp.' included in (MAFNZ, 2000b) either belong to the species that are already listed in the same reference or are species already in Australia (*C. gaveni* is not in WA but see separate entry for this species in this table). The species recorded in New Zealand but not in Australia are not associated with fresh apple and are not likely on pathway. Therefore, it is not necessary to take '*Carpophilus* spp.' into further consideration in this analysis	-	-	No
Cartodere spp. [Coleoptera: Corticariidae] Of the two species *C. castanea* (Broun) and *C. filum* (Aube) recognised in New Zealand (MAFNZ, 2001), only *C. filum* is not found in Australia	Fungus beetle	MAFNZ (2000b)	No (Hetschko, 1926); (Hinton, 1945)	Not likely Contaminant/secondary feeder on decaying plant material (MAFNZ, 2000b). This species was assessed as "Not likely" to have the potential for being on mature apple fruit in the present document based on the revised criteria set out in the methodology section. It is treated as contaminant and will be dealt with based on the approach described in the pest risk management section	-	-	No

Scientific name	Common name/s	Reference for presence in New Zealand	Presence in Australia Reference	Potential for being on mature apple fruit Comments if applicable	Potential for establishment or spread	Potential for consequences Comments if applicable	Consider species further?
Catoptes coronatus (Sharp) [Coleoptera: Curculionidae]	Broadnosed weevil	MAFNZ (2002b)	No	Not likely Adults occur in dead wood of a wide range of plants; larvae live in the soil and feed on various scrub roots (plant feeder); casual on apple; distribution restricted to the South Island of New Zealand (MAFNZ, 2002b). No records of interceptions of this species from New Zealand (DAFF-PDI, 2002)	-	-	No
Chrysomela aeneicollis Schaeffer (as *Atrichatus aeneicollis* in MAFNZ, 1999a) [Coleoptera: Chrysomelidae]	Chrysomelid beetle	MAFNZ (1999a)	No	Not likely No biological information available on this species, presumably foliage feeders like other chrysomelids (MAFNZ, 1999a). No records of interceptions of this species from New Zealand (DAFF-PDI, 2002)	-	-	No
Coccinella undecimpunctata L. [Coleoptera: Coccinellidae]	Elevenspotted ladybird	MAFNZ (2000b)	Yes (CSIRO/DAFF, 2005)	-	-	-	No
Conoderus exsul Sharp [Coleoptera: Elateridae]	Click beetle, Wireworm	MAFNZ (2000b)	No (Calder, 1996)	Not likely Packing house contaminants (MAFNZ, 2000b). This species was assessed as "Not likely" to have the potential for being on mature apple fruit in the present document based on the revised criteria set out in the methodology section. It is treated as contaminant and will be dealt with based on the approach described in the pest risk management section	-	- (Stone and Wilcox, 1978)	No (was yes in the last revised draft IRA but see the revised criteria for being on pathway)
Corticaria pubescens (Gyllenhall) [Coleoptera: Corticariidae]	Fungus beetle	MAFNZ (2000b)	Yes* (AQIS, 1998a)	Not likely Orchard or packing house contaminant (adult life stage), secondary feeder on decaying plant material (MAFNZ, 2000b). This species was assessed as "Not likely" to have the potential for being on mature apple fruit in the present document based on the revised criteria set out in the methodology section. It is treated as contaminant and will be dealt with based on the approach described in the pest risk management section	-	-	No
Corticaria serrata (Paykull) [Coleoptera: Corticariidae]	Fungus beetle	MAFNZ (2000b)	No	Not likely Orchard or packing house contaminant (adult life stage), secondary feeder on decaying plant material (MAFNZ, 2000b). This species was assessed as "Not likely" to have the potential for being on mature apple fruit in the present document based on the revised criteria set out in the methodology section. It is treated as contaminant and will be dealt with based on the approach described in the pest risk management section	-	-	No

Scientific name	Common name/s	Reference for presence in New Zealand	Presence in Australia Reference	Potential for being on mature apple fruit Comments if applicable	Potential for establishment or spread	Potential for consequences Comments if applicable	Consider species further?
Corticaria spp. [Coleoptera: Corticariidae] Five species of this genus are recognised in New Zealand: *C. elongata* (Gyllenhal) *C. fenestralis* (Linnaeus) *C. formicaephila* (Broun), *C. pubescens* and *C. serrata*. The last two species *C. pubescens* and *C. serrata* (see both above –listed species) are the most likely species to be involved (MAFNZ, 2001)	Fungus beetle	MAFNZ (2000b)	Uncertain	Not likely Orchard or packing house contaminant (adult life stage), secondary feeder on decaying plant material (MAFNZ, 2000b). This species was assessed as "Not likely" to have the potential for being on mature apple fruit in the present document based on the revised criteria set out in the methodology section. It is treated as contaminant and will be dealt with based on the approach described in the pest risk management section	-	-	No
Cortinicara hirtalis (Broun) [Coleoptera: Corticariidae]	Minute scavenger beetle	MAFNZ (2000b); HortResearch (1999b; 1999b)	Yes* (CSIRO/DAFF, 2005)	Not likely Orchard or packing house contaminant, saprophyte/ fungal feeder (MAFNZ, 2000b). This species was assessed as "Not likely" to have the potential for being on mature apple fruit in the present document based on the revised criteria set out in the methodology section. It is treated as contaminant and will be dealt with based on the approach described in the pest risk management section	-	-	No
Cortinicara spp. [Coleoptera: Corticariidae] Two species, *C. hirtalis* (Broun) and *C. meridiana* Johnson are recognised for New Zealand. The species *C. hirtalis* is the commoner species, and is the likely species to be involved (MAFNZ, 2001)	Fungus beetle	MAFNZ (2000b)	Uncertain	Not likely Orchard or packing house contaminant (adult life stage), secondary feeder on decaying plant material (MAFNZ, 2000b). This species was assessed as "Not likely" to have the potential for being on mature apple fruit in the present document based on the revised criteria set out in the methodology section. It is treated as contaminant and will be dealt with based on the approach described in the pest risk management section	-	-	No
Costelytra zealandica (White) [Coleoptera: Scarabaeidae]	Grass grub	MAFNZ (2000b)	No (Cassis et al., 1992)	Not likely Adults are packing house contaminants, polyphagous; adults defoliate; larvae are root feeders (MAFNZ, 2000b); can be a serious pasture plant feeder (Landcare Research, 1999)	-	-	No
Cryptolaemus montrouzieri Mulsant [Coleoptera: Coccinellidae]	Mealybug ladybird	Valentine (1967)	Yes (CSIRO/DAFF, 2005)	-	-	-	No

Scientific name	Common name/s	Reference for presence in New Zealand	Presence in Australia Reference	Potential for being on mature apple fruit Comments if applicable	Potential for establishment or spread	Potential for consequences Comments if applicable	Consider species further?
Cryptolestes spp. [Coleoptera: Laemophloeidae] Of the four species *C. ferrugineus, C. pusilloides, C. pusillus,* C. *capens* (Klimaszewski and Watt, 1997); (MAFNZ, 2001) recorded in New Zealand, only *C. capensis* is not found in Australia (Thomas, 2001). [Coleoptera: Laemophloeidae]	Flat grain beetle	MAFNZ (2000b)	No (Hetschko, 1926) (Thomas, 2001)	Not likely Adults are orchard or packing house contaminants, secondary feeders on decaying/dried plant material (MAFNZ, 2000b); (DAFF-PDI, 2002)	-	-	No
Cryptophagus spp. Two species *C. pilosus* Gyllenhal and *C. pseudodentatus* Bruce are reported from New Zealand (MAFNZ, 2001) [Coleoptera: Cryptophagidae]	Cryptophagid fungus beetle	MAFNZ (2000b)	No	Not likely Orchard or packing house contaminant (adult life stage), secondary feeder on decaying plant material (MAFNZ, 2000b). This species was assessed as "Not likely" to have the potential for being on mature apple fruit in the present document based on the revised criteria set out in the methodology section. It is treated as contaminant and will be dealt with based on the approach described in the pest risk management section	-	-	No
Dermestes maculatus De Geer [Coleoptera: Demestidae]	Hide beetle, skin beetle	MAFNZ (2000b)	Yes (CSIRO/DAFF, 2005)	-	-	-	No
Ernobius mollis (Linnaeus) [Coleoptera: Anobiidae]	Pine knot borer	MAFNZ (2000b)	Yes* (CSIRO/DAFF, 2005)	Not likely Adults are orchard or packing house contaminants, occasionally feed on apple foliage (MAFNZ, 2002b)	-	-	No
Eucolaspis brunnea (Fabricius) [Coleoptera: Chrysomelidae]	Bronze beetle	MAFNZ (2000b)	No	Not likely Adults are orchard or packing house contaminants, feed on apple foliage (MAFNZ, 1999a)	-	-	No
Gonipterus scutellatus (Gyllenhall) [Coleoptera: Curculionidae]	Gum tree weevil	Spiller and Wise (1982); MAFNZ (2002b)	Yes (CSIRO/DAFF, 2005)	-	-	-	No
Gymnetron pascuorum (Gyllenhall) [Coleoptera: Curculionidae]	Native weevil	MAFNZ (2000b)	No	Not likely Adults are orchard or packing house contaminants, larvae feed on *Plantago* spp. (weeds) (MAFNZ, 2000b)	-	-	No

Scientific name	Common name/s	Reference for presence in New Zealand	Presence in Australia Reference	Potential for being on mature apple fruit Comments if applicable	Potential for establishment or spread	Potential for consequences Comments if applicable	Consider species further?
Halmus chalybeus (Boisduval) [Coleoptera: Coccinellidae]	Steelblue ladybird	HortResearch (1999b)	Yes* (CSIRO/DAFF, 2005)	Not likely Adults and larvae of this species prey on scale insects including black scale (*Saissetia oleae*), blue gum scale and San José scale (*Diaspidiotus perniciosus*) on fruit (HortResearch, 1999b). Adults of steelblue ladybird would drop off when disturbed. Any remaining larvae would be eliminated during packing house processing	-	-	No
Harmonia conformis (Boisduval) (Syn. = *Leis conformis*) [Coleoptera: Coccinellidae]	Ladybird	Valentine (1967)	Yes (CSIRO/DAFF, 2005)	-	-	-	No
Harpalinae [Coleoptera: Carabidae]	Predatory ground beetle	MAFNZ (2000b)	Uncertain	Not likely Adults are orchard or packing house contaminants, phytophagous (seeds and pollen), larvae predatory in soil (MAFNZ, 2000b)	-	-	No
Hylastes ater Paykull [Coleoptera: Scolytidae]	Black pine bark beetle	Spiller and Wise (1982)	Yes (CSIRO/DAFF, 2005)	-	-	-	No
Irenimus compressus (Broun) [Coleoptera: Curculionidae]	Compressed weevil	MAFNZ (2002b)	No	Not likely Attacks brassicas, carrots, lucerne, clover (MAFNZ, 2002b)	-	-	No
Listroderes difficilis Germain (was *L. obliquus* Klug) [Coleoptera: Curculionidae]	Vegetable weevil	MAFNZ (2000b)	Yes (AQIS, 1998a)	-	-	-	No
Listronotus bonariensis (Kuschel) [Coleoptera: Curculionidae]	Argentine stem weevil	MAFNZ (2000b)	Yes (AQIS, 1998a)	-	-	-	No
Longitarsus fuliginosus (Broun) [Coleoptera: Chrysomelidae]	Native chrysomelid, golden flea beetle	MAFNZ (2000b)	No	Not likely Adults are orchard or packing house contaminants, possibly feed on grasses (MAFNZ, 2000b)	-	-	No
Micrambina rutila (Broun) [Coleoptera: Cryptophagidae]	Plaster beetle	MAFNZ (2000b)	No	Not likely Adults are orchard or packing house contaminants, secondary feeders on dead leaf and stem material (MAFNZ, 2000b)	-	-	No
Mitrastethus baridioides Redtenbacher [Coleoptera: Curculionidae]	Kauri weevil	MAFNZ (2000b)	No	Not likely Adults are orchard or packing house contaminants, larvae feed on damp pine logs (MAFNZ, 2000b)	-	-	No

Scientific name	Common name/s	Reference for presence in New Zealand	Presence in Australia Reference	Potential for being on mature apple fruit Comments if applicable	Potential for establishment or spread	Potential for consequences Comments if applicable	Consider species further?
Navomorpha sulcatus F. [Coleoptera: Cerambycidae]	Cerambycid beetle	Spiller and Wise (1982)	No	Not likely Larvae feed only on twigs and branches of apple and almond trees (Miller, 1922)	-	-	No
Notagonum submetallicum (White) [Coleoptera: Carabidae]	Submetallic ground beetle	MAFNZ (2000b)	Yes (Kuschel, 1990)	-	-	-	No
Oemona hirta (F.) [Coleoptera: Cerambycidae]	Lemon tree borer	MAFNZ (1999a)	No	Not likely Record is on shoots, polyphagous on wide range of woody hosts (MAFNZ, 1999a)	-	-	No
Otiorhynchus sp. [Coleoptera: Curculionidae]	Strawberry root weevil or Black vine weevil	MAFNZ (2000b)	Yes* (CABI, 2002); (Williams, 2000)	Three species of *Otiorhynchus* in New Zealand: *O.sulcatus, O. ovatus. O. rugosostriatus* (MAFNZ, 2000b) are in Australia	-	-	No
Phlyctinus callosus Boheman [Coleoptera: Curculionidae]	Garden weevil	MAFNZ (2000b)	Yes (CABI, 2005)	-	-	-	No
Ptinus tectus Boieldieu [Coleoptera: Anobiidae]	Australian spider beetle	MAFNZ (2000b)	Yes* (CSIRO/DAFF, 2005)	Not likely Contaminants normally associated with dried plant and animal material (MAFNZ, 2000b) This species was assessed as "Not likely" to have the potential for being on mature apple fruit in the present document based on the revised criteria set out in the methodology section. It is treated as contaminant and will be dealt with based on the approach described in the pest risk management section	-	-	No
Pyronota festiva (Fabricius) [Coleoptera: Scarabaeidae]	Manuka beetle	Spiller and Wise (1982)	No (Cassis et al., 1992)	Not likely A high country insect, only found close to Manuka bushes (*Leptospermum scoparium*) (Spiller and Wise, 1982; Miller, 1936)	-	-	No
Rhinocyllus conicus Froelich [Coleoptera: Curculionidae]	Nodding thistle receptacle weevil	MAFNZ (2000b)	Yes* (CABI, 2005)	Not likely Adults are orchard or packing house contaminants, larvae are associated with nodding thistle (MAFNZ, 2000b)	-	-	No
Rhyzobius ventralis (Erichson) [Coleoptera: Coccinellidae]	Gumtree scale ladybird	Valentine (1967)	Yes (CSIRO/DAFF, 2005)	-	-	-	No
Scopodes fossulatus (Blanchard) (as *Scopodes elaphroides* (White) in (MAFNZ, 2000b) [Coleoptera: Carabidae]	Ground beetle	MAFNZ (2000b)	No As endemic in New Zealand in (Larochelle and Lariviere, 2001)	Not likely Adults are orchard or packing house contaminants and predators, which are normally found under stones or bark exposed to the sun (MAFNZ, 2000b)	-	-	No

Scientific name	**Common name/s**	**Reference for presence in New Zealand**	**Presence in Australia Reference**	**Potential for being on mature apple fruit Comments if applicable**	**Potential for establishment or spread**	**Potential for consequences Comments if applicable**	**Consider species further?**
Sitona discoideus Gyllenhall [Coleoptera: Curculionidae]	Sitona weevil	MAFNZ (2000b)	Yes (CSIRO/DAFF, 2005)	-	-	-	No
Sitophilus oryzae (L.) [Coleoptera: Curculionidae]	Rice weevil	MAFNZ (2000b)	Yes (CSIRO/DAFF, 2005)	-	-	-	No
Staphylinidae indet. [Coleoptera: Staphylinidae]	Rove beetle	MAFNZ (2000b)	Uncertain	Not likely Adults are orchard contaminants, whose species may be both predators and scavengers. Both adults and larvae are mobile and often highly active predators attacking eggs, larvae, pupae and adults of most soft bodied soil arthropods (MAFNZ, 2000b; Scott, 1984)	-	-	No
Stethorus bifidus Kapur [Coleoptera: Coccinellidae]	Ladybird	MAFNZ (2000b)	No	Not likely Adults and larvae are predators on mites and adults are packing house contaminants, (MAFNZ, 2000b). The host mites can be found around calyx (HortResearch, 1999b). Adults of the ladybirds would drop off when disturbed and any remaining larvae would be eliminated during packing house processing	-	-	No
Stethorus histrio Chazeau [Coleoptera: Coccinellidae]	Mite-eating ladybird	HortResearch (1999b)	Yes (Houston, 1980), (Waterhouse and Sands, 2001)	-	-	-	No
Stethorus sp. [Coleoptera: Coccinellidae]	Mite-eating ladybird	HortResearch (1999b)	Uncertain	Not likely Adults and larvae of *Stethorus* are predators. *Stethorus* adults are active when in fruit trees and if disturbed will often fall to the ground. They are good fliers and therefore tend to concentrate in areas of the orchard where mites are plentiful and disappear when the mite population becomes low. Eggs are laid mostly on the undersides of the leaf, near the primary veins (Hodek, 1973). The host mites can be found around calyx (HortResearch, 1999b). Adults of the ladybirds would drop off when disturbed and any remaining larvae would be eliminated during packing house processing	-	-	No
Xyleborus saxeseni (Ratzeburg) [Coleoptera: Scolytidae]	Keyhole ambrosia beetle	MAFNZ (1999a)	Yes (Abbott, 1985)	-	-	-	No

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Xyloteles laetus White [Coleoptera: Cerambycidae]	Cerambycid beetle	MAFNZ (1999a)	No	Not likely Record is on stems, adults usually found on trunks and thicker branches of dead trees and shrubs; larvae presumably are boring in these plant parts, hosts include many native and introduced woody trees and shrubs (MAFNZ, 1999a)	-	-	No
Insects - Demaptera							
Forficula auricularia L. [Demaptera: Forficulidae]	European earwig	MAFNZ (2000b)	Yes (CSIRO/DAFF, 2005)	-	-	-	No
Insects - Diptera							
Allograpta ropalus (Walker) (Syn. = *Syrphus ropalus*) [Diptera: Syrphidae]	Syrphid fly	Valentine (1967); HortResearch (1999b)	No (Evenhuis, 2001)	Not likely Light brown apple moth *Epiphyas postvittana* was listed as a host species of this syrphid fly by Valentine (1967). However, this species is not listed in HortResearch (1999b) as a natural enemy of the light brown apple moth, indicating that the species is not an important predator of this moth in apple orchards	-	-	No
Anomalomyia guttata (Hutton) [Diptera: Mycetophilidae]	Fungus gnat	MAFNZ (2000b)	No (McLaren and Fraser, 1994)	Not likely Adults are orchard or packing house contaminants, larvae associated with decomposing vegetable matter (MAFNZ, 2000b)	-	-	No
Antipodiphora tonnoiri (Schmitz) [Diptera: Phoridae]	Native phorid fly	MAFNZ (2000b)	No (McLaren and Fraser, 1994)	Not likely Adults are orchard or packing house contaminants, larvae are secondary feeders on decaying plant material (MAFNZ, 2000b)	-	-	No
Arthrocnodax sp. (Syn. = *Anthrocnodax*) [Diptera: Cecidomyiidae]	Cecidomyiid fly	HortResearch (1999b)	Yes (HortResearch, 1999b)	-	-	-	No
Bradysia sp. Winnertz [Diptera: Sciaridae]	Fungus gnat	MAFNZ (2002b)	Uncertain (genus present) (CSIRO/DAFF, 2005)	Not likely Larvae feed on decomposing plant material but some species may be damaging to seedlings in greenhouses (MAFNZ, 2002b)	-	-	No
Brevicornu maculatum (Tonnoir) [Diptera: Mycetophilidae]	Fungus gnat	MAFNZ (2000b)	No (McLaren and Fraser, 1994)	Not likely Adults are orchard or packing house contaminants, larvae associated with decomposing vegetative matter (MAFNZ, 2000b)	-	-	No
Calliphora stygia F. [Diptera: Calliphoridae]	Brown blowfly	MAFNZ (2000b)	Yes (McLaren and Fraser, 1994)	-	-	-	No

Scientific name	Common name/s	Reference for presence in New Zealand	Presence in Australia Reference	Potential for being on mature apple fruit Comments if applicable	Potential for establishment or spread	Potential for consequences Comments if applicable	Consider species further?
Cerodontha australs Malloch [Diptera: Agromyzidae]	Wheat sheath miner	MAFNZ (2002b)	Yes* (Evenhuis, 1989)	Not likely Cereal pest but casual on other hosts (MAFNZ, 2002b)	-	-	No
Cryptochetum iceryae Williston [Diptera: Cryptochetidae]	Cryptochetid fly	Valentine (1967)	Yes* (Evenhuis, 1996b); (Fasulo and Brooks, 1993)	Not likely *Icerya purchasi* listed as host. This fly was introduced from Australia. It is a parasite that lays its eggs in the mature larvae and pupae of the cottony cushion scale that are not on fruit (Fasulo and Brooks, 1993)	-	-	No
Culex pervigilans Bergroth [Diptera: Culicidae]	Vigilant mosquito	MAFNZ (2000b)	No (McLaren and Fraser, 1994)	Not likely Adults are orchard or packing house contaminants, and they are nectar and blood feeders, larvae are aquatic (MAFNZ, 2000b). The species has potential veterinary importance including as potential intermediate host for dog heartworm *Dirofilaria immitis* (MAFNZ , 2000d)	-	-	No
Dasineura mali Keiffer [Diptera: Cecidomyiidae]	Apple leafcurling midge	MAFNZ (2000b)	No (McLaren and Fraser, 1994)	Likely Larvae are primary pest on foliage; larvae can pupate on fruit (MAFNZ, 2000b)	Feasible	Significant Apple tree shoots damaged and tree growth retarded resulting in decreased fruit yield in Europe and New Zealand (Tomkins et al., 1994); (Smith and Chapman, 1995); (CABI, 2002a)	Yes
Diadiplosis koebelei [Diptera: Cecidomyiidae]	Cecidomyiid fly	HortResearch (1999b)	Yes Introduced into New Zealand from Australia (HortResearch, 1999b)	-	-	-	No

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Diadiplosis sp. [Diptera: Cecidomyiidae]	Cecidomyiid fly	HortResearch (1999b)	Uncertain	Not likely Larvae of this fly have been recorded feeding on mealybugs (HortResearch, 1999b). Mealybugs can be found in calyx and stem end of fruit (HortResearch, 1999b; Scott, 1984). It is considered that this species would not be likely on pathway because (1) packinghouse processes have been shown to eliminate most its host mealybugs (Whiting et al., 1998) and consequently their associated predators, (2) as predators, this fly would also be eliminated by packinghouse process (unlike parasitoids live inside their hosts)	-	-	No
Drosophila spp. [Diptera: Drosophilidae]	Vinegar flies	HortResearch (1999b)	Uncertain Many species of the genus present in Australia	Not likely Species of *Drosophila* are attracted to and feed upon a greater variety of fermenting substances (Evenhuis, 2001). This species was assessed as "Not likely" to have the potential for being on mature apple fruit in the present document based on the revised criteria set out in the methodology section. It is treated as contaminant and will be dealt with based on the approach described in the pest risk management section	-	-	No
Euryomma peregrimum (Meigen) [Diptera: Fanniidae]	Muscid fly	MAFNZ (2000b)	Yes* (McLaren and Fraser, 1994)	Not likely Adults are orchard or packing house contaminants, larvae associated with animal skins and hides (MAFNZ, 2000b); (DAFF-PDI, 2002)	-	-	No
Hydrellia tritici Coquillett [Diptera: Ephydridae]	Black pasture fly	MAFNZ (2000b)	Yes (McLaren and Fraser, 1994)	-	-	-	No
Melangyna novaezealandiae Macquart (Syn. = *Syrphus ortas*) [Diptera: Syrphidae]	Syrphid fly	Valentine (1967); HortResearch (1999b)	No (Evenhuis, 2001)	Not likely Light brown apple moth *Epiphyas postvittana* was listed as a host species of this syrphid fly by Valentine (1967). However, this species is not listed in HortResearch (1999b) as a natural enemy of the light brown apple moth, indicating it is not an important predator of this moth in apple orchards	-	-	No

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Melanostoma fasciatum Macquart [Diptera: Syrphidae]	Syrphid fly	HortResearch (1999b)	No (Evenhuis, 2001)	Not likely Larvae of this native hover fly have been recorded feeding on longtailed mealybug (*Pseudococcus longispinus*) found on the leaves, bark and fruit of apple. It is considered that this species would not be likely on pathway because (1) packinghouse processes have been shown to eliminate most its host mealybugs (Whiting et al., 1998) and consequently their associated predators, (2) as predators, this fly would also be eliminated by packinghouse process (unlike parasitoids live inside their hosts)	-	-	No
Mycetophila spp. [Diptera: Mycetophilidae]	Fungus gnats	MAFNZ (2000b)	Uncertain	Not likely Orchard or packing house contaminant (adult life stage), secondary feeder on decaying plant material (MAFNZ, 2000b). This species was assessed as "Not likely" to have the potential for being on mature apple fruit in the present document based on the revised criteria set out in the methodology section. It is treated as contaminant and will be dealt with based on the approach described in the pest risk management section	-	-	No
Pales feredayi (Hutton) [Diptera: Tachinidae]	Tachinid fly	Valentine (1967)	No (Evenhuis, 1996a)	Not likely A parasitic fly of tortricids, noctuids and other species. Leafroller caterpillars parasitised by this fly continue to develop, usually to the pupal stage before dying. By this stage the parasite has formed a puparium inside the leafroller pupa from which the adult fly later emerges (HortResearch, 1999b). Although larvae and pupae of host can be found on fruit and in calyx (HortResearch, 1999b; Scott, 1984), it is considered unlikely that this fly will remain on the pathway because (1) only a small percentage of leafroller larvae are parasitised, and (2) most leafroller larvae actually feed on leaves rather than fruit	-	-	No

Scientific name	Common name/s	Reference for presence in New Zealand	Presence in Australia Reference	Potential for being on mature apple fruit Comments if applicable	Potential for establishment or spread	Potential for consequences Comments if applicable	Consider species further?
Pales funesta (Hutton) [Diptera: Tachinidae]	Tachinid fly	Valentine (1967)	No (Evenhuis, 1996a)	Not likely Leafroller caterpillars parasitised by this fly parasitic continue to develop, usually to the pupal stage before dying. By this stage the parasite has formed a puparium inside the leafroller pupa from which the adult fly later emerges (HortResearch, 1999b). Although larvae and pupae of host can be found on fruit and in calyx (HortResearch, 1999b; Scott, 1984), it is considered that it is unlikely that this fly will be on pathway because (1) only less than 0.5% of lightbrown apple moths, and 1-6% of Greenheaded leafrollers were parasitised by *Pales funesta* in a three year study of an Auckland apple orchard (HortResearch, 1999b), and (2) most leafroller larvae actually feed on leaves rather than fruit	-	-	No
Syrphidae [Diptera: Syrphidae]	Hoverflies	MAFNZ (2000b)	Uncertain	Not likely MAFNZ (2000b) stated that adults are orchard or packing house contaminants and predators on aphids. However, this record was removed in (MAFNZ, 2002b). It is considered that the Syrphidae as listed in (MAFNZ, 2000b) are not likely to be on the pathway	-	-	No
Trigonospila brevifacies (Hardy) [Diptera: Tachinidae]	Tachinid fly	Munro (1998)	Yes (McLaren and Fraser, 1994)	-	-	-	No
Uclesiella irregularis Malloch (misspelled as *U. irregulqaris*) [Diptera: Tachinidae]	Tachinid fly	Valentine (1967); Evenhuis (1996a)	No (Evenhuis, 1996a)	Not likely Valentine (1967) listed light brown apple moth, *Epiphyas postvittana,* as a host species of this tachinid fly. However, there is no recent record of this fly as a biocontrol agent of light brown apple moth in HortResearch (1999b), indicating *U. irregularis* is either no longer found or is unimportant in apple orchards in New Zealand	-	-	No
Insects - Hemiptera							
Acyrthosiphon pisum (Harris) [Hemiptera: Aphididae]	Pea aphid	MAFNZ (2002b)	Yes (CSIRO/DAFF, 2005)	-	-	-	No

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Amphipsalta cingulata (Fabricius) [Hemiptera: Cicadidae]	Short-winged clapping cicada	HortResearch (1999b)	No (Fletcher, 1998)	Not likely Cicada eggs are often laid in groups beneath the surface of plant tissues, such as in stems or fruits. Apple fruits often present with diagonal rows of oviposition (egg-laying) scars made by female cicadas (HortResearch, 1999b). MAFNZ (2003a) states that this species is “Occasional/very infrequent but quite conspicuous damage, graded out in packing house.” This information indicates that it is unlikely that this species will be on export quality apples	-	-	No
Amphipsalta zelandica (Boisduval) [Hemiptera: Cicadidae]	Long-winged clapping cicada	HortResearch (1999b)	No (Fletcher, 1998)	Not likely Cicada eggs are often laid in groups beneath the surface of plant tissues, such as in stems or fruits. Apple fruits often present with diagonal rows of oviposition (egg-laying) scars made by female cicadas (HortResearch, 1999b). MAFNZ (2003a) states that this species is “Occasional/very infrequent but quite conspicuous damage, graded out in packing house.” This information indicates that it is unlikely that this species will be on export quality apples	-	-	No
Anzora unicolor (Walker) (Syn. = *Sephena cinerea* Kirkaldy) [Hemiptera: Flatidae]	Flatid hopper, gray plant hopper	Spiller and Wise (1982)	Yes (Fletcher, 1979); (Fletcher and Larivière, 2001).	-	-	-	No
Aonidiella aurantii (Maskell) [Hemiptera: Diaspididae]	California red scale	MAFNZ (2000b)	Yes (Smith et al., 1997)	-	-	-	No
Aphis gossypii Glover [Hemiptera: Aphididae]	Melon aphid	MAFNZ (2000b)	Yes (CSIRO/DAFF, 2005)	-	-	-	No
Aphis spiraecola Patch [Hemiptera: Aphididae]	Apple aphid	Spiller and Wise (1982); CABI (2005)	Yes (CSIRO/DAFF, 2005)	-	-	-	No
Aspidiotus nerii Bouché [Hemiptera: Diaspididae]	Oleander scale	MAFNZ (2000b)	Yes (CSIRO/DAFF, 2005)	-	-	-	No
Aulacorthum solani (Kaltenbach) [Hemiptera: Aphididae]	Foxglove aphid	MAFNZ (1999a); Spiller and Wise (1982)	Yes (CABI, 2005)	-	-	-	No
Brentiscerus putoni (F.B. White) [Hemiptera: Lygaeidae]	Lygaeid bug	MAFNZ (2000b)	Yes* (AQIS, 1998a)	Not likely Orchard or packing house contaminants, normally seed-feeder on native hosts (MAFNZ, 2000b)	-	-	No

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Calocoris norvegicus (Gmelin) [Hemiptera: Miridae]	Potato mirid	MAFNZ (1999a)	Yes* (Williams, 2000)	Not likely Record is on leaves (no life stage recorded); probably an adult contaminant; nymphs of this species are usually found on low growing vegetables and herbs; nymphs are primary feeders (MAFNZ, 1999a)	-	-	No
Cardiastethus consors White [Hemiptera: Anthocoridae]	Anthocorid bug	Larivière (2000)	No (Cassis and Gross, 2002a)	Not likely A predatory bug related to the pirate bug (*Orius vicinus*). C. *consors* is reported to feed on twospotted spider mite and is a probable predator of psocids. It is not likely that this predatory bug will be on the pathway because it is encountered only occasionally in pipfruit orchards (HortResearch, 1999b)	-	-	No
*Cardiastethus power*i White (Syn. = *Cardiastethus power*) [Hemiptera: Anthocoridae]	Anthocorid bug	Larivière (2000)	No (Cassis and Gross, 2002a)	Not likely A predatory bug related to the pirate bug that is reported to feed on twospotted spider mite (HortResearch, 1999b). It is not likely that this predatory bug will be on the pathway because it is encountered only occasionally in apple orchards	-	-	No
Cavariella aegopodii (Scopoli) [Hemiptera: Aphididae]	Carrot aphid	MAFNZ (2002b)	Yes (CSIRO/DAFF, 2005)	-	-	-	No
Cermada punctimargo (Walker) (as *Cixius punctimargo* Walker in (MAFNZ, 2002b) [Hemiptera: Cixiidae]	Cixiid plant hopper	MAFNZ (2002b)	No (Fletcher and Larivière, 2001)	Not likely Nymphs feed on roots of shrubs, broadleaf and podocarp trees. Genus *Cixius* is cosmopolitan (MAFNZ, 2002b)	-	-	No
Cermatulus nasalis (Westwood) [Hemiptera: Pentatomidae]	Pentatomid bug	Larivière (2000)	Yes (CSIRO/DAFF, 2005)	-	-	-	No
Ceroplastes sinensis Del Guercio [Hemiptera: Coccidae]	Chinese wax scale	MAFNZ (1999a)	Yes (Qin and Gullan, 1994)	-	-	-	No
Coccus hesperidum L. [Hemiptera: Coccidae]	Brown soft scale	Spiller and Wise (1982)	Yes (Ben-Dov, 2002)	-	-	-	No
Diaspidiotus ostreaeformis (Curtis (as *Quadraspidiotus ostreaeformis* (Curtis) in (MAFNZ, 2000b) [Hemiptera: Diaspididae]	Oystershell scale, Pear Oyster Scale	MAFNZ (2000b)	Yes* (CSIRO/DAFF, 2005)	Likely Oystershell scale infection is usually concentrated around the calyx or stem end, but may occur anywhere on the fruit surface (HortResearch, 1999b)	Feasible	Significant Oystershell scale is a major scale pest of apple and pear in the southern regions of New Zealand (HortResearch, 1999b)	Yes*

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Diaspidiotus perniciosus (Comstock) (as *Quadraspidiotus perniciosus* in (MAFNZ, 2000b) [Hemiptera: Disapidae]	San Jose scale	MAFNZ (2000b)	Yes (CSIRO/DAFF, 2005)	-	-	-	No
Dictyotus caenosus (Westwood) [Hemiptera: Pentatomidae]	Brown shield bug	MAFNZ (2000b)	Yes (Ingram, 1998)	-	-	-	No
Dieuches notatus (Dallas) [Hemiptera: Lygaeidae]	Lygaeid bug	MAFNZ (2000b)	Yes* (May, 1965)	Not likely Adults are orchard or packing house contaminants, primary feeders on water cress in water courses (MAFNZ, 2000b)	-	-	No
Edwardsiana crataegi (Douglas) [Hemiptera: Cicadellidae]	Froggatt's apple leafhopper	MAFNZ (2000b) but unconfirmed (Fletcher and Larivière, 2002)	No (Fletcher and Larivière, 2002)	Not likely Conflicting evidence exists in relation to the presence of this species in New Zealand. Recent work indicates that the presence of *E. crataegi* in New Zealand has not been confirmed (Fletcher and Larivière, 2002). However, this species is considered as pest of apple in NZ and information on its distribution, biology and control is available in HortResearch (1999b) which indicates that it only feeds on leaves of apple tree	-	-	No
Eriococcus coccineus Cockerel [Hemiptera: Eriococcidae]	Spine scale insect	MAFNZ (1999a)	Yes (Miller and Gimpel, 2002b)	-	-	-	No
Eriosoma lanigerum (Hausmann) [Hemiptera: Aphididae]	Woolly apple aphid	MAFNZ (2000b)	Yes (CSIRO/DAFF, 2005)	-	-	-	No
Halticus minutus Reuter [Hemiptera: Miridae]	Mirid bug	MAFNZ (2002b)	Yes* (Cassis and Gross, 2002a)	Not likely Feeds on leafy vegetables. It has been recorded on beans, lucerne, maize, turnips, kumara, curcurbits and pasture (MAFNZ, 2002b)	-	-	No
Hemiberlesia lataniae (Signoret) [Hemiptera: Diaspididae]	Lataniae scale	MAFNZ (2000b)	Yes (CABI, 2005)	-	-	-	No
Hemiberlesia rapax (Comstock) [Hemiptera: Diaspididae]	Greedy scale	MAFNZ (2000b)	Yes (CSIRO/DAFF, 2005)	-	-	-	No
Icerya purchasi Maskell [Hemiptera: Margarodidae]	Cottony cushion scale	Spiller and Wise (1982)	Yes (CSIRO/DAFF, 2005)	-	-	-	No

Scientific name	Common name/s	Reference for presence in New Zealand	Presence in Australia Reference	Potential for being on mature apple fruit Comments if applicable	Potential for establishment or spread	Potential for consequences Comments if applicable	Consider species further?
Lepidosaphes ulmi (L) [Hemiptera: Diaspididae]	Apple mussel scale	CABI (2005)	Yes (CSIRO/DAFF, 2005)	-	-	-	No
Lindingaspis rossi (Maskell) [Hemiptera: Diaspididae]	Ross' black scale	Spiller and Wise (1982)	Yes (CSIRO/DAFF, 2005)	-	-	-	No
Lyctocoris campestris (Fabricius) [Hemiptera: Anthocoridae]	Debris bug	Larivière (2000)	No (Cassis and Gross, 2002a)	Not likely This is a predatory bug of insects in stored grain and other stored commodities (Throne et al., 2000)	-	-	No
Macrosiphum euphorbiae (Thomas) [Hemiptera: Aphididae]	Potato aphid	MAFNZ (1999a)	Yes (CABI, 2005)	-	-	-	No
Macrosiphum rosae (L.) [Hemiptera: Aphididae]	Rose aphid	Spiller and Wise (1982)	Yes (CSIRO/DAFF, 2005)	-	-	-	No
Myzus persicae (Sulzer) [Hemiptera: Aphididae]	Green peach aphid	MAFNZ (1999a)	Yes (CABI, 2005)	-	-	-	No
Nabis kinbergii Reuter (also as *Nabis capsiformis* (Germar); however, *Nabis capsiformis* is not listed by (Larivière, 2000) as present in New Zealand, reference to *Nabis capsiformis* (Germar) in (Valentine, 1967) should be referred to *N. kinbergii* the species that has consistently been misidentified in both Australia and New Zealand as *N. capsiformis* see (Woodward, 1982); (Woodward and Strommer, 1982) [Hemiptera: Nabidae]	Nabid bug	Larivière (2000)	Yes (Cassis and Gross, 2002a); (Woodward and Strommer, 1982)	-	-	-	No
Nezara viridula (L.) [Hemiptera: Pentatomidae]	Green vegetable bug	MAFNZ (1999a)	Yes (CABI, 2005)	-	-	-	No

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Nipaecoccus aurilanatus (Maskell) (Syn. = *Pseudococcus aurilanatus* (Maskell)) [Hemiptera: Pseudococcidae]	Golden mealybug	MAFNZ (2000b)	Yes (Williams, 1985)	-	-	-	No
Nysius huttoni White [Hemiptera: Lygaeidae]	Wheat bug	MAFNZ (2000b)	No (Cassis and Gross, 2002b)	Not likely MAFNZ (2003a) indicates that this species is a contaminant of apple fruit. Wheat bug is a seed feeder on grasses and herbaceous hosts (MAFNZ, 2000b). Wheat bug is considered a quarantine pest on apples exported to the USA (Lay-Yee et al., 1997). This species was assessed as "Not likely" to have the potential for being on mature apple fruit in the present document based on the revised criteria set out in the methodology section. It is treated as contaminant and will be dealt with based on the approach described in the pest risk management section	-	-	No (was yes in the last revised draft IRA but see method section for the revised criteria for being on the pathway)
Oechalia schellenbergii Guérin-Meneville [Hemiptera: Pentatomidae]	Predatory shield bug	Larivière (2000)	Yes (CSIRO/DAFF, 2005)	-	-	-	No
Orius vicinus Ribaut [Hemiptera: Anthocoridae]	Anthocorid bug	HortResearch (1999b)	No (Cassis and Gross, 2002a)	Not likely HortResearch (1999b) indicates that this large predatory bug was discovered in Otago in 1992 and has since been found in Canterbury; it feeds on a wide variety of insects and mites, including European red mite, twospotted spider mite, rust mites, aphids, and Froggatt's apple leafhopper. It is considered packing house processes would eliminate it	-	-	No
Pachybrachius inornatus (Walker) (as *Remaudiereana inornatus* in (MAFNZ, 2000b)) [Hemiptera: Lygaeidae]	Weed seed bug	MAFNZ (2000b)	Yes* (AQIS, 1998a)	Not likely Adults are orchard or packing house contaminants, seed feeder on herbaceous hosts (MAFNZ, 2000b)	-	-	No

Scientific name	Common name/s	Reference for presence in New Zealand	Presence in Australia Reference	Potential for being on mature apple fruit Comments if applicable	Potential for establishment or spread	Potential for consequences Comments if applicable	Consider species further?
Paracoccus cavaticus Cox [Hemiptera: Pseudococcidae]	Mealy bug	MAFNZ (2000b)	No (Ben-Dov and German, 2002b)	Not likely It is not clear why this species is listed as having pest status on apple fruit (potential primary); it is normally found on bark and cracks on woody stems of native hosts. This species was listed in the *Draft import risk analysis on the importation of apples (*Malus x domestica *Borkh.) from New Zealand* (BA, 2000) but further investigation of the reference cited (Cox, 1987) indicates that apple is not listed as its host	-	-	No
Paracoccus glaucus (Maskell) (Syn. = *Pseudococcus glaucus*) [Hemiptera: Pseudococcidae]	Mealybug	Spiller and Wise (1982); Cox (1987)	No (Ben-Dov and German, 2002c)	Not likely Occurs on undersides of leaves (Cox, 1987; Spiller and Wise, 1982)	-	-	No
Paracoccus sp. nr. *cavaticus* [Hemiptera: Pseudococcidae]	Mealy bug		Uncertain	Not likely It is most likely not on pathway because *P. cavaticus*, a species closely related to *Paracoccus* sp. nr *cavaticus*, is normally found on bark and cracks on woody stems of native hosts (MAFNZ, 1999a)	-	-	No
Parlatoria desolator McKenzie (All records of *Parlatoria pergandii* Comstock in New Zealand actually refer to *P. desolator* (Charles and Henderson, 2002) [Hemiptera: Diaspididae]	Diaspidid scale	McKenzie (1960)	No (Miller and Gimpel, 2002a)	Not likely Specimens occur on stems of host (McKenzie, 1960)	-	-	No
Parlatoria pittospori Maskell (Reference of *Parlatoria camelliae* Comstock on apple in (Spiller and Wise, 1982) should be referred to *P. pittospori* Maskell, no other reference of *P. camelliae* in New Zealand (Henderson, 2000) [Hemiptera: Diaspididae]	Mauve pittosporum scale	HortResearch (1999b)	Yes (CSIRO/DAFF, 2005)	-	-	-	No

Scientific name	**Common name/s**	**Reference for presence in New Zealand**	**Presence in Australia Reference**	**Potential for being on mature apple fruit Comments if applicable**	**Potential for establishment or spread**	**Potential for consequences Comments if applicable**	**Consider species further?**
Parthenolecanium corni (Bouché) [Hemiptera: Coccidae]	Brown scale, Plum scale	Ben-Dov (1993); Hodgson and Henderson (2000)	Yes* (CSIRO/DAFF, 2005)	Not likely This soft scale sucks plant juices from leaves and twigs. They settle mostly on the underside of leaves, especially along the veins during spring moving back to the twigs in autumn (Henderson, 2001)	-	-	No
Phenacoccus graminicola Leonardi [Hemiptera: Pseudococcidae]	Mealybug	Cox (1987)	Yes (Williams, 1985)	-	-	-	No
Philaenus spumarius L. [Hemiptera: Cercopidae]	Spittle bug	Larivière (2000)	No (Fletcher, 1998)	Not likely Spittle bugs do not feed on apples or pears but are sometimes seen feeding on the shoots and stems. Nymphs produce spittle (thick foam) masses on their host plants in which they hide (CABI, 2005)	-	-	No
Phylloxera sp. [Hemiptera: Phylloxeridae]	Gall phylloxera	MAFNZ (2000b)	Uncertain	Not likely Only the oak leaf phylloxera *P. glabra* (von Heyden) is recorded in New Zealand (MAFNZ, 2000b)	-	-	No
Planococcus mali Ezzat & McConnell [Hemiptera: Pseudococcidae]	Mealybug	MAFNZ (2000b)	Yes* (Williams, 1985)	Likely Two specimens were intercepted in New York on apple fruit from Tasmania in 1946 (Ezzat and McConnell, 1956). It has also been recorded on apple (*Malus pumila*) in New Zealand (Cox, 1987)	Feasible	Significant Reported as a pest of blackcurrants in New Zealand (Cox, 1989)	Yes*
Plinthisus spp. [Hemiptera: Lygaeidae]	Seed bug	MAFNZ (2000b)	Uncertain	Not likely Adults are orchard or packing house contaminants, seed feeder on herbaceous hosts (MAFNZ, 2000b)	-	-	No
Ploiaria antipoda (Bergroth) [Hemiptera: Reduviidae]	Fragile assassin bug	Larivière (2000)	No (Cassis and Gross, 2002a)	Not likely Adults are mostly generalist predators in gardens and fields	-	-	No

Scientific name	Common name/s	Reference for presence in New Zealand	Presence in Australia Reference	Potential for being on mature apple fruit Comments if applicable	Potential for establishment or spread	Potential for consequences Comments if applicable	Consider species further?
Pseudococcidae species [Hemiptera: Pseudococcidae]	Mealybugs	MAFNZ (2000b)	No Nine species of mealybug are known from apple of which six species are known from Australia and three *Paracoccus* are not from Australia see next column for details	Not likely In the *Draft import risk analysis on the importation of apples (*Malus x domestica *Borkh.) from New Zealand* (BA, 2000), 'Pseudococcidae species' was considered further and a full risk assessment was undertaken. However, in its submission on the draft IRA, New Zealand Government provided clarification about the reference to 'Pseudococcidae species' in their list. The following are excerpts from their response (HAL, 2000): "Appendix 1 of the draft IRA lists all pest species known to be associated with apple in New Zealand (table 15). Included in this list are 10 species of the family Pseudococcidae. Of these, six species are considered by AFFA to be present in the entry pathway and therefore of quarantine interest. However, all six species are already established in Australia and are therefore not of concern. "The apple pest list includes a Pseudococcidae sp. record but this is almost certainly one of the 10 species mentioned specifically elsewhere in the pest list. MAF has in place an official surveillance system for mealybugs as part of USDA pre-clearance program. In this program adult pseudococcids are identified to species level to monitor any changes in the mealy bug species complex (as USDA do not require immature mealybugs to be identified). This surveillance data provides evidence to support our contention that all mealybugs on apple fruit are those listed on the apple pest list." Further assessment of the available information clearly supports New Zealand's statements. The nine identified species of mealybugs on apple in New Zealand are: *Paracoccus cavaticus, Paracoccus glaucus,* and *Paracoccus* sp. near *cavaticus*, *Phenacoccus graminicola, Planococcus mali* and *Pseudococcus calceolariae, Pseudococcus longispinus, Pseudococcus similans,* and *Pseudococcus viburni*. The three species of *Paracoccus* are not reported from Australia but they attack only leaves and are not found on fruit and therefore not likely on pathway. The other six species found on fruit belonging to the genera *Phenacoccus, Planococcus* and *Pseudococcus* are all present in Australia. Also, (MAFNZ, 2000b) state Pseudococcidae is a one-off record, citing the book 'Insects of Australia' (CSIRO, 1970) as reference From the above evidence, it is justifiable to remove 'Pseudococcidae species' from further consideration in this analysis.	-	-	No

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Pseudococcus calceolariae (Maskell) [Hemiptera: Pseudococcidae] (*Pseudococcus similans* (Lidgett) listed in (MAFNZ, 2000b) is now a junior synonym of *Pseudocuccus calceolariae* (Maskell) (Charles et al., 2000)	Citrophilus mealybug	MAFNZ (2000b)	Yes* (Ben-Dov and German, 2002a)	Likely Can be on citrus and apple fruit; occurring on the aerial parts of the host-plant (Cox, 1987)	Feasible	Significant This is a highly polyphagous species, reported as a pest of citrus and grapevines (CABI, 2002)	Yes*
Pseudococcus longispinus (Targioni-Tozzetti) [Hemiptera: Pseudococcidae]	Long-tailed mealybug	MAFNZ (2000b)	Yes (Ben-Dov and German, 2002d)	-	-	-	No
Pseudococcus viburni (Signoret) (Syn. = *P. affinis*) [Hemiptera: Pseudococcidae]	Obscure mealybug	MAFNZ (2000b)	Yes (AQIS, 1998a)	-	-	-	No
Rhopalosiphum insertum (Walker) [Hemiptera: Aphididae]	apple-grass aphid	CABI (2005)	Uncertain As yes in (Ridland and Carver, 1987) quoted in hide (CABI, 2005), as Uncertain in (CSIRO/DAFF, 2005)	Not likely The species is found on leaves, stems, roots, and growing points (CABI, 2005)	-	-	No
Rhopalosiphum padi (Linnaeus) [Hemiptera: Aphididae]	Cereal aphid	MAFNZ (2002b)	Yes (CSIRO/DAFF, 2005)	-	-	-	No
Rhypodes clavicornis (F) [Hemiptera: Lygaeidae]	Seed bug	MAFNZ (2000b)	No	Not likely Adults are orchard or packing house contaminants, seed feeder on herbaceous hosts (MAFNZ, 2000b)	-	-	No
Rhypodes serricatus Usinger [Hemiptera: Lygaeidae]	Seed bug	MAFNZ (2000b)	No	Not likely Adults are orchard or packing house contaminants, seed feeder on herbaceous hosts (MAFNZ, 2000b)	-	-	No
Saissetia oleae (Olivier) [Hemiptera: Coccidae]	Black scale	CABI (2005)	Yes (CSIRO/DAFF, 2005)	-	-	-	No

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Scolypopa australis (Walker) [Hemiptera: Ricaniidae]	Passionvine leafhopper	MAFNZ (1999a)	Yes (CSIRO/DAFF, 2005)	-	-	-	No
Sejanus albisignatus (Knight) (Syn. = *Idatiella albisignata*) [Hemiptera: Miridae]	Mirid bug	Collyer (1976)	Yes (Cassis and Gross, 1995)	-	-	-	No
Sidnia kinbergi (Stål) (Syn. = *Eurystylus australis*) [Hemiptera: Miridae]	Mirid bug	Larivière (2000)	Yes (Cassis and Gross, 2002a)	-	-	-	No
Siphanta acuta (Walker) [Hemiptera: Faltidae]	Green plant hopper	MAFNZ (2000b)	Yes (CSIRO/DAFF, 2005)	-	-	-	No
Therioaphis trifolii (Monell) form *maculata* [Hemiptera: Aphididae]	Spotted alfalfa aphid	MAFNZ (2002b)	Yes (CSIRO/DAFF, 2005)	-	-	-	No
Insects - Hymenoptera							
Adelius sp. [Hymenoptera: Braconidae]	Braconid parasitic wasp	Valentine (1967)	Uncertain	Not likely Valentine (1967) listed the Brownheaded leafroller *Ctenopseutis obliquana* as host species of this parasitic wasp. However, there is no recent record of this species in HortResearch (1999b), indicating the wasp is either no longer found or is unimportant in apple orchards in New Zealand. It is therefore unlikely that the wasp will be on the pathway	-	-	No
Apanteles tasmanicus Carneron [Hymenoptera: Braconidae]	Leafroller parasite	MAFNZ (2000b)	Yes (AQIS, 1998a), (Clunie and Berry, 2002)	-	-	-	No
Aphelinus abdominalis (Dalman) [Hymenoptera: Aphelinidae]	Aphelinid parasitic wasp	HortResearch (1999b)	Yes (Waterhouse and Sands, 2001:115)	-	-	-	No
Aphelinus mali (Haldeman) [Hymenoptera: Aphelinidae]	Aphelinid parasitic wasp	Wearing and Thomas (1978)	Yes (CABI, 2005)	-	-	-	No

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Aphytis chilensis Howard [Hymenoptera: Aphelinidae]	Aphelinid parasitic wasp	HortResearch (1999b)	Yes (Waterhouse and Sands, 2001:194); (Rosen and De Bach, 1979:352)	-	-	-	No
Aphytis chrysomphali (Mercet) [Hymenoptera: Aphelinidae]	Red scale parasite	Valentine (1967)	Yes (CSIRO/DAFF, 2005)	-	-	-	No
Aphytis diaspidis (Howard) [Hymenoptera: Aphelinidae]	Aphelinid parasitic wasp	HortResearch (1999b)	Yes (Waterhouse and Sands, 2001:178)	-	-	-	No
Aphytis mytilaspidis (Le Baron) [Hymenoptera: Aphelinidae]	Aphelinid parasitic wasp	HortResearch (1999b)	No (Rosen and De Bach, 1979:464)	Likely This parasitic wasp is widespread and frequent in armoured scale populations of various species throughout New Zealand. Its preferred armoured scale host is the mussel scale, *Lepidosaphes ulmi* (HortResearch, 1999b). Mussel scale is found on fruit as well as the bark and stems of apple trees. Fruit infection by this scale is not confined to the calyx or stem end and is frequently all over the surface, accompanied by fruit discolouration (HortResearch, 1999b)	Feasible	Not significant As this wasp is used as a biocontrol agent against pest armoured scales (HortResearch, 1999b) and these pests are also present in Australia, it is expected that the wasp would not have a negative impact in Australia	No

Scientific name	Common name/s	Reference for presence in New Zealand	Presence in Australia Reference	Potential for being on mature apple fruit Comments if applicable	Potential for establishment or spread	Potential for consequences Comments if applicable	Consider species further?
Ascogaster quadridentata Wesmael [Hymenoptera: Braconidae]	Braconid parasitic wasp	Valentine (1967)	No Introduced but failed to establish (Waterhouse and Sands, 2001:362)	Not Likely *Cydia pomonella* listed as host species. This wasp lays its eggs individually in codling moth eggs. After hatching the codling moth caterpillar completes its development in the fruit and overwinters under the bark. The adult parasitoid wasp does not emerge until the following spring, having taken a full year to develop within the codling moth caterpillar. As a result of its slow development, this wasp does not protect the fruit from damage and its benefit is in reducing codling moth populations long-term. Although this parasitoid can survive in organic and IFP orchards, the codling moth populations should be too low for it to be important. It is considered that this wasp is unlikely to be on the pathway because (1) orchards designated for export will have very low populations of codling moth as stated above, (2) not every codling moth will be parasited, and (3) fruit infested by codling moth will likely be removed from export	-	-	No
Aspicolpus hudsoni Turner (misspelt as *Apsicolpus*) [Hymenoptera: Braconidae]	Braconid parasitic wasp	Wang and Shi (1999)	No (Shenefelt, 1970)	Not likely Parasitoid of lemon tree borer *Oemona hirta* that bores in the trunk and branches of its host tree often damaging the framework of the host tree (Clearwater, 1989)	-	-	No
Caliroa cerasi (L.) [Hymenoptera: Tenthredinidae]	Cherryslug, pear slug sawfly	MAFNZ (1999a)	Yes (CABI, 2005)	-	-	-	No
Campoplex sp. [Hymenoptera: Ichneumonidae]	Ichneumonid parasitic wasp	Wang and Shi (1999)	Uncertain	Not likely Parasitoid of lemon tree borer *Oemona hirta* that bores in the trunk and branches of its host tree often damaging the framework of the host tree (Clearwater, 1989)	-	-	No
Coccophagus gurneyi Compere [Hymenoptera: Aphelinidae]	Aphelinid parasitic wasp	HortResearch (1999b)	Yes (Waterhouse and Sands, 2001:228)	-	-	-	No
Coccophagus ochraceus Howard [Hymenoptera: Aphelinidae]	Aphelinid parasitic wasp	Valentine (1967)	Yes (Waterhouse and Sands, 2001:161)	-	-	-	No
Coccophagus scutellaris (Dalman) [Hymenoptera: Aphelinidae]	Aphelinid parasitic wasp	Valentine (1967)	Yes (Waterhouse and Sands, 2001:168)	-	-	-	No

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Cotesia ruficrus (Haliday) (Syn. = *Apanteles ruficrus*) [Hymenoptera: Braconidae]	Braconid parasitic wasp	Valentine (1967)	Yes (Waterhouse and Sands, 2001:354); (Austin and Dangerfield, 1992:22)	-	-	-	No
Diadegma sp. [Hymenoptera: Ichneumonidae]	Ichneumonid parasitic wasp	HortResearch (1999b)	Uncertain	Not Likely This wasp parasitises a very small percentage of brownheaded leafroller, greenheaded leafroller or light brown apple moths in orchards (HortResearch, 1999b). Since only a small percentage of the host leafroller caterpillars will be found on fruit, it is considered unlikely that this wasp would be on the pathway	-	-	No
Diplazon laetatorius (Fabricius) [Hymenoptera: Ichneumonidae]	Ichneumonid parasitic wasp	HortResearch (1999b)	Yes (Waterhouse and Sands, 2001:262, 401)	-	-	-	No
Dolichogenidea sicaria (Marshall) (Syn. = *Apanteles sicarius*) [Hymenoptera: Braconidae]	Braconid parasitic wasp	Valentine (1967) This species was incorrectly reported and is not known from Australasian Region (Valentine and Walker, 1991)	No (Valentine and Walker, 1991)	-	-	-	No
Echthromorpha intricatoria (Fabricius) (misspelt as *Ecthromorpha intricatoria*) [Hymenoptera: Ichneumonidae]	Ichneumonid parasitic wasp	Valentine (1967)	Yes (CSIRO/DAFF, 2005)	-	-	-	No
Encarsia citrina (Craw) (Syn. = *Aspidiotiphagus citrinus*) [Hymenoptera: Aphelinidae]	Aphelinid parasitic wasp	HortResearch (1999b)	Yes (Astridge and Elder, 2000)	-	-	-	No

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Encarsia perniciosa (Tower) (Syn. = *Prospaltella perniciosa*) [Hymenoptera: Aphelinidae]	Red scale parasite	HortResearch (1999b)	Yes (CSIRO/DAFF, 2005)	-	-	-	No
Epitetracnemus intersectus (Fonscolombe) (Syn. = *Anabrolepis zetterstedtii*) [Hymenoptera: Encyrtidae]	Encrytid parasitic wasp	Valentine (1967)	No (Noyes, 2003)	Not likely This species is a parasitoid of Mussel scale, San Jose scale and Oystershell scale. However, the importance of *Epitetracnemus zetterstedtii* in control of these scales in New Zealand is unknown but it has been rarely reported (HortResearch, 1999b). Based on this evidence, it is considered that this parasitoid is unlikely to be on the pathway	-	-	No
Eupsenella sp. [Hymenoptera: Bethylidae]	Bethylid parasitic wasp	Berry (1998)	Yes introduced into New Zealand from Australia see (Berry, 1998)	-	-	-	No
Eupteromalus sp. [Hymenoptera: Pteromalidae]	Pteromalid parasitic wasp	Valentine (1967)	Uncertain	Not likely Valentine (1967) listed the Light brown apple moth, *Epiphyas postvittana,* as a host species of this parasitoid. However, there is no recent record of this species in HortResearch (1999b), indicating the wasp is either no longer found or is unimportant in apple orchards in New Zealand. It is therefore unlikely that the wasp will be on the pathway	-	-	No
Euxanthellus philippiae Silvestri [Hymenoptera: Aphelinidae]	Aphelinid parasitic wasp	HortResearch (1999b)	No Introduced into NSW but failed to establish (Waterhouse and Sands, 2001:148)	Not likely The host species *Coccus hesperidum* is found on stems, leaves and green twigs where they are associated with veins (Copland and Ibrahim, 1985)	-	-	No

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Glabridorsum stokesii (Cameron) (misspelt as *Glabridorsum stokesi*) [Hymenoptera: Ichneumonidae]	Ichneumonid parasitic wasp	HortResearch (1999b)	Yes (Waterhouse and Sands, 2001:361); (Townes et al., 1961); (Yu and Horstmann, 1997a:248)	-	-	-	No
Goniozus sp. [Hymenoptera: Bethylidae]	Bethylid parasitic wasp	Berry (1998)	Yes introduced into New Zealand from Australia see (Berry, 1998)	-	-	-	No
Liotryphon caudatus (Ratzeburg) (Syn. = *Apistephialtes caudatus*) [Hymenoptera: Ichneumonidae]	Ichneumonid parasitic wasp	HortResearch (1999b)	No (Yu and Horstmann, 1997b)	Not likely A parasitoid of codling moth *Cydia pomonella* introduced to New Zealand and reported from Hawke's Bay northwards. Only a very small percentage of codling moth caterpillars are attacked by this wasp, which is only rarely reported (HortResearch, 1999b). Based on this evidence it is considered that *Liotryphon caudatus* is unlikely to be on the pathway	-	-	No
Metaphycus claviger (Timberlake) (misspelt as *Metaphychus claviger*) [Hymenoptera: Encyrtidae]	Encrytid parasitic wasp	Noyes (1988)	Yes (Noyes, 1988)	-	-	-	No
Meteorus pulchricornis (Wesmael) [Hymenoptera: Braconidae]	Braconid parasitic wasp	Berry (1997); HortResearch (1999b)	No (Huddleston, 1983), (Stevens et al., 2000)	Not likely This species is a parasitoid of several families of Lepidoptea including Tortricidae and Noctuidae. Light brown apple moth is also a host (Berry, 1997). When feeding on fruit, larvae of Noctuidae usually chew on the surface, also only a small percentage of Light brown apple moth larvae will bore into the fruit and these are not likely to be parasited by this wasp. It is therefore considered that this wasp is unlikely to be on the pathway	-	-	No

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Monomorium antarcticum (Smith) (Syn. = *Chelaner antarcticum* [Hymenoptera: Formicidae]	Southern ant	MAFNZ (2000b)	No (Shattuck and Barnett, 1999)	Not likely orchard or packing house contaminant (adult life stage) contaminant/ general scavenger (MAFNZ, 2000b). This species was assessed as "Not likely" to have the potential for being on mature apple fruit in the present document based on the revised criteria set out in the methodology section. It is treated as contaminant and will be dealt with based on the approach described in the pest risk management section	-	-	No
Phyllacteophaga froggatti Rick [Hymenoptera: Pergidae]	Leafblister sawfly	MAFNZ (2002b)	Yes (CSIRO/DAFF, 2005)	-	-	-	No
Platygaster demades (Walker) [Hymenoptera: Platygasteridae]	Platygasterid parasitic wasp	HortResearch (1999b), Tomkins et al. (2000)	No (Vlug, 1995)	Likely Parasitoid of apple leafcurling midge *Dasineura mali*. Mature larvae and pupae of the apple leafcurling midge can be found in calyx (Tomkins et al., 2000)	Feasible	Not significant This wasp is a biocontrol agent for both pear leafcurling midge and apple leafcurling midge in New Zealand (HortResearch, 1999b). It would have a positive impact because it would attack pear leafcurling midge if introduced into Australia	No
Signiphora merceti Malenotti (misspelt as *mercati*) [Hymenoptera: Signiphoridae]	Signiphorid wasp	Blank et al. (1995)	No (Noyes, 2003)	Not likely Parasitoid of greedy scale *Hemiberlesia rapax*. In New Zealand the host Greedy scale is present in most North Island regions, and so far has been found as far south as Canterbury. Greedy scale is a continual pest on kiwifruit and feijoas, and an infrequent pest on apples, figs, quinces, pears, and peaches (HortResearch, 1999b)	-	-	No

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Sympiesis sp. [Hymenoptera: Eulophidae]	Eulophid parasitic wasp	HortResearch (1999b)	Uncertain	Not likely Several of these eulophid wasps are produced from a single leafroller caterpillar. Even in unsprayed or organic apple orchards a very small percentage of leafrollers (< 3%) are found to be parasitised by these wasps (HortResearch, 1999b). Since there are very few caterpillars found on apple fruit and less than 3% are parasitised it is considered that this wasp is unlikely to be on the pathway	-	-	No
Tetracnemoidea peregrina (Compère) (Syn. = *Hungariella peregrina*) [Hymenoptera: Encyrtidae]	Encrytid parasitic wasp	HortResearch (1999b)	Yes (Waterhouse and Sands, 2001:233, 235)	-	-	-	No
Tetracnemoidea sp. (Syn. = *Hungariella* sp.) [Hymenoptera: Encyrtidae]	Encrytid parasitic wasp	Valentine (1967)	Uncertain	Not likely *Nipaecoccus aurilanatus* listed as host species, which occurs on the small branches and young stems of its host plants (Ben-Dov and German, 2002f)	-	-	No
Tetracnemoidea sydneyensis (Timberlake) (Syn. = *Anarhopus sydneynsis*) [Hymenoptera: Encyrtidae]	Encyrtid parasitic wasp	HortResearch (1999b)	Yes* (Wilson, 1960)	Likely *Tetracnemoidea sydneyensis* (Timberlake) appears to be a recent and accidental introduction and was first recorded in New Zealand in 1962. It originates from Australia. In a survey of mealybug natural enemies from 1990-92, this species was recorded in all regions surveyed, from Northland to Hawke's Bay, but always from longtailed mealybugs. It was present on citrus, persimmon, and grapes, and may be expected also to occur on longtailed mealybugs attacking pipfruit (HortResearch, 1999b)	Feasible	Not significant This wasp is a biocontrol agent of longtailed mealybug in New Zealand (HortResearch, 1999b). It would have a positive impact because it would attack longtailed mealybug if introduced into Australia	No
Theocolax formiciformis Westwood [Hymenoptera: Pteromalidae]	Parasitic wasp	MAFNZ (2000b)	Yes (Noyes, 2003)	-	-	-	No
Trichogrammanza funiculatum Carver [Hymenoptera: Trichogrammatidae]	Trichogrammatid parasitic wasp	Stevens (2000)	Yes (Carver, 1978); (Oatman and Pinto, 1987)	-	-	-	No

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Trichogrammatoidea bactrae Nagaraja [Hymenoptera: Trichogrammatidae]	Trichogrammatid parasitic wasp	Stevens (2000)	Yes (Scholz, 1997); (HAL, 2000); (Waterhouse and Sands, 2001:375); (BioResources Pty. Ltd., 2002a)	-	-	-	No
Trissolcus basalis (Wollaston) (Syn. = *Asolcus basalis*) [Hymenoptera: Scelionidae]	Scelionid parasitic wasp	Valentine (1967)	Yes (CSIRO/DAFF, 2005); (Waterhouse and Sands, 2001:207)	-	-	-	No
Vespula germanica (Fabricius) [Hymenoptera: Vespoidea]	European wasp	HortResearch (1999b)	Yes* (CSIRO/DAFF, 2005)	Not likely The European wasp is a general predator that feeds on a variety of insects and damages fruit (Spradbery, 1973)	-	-	No
Xanthocryptus novozelandicus (Dalla Torre) [Hymenoptera: Ichneumonidae]	Ichneumonid parasitic wasp	HortResearch (1999b)	Yes (Townes et al., 1961); (Yu and Horstmann, 1997a)	-	-	-	No
Xanthopimpla rhopaloceros (Krieger) [Hymenoptera: Ichneumonidae]	Ichneumonid parasitoid	Munro (1998)	Yes (Munro, 1998)	-	-	-	No
Insects - Lepidoptera							
Aenetus virescens (Doubleday) [Lepidoptera: Hepialidae]	Puriri moth	MAFNZ (1999a)	No (Nielsen et al., 1996)	Not likely Record is of larva boring into trunks of apple; attacks a wide range of native hosts, and some introduced hosts (MAFNZ, 1999a; DAFF-PDI, 2002)	-	-	No
Agonopterix alstroemeriana (Clerck) [Lepidoptera: Oecophoridae]	Hemlock moth	MAFNZ (2000b)	No (Nielsen et al., 1996)	Not likely Adults are packing house contaminants and larvae feed on hemlock (weed in orchard), (MAFNZ, 2000b)	-	-	No
Agrotis ipsilon (Hufnagel) (as *A. ipsilon aneituma* (Walker) in (MAFNZ, 2000b) [Lepidoptera: Noctuidae]	Greasy cutworm	MAFNZ (2000b)	Yes (Nielsen et al., 1996)	-	-	-	No

Scientific name	Common name/s	Reference for presence in New Zealand	Presence in Australia Reference	Potential for being on mature apple fruit Comments if applicable	Potential for establishment or spread	Potential for consequences Comments if applicable	Consider species further?
Capua semiferana (Walker) [Lepidoptera: Tortricidae]	Leafroller	MAFNZ (2000b)	No (Nielsen et al., 1996)	Not likely This species has been reported as infesting fruit on two properties in Nelson (MAFNZ, 2002a). BA sought further information and clarification with New Zealand MAF. MAFNZ (2003a) responded that this species "feeds on dried organic matter, for example, dried seed heads of weeds, etc., occasionally found round the calyx of apple fruit". Further information was provided in a subsequent email after MAF consulted with entomologists John Dougdale, a lepidopterist, and Jim Walker, apple entomologist of HortResearch. The email states: "It has only occasionally been found on apples - the last I [John Dougdale] knew of was in Nelson about 5 years ago. It is very uncommon for it to infest apples and these events (as we re-call) were associated with a wet season, rank understorey vegetation and low branching trees. In this situation a few infested fruit were found where larvae had moved on to fruit. These infestations were found either on the stem or calyx of the fruit and are actually quite rare. Infestation could be more likely found around the old floral parts in the calyx - but it has to be considered as a rare and uncommon occurrence under normal orchard management. "Normal orchard management (mowing) and insect control within the sector's IFP programmes should ensure that these events remain classified as rare or very infrequent."	-	-	No
Chrysodeixis eriosoma (Doubleday) [Lepidoptera: Noctuidae]	Green looper	MAFNZ (2000b)	Yes (Nielsen et al., 1996)	-	-	-	No
Cleora scriptaria (Walker) [Lepidoptera: Geometridae]	Geometrid moth	MAFNZ (2000b)	No (Nielsen et al., 1996)	Not likely Adults are packing house contaminants and have "habit of resting with outstretched wings on walls of sheds and other buildings; larvae feed on a great variety of shrubs", causing damage to pepper tree 'Kawakawa' *Macropiper excelsum* (Hodge et al., 1998), No records of larva feeding in apple fruit (MAFNZ, 2000b)	-	-	No

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'Cnephasia' jactatana (Walker) [Lepidoptera: Tortricidae]	Black lyre moth	MAFNZ (2000b); Hoare (2000a)	No (Nielsen et al., 1996)	Not likely There are no published records of this species feeding on apple. However, Hoare (2000b) indicates that "it is a highly polyphagous species, which is likely to feed on apple occasionally". However, clarification was sought from New Zealand about the species' status on apple. MAFNZ (2003c) replied: "this species is recorded only from citrus, kiwifruit and nectarine (once). It has no status as a pest of apple." and there have been "0 interceptions on apple exports to the USA over the last 10 years."	-	-	No
Ctenopseustis herana (Feld. & Rogen.) [Lepidoptera: Tortricidae]	Brownheaded leafroller	MAFNZ (2000b)	No (Nielsen et al., 1996)	Likely Apples and other fruits may suffer considerable internal damage, and larvae eject frass (droppings) outside the fruit or protective shelter (Thomas, 1979)	Feasible	Significant Naturally polyphagous, primary orchard pest in New Zealand (Dugdale, 1990); (Wearing et al., 1991)	Yes
Ctenopseustis obliquana (Walker) [Lepidoptera: Tortricidae]	Brownheaded leafroller	MAFNZ (2000b)	No (Nielsen et al., 1996)	Likely Apples and other fruits may suffer considerable internal damage, and larvae eject frass (droppings) outside the fruit or protective shelter (Thomas, 1979)	Feasible	Significant Naturally polyphagous, primary orchard pest in New Zealand (Dugdale, 1990); (Wearing et al., 1991)	Yes
Cydia pomonella (L) [Lepidoptera: Tortricidae]	Codling moth	MAFNZ (2000b)	Yes* (CSIRO/DAFF, 2005)	Likely Codling moth larvae cause important damage that is confined to the fruit (Wearing, 1998)	Feasible	Significant Major pest of apple worldwide (CABI, 2002)	Yes*
Diasemia grammalis Doubleday [Lepidoptera: Pyralidae]	Pyralid moth	MAFNZ (2000b)	No (Nielsen et al., 1996)	Not likely Adults are orchard or packing house contaminants, larvae feed on native grasses and herbaceous spp. (MAFNZ, 2000b)	-	-	No
Elachista sp. [Lepidoptera: Elashistidae]	Grass miner moth	MAFNZ (2000b)	Uncertain	Not likely Associated with grasses (MAFNZ, 2000b)	-	-	No
Endrosis sarcitrella (L.) [Lepidoptera: Oecophoridae]	White shouldered house moth	MAFNZ (2000b)	Yes (CSIRO/DAFF, 2005)	-	-	-	No

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Ephestia elutella (Hübner) [Lepidoptera: Pyralidae]	Tobacco moth	MAFNZ (2000b)	Yes (CSIRO/DAFF, 2005)	-	-	-	No
Epiphyas postvittana (Walker) [Lepidoptera: Tortricidae]	Lightbrown apple moth	MAFNZ (2000b)	Yes (CSIRO/DAFF, 2005)	-	-	-	No
Epyaxa rosearia (Doubleday) [Lepidoptera: Geometridae]	Native looper	MAFNZ (2002b)	No (Nielsen et al., 1996)	Not likely Very minor plant feeder; biology, including host species, not well known (MAFNZ, 2002b). Apparently only feeds on leaves since this species has been reported as a most significant defoliating insect on Caucasian clover (Watson et al., 1996)	-	-	No
Eudonia paltomacha (Meyrick) [Lepidoptera: Pyralidae]	Sod webworm	MAFNZ (2000b)	No (Nielsen et al., 1996)	Not likely Adults are orchard or packing house contaminants, larvae feed on grasses and herbaceous hosts (MAFNZ, 2000b)	-	-	No
Eudonia psammitis (Meyrick) [Lepidoptera: Pyralidae]	Sod webworm	MAFNZ (2000b)	No (Nielsen et al., 1996)	Not likely Adults are orchard or packing house contaminants, larvae feed on grasses and herbaceous hosts (MAFNZ, 2000b)	-	-	No
Eudonia sp. nr. *lepatalea* Meyrick [Lepidoptera: Pyralidae]	Pyralid moth	MAFNZ (2002b)	Uncertain	Not likely Most *Eudonia* spp. feed on moss but some are grass feeders; identifier classified species as native, plant feeder status unknown (MAFNZ, 2002b)	-	-	No
Graphania lignana Walker [Lepidoptera: Noctuidae]	Cutworm moth	MAFNZ (2002b)	No (Nielsen et al., 1996)	Not likely Plant feeder. Minor plant feeder of pasture and rangeland plants (MAFNZ, 2002b)	-	-	No
Graphania mutans (Walker) [Lepidoptera: Noctuidae]	Grey brown cutworm	MAFNZ (1999a)	No (Nielsen et al., 1996)	Likely Eggs sometimes laid on fruit and larvae can feed on fruit (Landcare Research, 1999)	Feasible	Significant Most important noctuid pest in New Zealand apple orchards (Burnip et al., 1995)	Yes
Graphania sp. [Lepidoptera: Noctuidae]	Cutworm	Collyer and van Geldermalsen (1975)	Uncertain	Not likely Larvae feed on leaves and young fruit (Collyer and van Geldermalsen, 1975). There have apparently been no other records of *Graphania* sp. This species is unlikely to be on pathway because it only feeds on young fruit (Collyer and van Geldermalsen, 1975)	-	-	No
Graphania ustistriga (Walker) [Lepidoptera: Noctuidae]	Large grey cutworm moth	MAFNZ (2000b)	No (Nielsen et al., 1996)	Not likely Larvae feed on a wide range of dicotyledonous plants and *Pinus radiata* (MAFNZ, 2000b)	-	-	No

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Grapholita molesta Busck (Syn. = *Cydia molesta*) [Lepidoptera: Tortricidae]	Oriental fruit moth	MAFNZ (2000b)	Yes* (CSIRO/DAFF, 2005)	Likely Oriental fruit moth has been recorded feeding on apple fruit (CABI, 2002)	Feasible	Significant Serious international pest especially of peaches, nectarines and apricots (Rothschild and Vickers, 1991); (CABI, 2002)	Yes*
Gymnobathra parca (Butler) [Lepidoptera: Oecophoridae]	Oecophorid moth	MAFNZ (2000b)	No (Nielsen et al., 1996)	Not likely Adults are orchard or packing house contaminants, case bearing larvae feed in leaf litter (MAFNZ, 2000b)	-	-	No
Helastia corcularia Guenee [Lepidoptera: Geometridae]	Geometrid moth	MAFNZ (2000b)	No (Nielsen et al., 1996)	Not likely Adults are orchard or packing house contaminants, larvae feed in moss (MAFNZ, 2000b)	-	-	No
Helastia cryptica Craw [Lepidoptera: Geometridae]	Geometrid moth	MAFNZ (2000b)	No (Nielsen et al., 1996)	Not likely Adults are orchard or packing house contaminants, larvae feed on dead leaves (MAFNZ, 2000b)	-	-	No
Helicoverpa armigera Hubner (Syn. = *Heliothis armiger confertus* Walker in AGWEST Submission, (Matthews, 1999): 111) considers *Heliothis armiger confertus* Walker as part of *Helicoverpa armigera* Hubner [Lepidoptera: Noctuidae]	Tomato fruit worm, Corn earworm, Cotton bollworm, Tobacco budworm	MAFNZ (2000b); Spiller and Wise (1982)	Yes (CSIRO/DAFF, 2005)	-	-	-	No
Hofmannophila pseudospretella (Stainton) [Lepidoptera: Oecophoridae]	Oecophorid moth (Brown House Moth)	Spiller and Wise (1982)	Yes* (Nielsen et al., 1996)	Not likely Spiller and Wise (1982) question whether *Malus sylvestris* is a host for this species. BA sought further information about the species association with apple. MAFNZ (2003a) replied: "There are no recent records of this moth infesting the tree or fruit and no research is planned or ever been done." Based on this information, it can be concluded that this species is unlikely to be associated with apple fruit	-	-	No
Hyalophora cecropia (L.) [Lepidoptera: Saturniidae]	"Robin moth"	MAFNZ (1999a)	No (Nielsen et al., 1996)	Not likely Record is on "tree" (life stage not recorded), polyphagous (MAFNZ, 1999a)	-	-	No

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Hygraula nitens Butler [Lepidoptera: Pyralidae]	Pyralid water moth	MAFNZ (2000b)	Yes (Nielsen et al., 1996)	-	-	-	No
Leucania stenographa Lower (Syn. = *Mythimna stenographa, Leucania loreyi, Mythimna loreyimima*) [Lepidoptera: Noctuidae]	Sugarcane army worm	MAFNZ (2002b)	Yes (Nielsen et al., 1996)	-	-	-	No
Liothula omnivora Fereday [Lepidoptera: Psychidae]	Bagmoth	MAFNZ (1999a)	No (Nielsen et al., 1996)	Not likely Record on leaves, polyphagous (MAFNZ, 1999a)	-	-	No
Lyonetiidae [Lepidoptera: Lyonetiidae]	Lyonetiid moth	MAFNZ (2000b)	Uncertain	Not likely Adults are orchard or packing house contaminants, larvae can be primary on other hosts, mostly saphrophytic (MAFNZ, 2000b)	-	-	No
Mythimna separata Walker (was *Pseudaletia separata* (Walker)) [Lepidoptera: Noctuidae]	Cosmopolitan armyworm	MAFNZ (2000b)	Yes (Nielsen et al., 1996)	-	-	-	No
Opodiphthera eucalypti (Scott) [Lepidoptera: Saturniidae]	Gum emperor moth	MAFNZ (1999a)	Yes (Nielsen et al., 1996)	-	-	-	No
Opogona omoscopa (Meyrick) [Lepidoptera: Tineidae]	Detritus moth	MAFNZ (2000b)	Yes (CSIRO/DAFF, 2005)	-	-	-	No
Orocrambus spp. [Lepidoptera: Pyralidae]	Grass and moss moths	MAFNZ (2000b)	Uncertain	Not likely Adult orchard or packing house contaminants (MAFNZ, 2000b)	-	-	No
Phrissogonus laticostatus (Walker) [Lepidoptera: Geometridae]	Geometrid moth	MAFNZ (2002b)	Yes (CSIRO/DAFF, 2005)	-	-	-	No
Phthorimaea operculella Zeller [Lepidoptera: Gelechiidae]	Potato tuber moth	MAFNZ (2000b)	Yes (CABI, 2005)	-	-	-	No
Phyllonorycter messaniella (Zeller) [Lepidoptera: Gracillariidae]	Gracillariid moth	Spiller and Wise (1982); CSIRO (1991)	Yes (Nielsen et al., 1996)	-	-	-	No

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Planotortrix excessana (Walker) [Lepidoptera: Tortricidae]	Greenheaded leafroller	MAFNZ (2000b)	No (Nielsen et al., 1996)	Likely The calyx of various fruits, especially pip fruits, may be invaded by young larvae but show no external damage (Green, 1979)	Feasible	Significant Naturally polyphagous, primary orchard pest in New Zealand (Dugdale, 1990); (Wearing et al., 1991)	Yes
Planotortrix octo Dugdale [Lepidoptera: Tortricidae]	Greenheaded leafroller	MAFNZ (2000b)	No (Nielsen et al., 1996)	Likely The calyx of various fruits, especially pip fruits, may be invaded by young larvae but show no external damage (Green, 1979)	Feasible	Significant Naturally polyphagous, primary orchard pest in New Zealand (Dugdale, 1990), (Wearing et al., 1991)	Yes
Plutella xylostella (L.) [Lepidoptera: Yponomeutidae]	Diamond back moth	MAFNZ (2000b)	Yes (Nielsen et al., 1996)	-	-	-	No
Pseudocoremia suavis Butler [Lepidoptera: Geometridae]	Black-waved brown moth	MAFNZ (1999a)	No (Nielsen et al., 1996)	Not likely Record on twigs (MAFNZ, 1999a)	-	-	No
Pyralidae [Lepidoptera: Pyralidae]	Pyralid moth	MAFNZ (2000b)	Uncertain	Not likely It is most likely that this is an orchard or packing house contaminants record as the other eight records of this family listed in New Zealand are all contaminants (*Diasemia grammalis*, *Ephestia elutella*, *Eudonia paltomacha*, *Eudonia psammitis*, *Eudonia* sp. nr. *lepatalea*, *Hygraula nitens*, *Orocrambus* spp., and *Scoparia* spp.) The assessment for these eight species indicate that they are either present in Australia or have an unlikely potential for importation. Therefore, the potential for importation of this 'Pyralidae' could also be rated unlikely	-	-	No

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Pyrgotis plagiatana (Walker) [Lepidoptera: Tortricidae]	Native leafroller	MAFNZ (2000b)	No (Nielsen et al., 1996)	Likely This native leafroller species is occasionally found attacking apples and pears, particularly in Otago (HortResearch, 1999b)	Feasible	Significant Naturally polyphagous, incidental orchard pest of apples and pears in New Zealand (Wearing et al., 1991)	Yes
Scoparia spp. [Lepidoptera: Pyralidae]	Sod webworms	MAFNZ (2000b)	Uncertain	Not likely Adults are orchard or packing house contaminants, larvae feed on herbaceous and grass hosts (MAFNZ, 2000b)	-	-	No
Scopula rubraria Doubleday [Lepidoptera: Geometridae]	Common pasture moth	MAFNZ (2000b)	Yes (Nielsen et al., 1996)	-	-	-	No
Spodoptera litura (F.) [Lepidoptera: Noctuidae]	Cluster caterpillar	MAFNZ (1999a)	Yes (Nielsen et al., 1996)	-	-	-	No
Stathmopoda horticola Dugdale (as *Stathmopoda* sp. (*skelloni* auct. nec. Butler) in (AQIS, 1998a) [Lepidoptera: Oecophoridae]	Oecophorid moth (Garden Featherfoot)	Landcare Research (1999)	No (Nielsen et al., 1996)	Likely Larvae colonise calyx of the fruit feeding on the dead flower sepals; last 2 instars cause direct damage to fruit surfaces around the calyx (Scott, 1984)	Feasible	Significant Becoming a pest of kiwifruit and apples in New Zealand (Scott, 1984)	Yes
Stathmopoda plumbiflua Meyrick [Lepidoptera: Oecophoridae]	Oecophorid moth	MAFNZ (2000b)	No (Nielsen et al., 1996)	Likely Larvae feed on dying flowers and fruit (MAFNZ, 2000b)	Feasible	Not significant Larvae feed on dead and dying plant parts (Dugdale, 2000)	No
Strepsicrates macropetana (Meyrick) [Lepidoptera: Tortricidae]	Eucalyptus leafroller	MAFNZ (2000b)	Yes (CSIRO/DAFF, 2005)	-	-	-	No
Symmetrischema plaesiosema Turner (Syn. = *Symmetrischema tangolias* (Gyen)) [Lepidoptera: Gelechiidae]	Tomato stem borer	MAFNZ (2000b)	Yes (CSIRO/DAFF, 2005)	-	-	-	No

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Tachystola acroxantha Meyrick (Syn. = *Parocystola acroxantha*) [Lepidoptera: Oecophoridae]	Oecophorid moth	MAFNZ (2000b)	Yes* (Nielsen et al., 1996)	Not likely Adults are orchard or packing house contaminants, larvae feed on dead foliage and stems (MAFNZ, 2000b)	-	-	No
Tineola bissellicita (Hummel) [Lepidoptera: Tineidae]	Clothes moth	MAFNZ (2000b)	Yes (CSIRO/DAFF, 2005)	-	-	-	No
Tingena spp. [Lepidoptera: Oecophoridae]	Native litter feeding moth	MAFNZ (2000b)	Uncertain	Not likely Adults are orchard or packing house contaminants, native, feeding habits not known (MAFNZ, 2000b)	-	-	No
Tortricinae species [Lepidoptera: Tortricidae]	Leafrollers	MAFNZ (2000b)	Uncertain	Not considered further (see reason below). In the *Draft import risk analysis on the importation of apples from New Zealand* (BA, 2004), 'Tortricinae species' was considered further. However, in its submission on the draft IRA, New Zealand Government provided clarification about the reference to 'Tortricinae species' in their list. The following are excerpts from their response: "the apple fruit pest list contains records from over 20 years of export inspection records. Any members of the Tortricinae family that have been found on apple fruit have been identified to species level and are individually recorded on the apple pest list presented to AFFA." Therefore, the unidentified species of Tortricinae most likely belong to one of the species already on the list and are not considered further in this analysis	-	-	No
Insects - Neuroptera							
Cryptoscenea australiensis (Enderlein) [Neuroptera: Coniopterygidae]	Lacewings	Charles (1993)	Yes (New, 1996)	-	-	-	No
Drepanacra binocula (Newman) [Neuroptera: Hemerobiidae]	Lacewings	HortResearch (1999b)	Yes (New, 1996)	-	-	-	No

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Micromus tasmaniae (Walker) [Neuroptera: Memerobiidae]	Tasmanian lacewing	MAFNZ (2000b)	Yes (AQIS, 1998a)	-	-	-	No
Insects - Psocoptera							
Ectopsocus spp. [Psocoptera: Ectopsocidae]	Psocid/book lice	MAFNZ (2000b)	Uncertain	Likely Secondary feeders on decaying plant material (MAFNZ, 2000b). Species of this genus have been intercepted in Australia on kiwifruit and other commodities from New Zealand (DAFF-PDI, 2002)	Feasible	Not significant Secondary feeders on decaying plant material (MAFNZ, 2000b)	No
Psocoptera	Psocid/book lice	MAFNZ (2000b)	Uncertain	Likely Contaminants/secondary, associated with decaying plant material (MAFNZ, 2000b). See comments under *Ectopsocus* spp. below	Feasible	Not significant Secondary feeders on decaying plant material (MAFNZ, 2000b)	No
Insects - Thysanoptera							
Aeolothrips fasciatus (Linn.) [Thysanoptera: Aeolothripidae]	Banded thrips	HortResearch (1999b)	Yes* (Mound, 2001)	Not likely Feed incidentally on the foliage of apples (HortResearch, 1999b). On potato foliage (Cottier, 1931)	-	-	No
Apterygothrips collyerae Mound & Walker [Thysanoptera: Phlaeothripidae]	Thrips	MAFNZ (1999a)	No (Mound, 1996); (Mound, 2001)	Not Likely *Apterygothrips collyerae* is predatory on a wide range of mites (including European red mite *Panonychus ulmi* (Koch)) and other small arthropods and has only been recorded on leaves and twigs (MAFNZ, 1999a). It is therefore considered that this thrips species is unlikely to be on the pathway.(Collyer, 1976)	-	-	No
Baenothrips moundi (Stannard) [Thysanoptera: Phlaeothripidae]	Thrips	MAFNZ (2000b)	Yes (Mound, 1996); (Mound, 2001)	-	-	-	No
Frankliniella occidentalis (Pergande) [Thysanoptera: Thripidae]	Western flower thrips	CABI (2005)	Yes, official control in Tas (CSIRO/DAFF, 2005); (Mound, 2001)	Not likely CABI (2002) indicates that the species affect leaves, and inflorescence of the plants. It can be associated with apple fruit at harvest if the population and infestation is high but this is an unlikely scenario in export orchards because of pest control in IFP	-	-	No

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Haplothrips kurdjumovi Karny (Syn. = *H. faurei*) [Thysanoptera: Phlaeothripidae]	Thrips	MAFNZ (1999a)	No (Mound, 1996); (Mound, 2001)	Not likely *Haplothrips kurdjumovi* feeds on eggs of the European red mite *Panonychus ulmi*, and also on other mites and moth eggs. It has only been recorded on flowers (MAFNZ, 1999a), therefore it is considered that the species is unlikely to be on the pathway	-	-	No
Haplothrips niger (Osborn) [Thysanoptera: Phlaeothripidae]	Red clover thrips	MAFNZ (1999a)	Yes* (Mound, 1996); (Mound, 2001)	Not likely Record is on flowers, usually found on red and white clover where it is a pest, status on apple not known, probably a contaminant from ground cover clovers (MAFNZ, 1999a). Based on the above information, it is unlikely that this species will be on export apple fruit. (DAFF-PDI, 2002)	-	-	No
Heliothrips haemorrhoidalis (Bouche) [Thysanoptera: Thripidae]	Greenhouse thrips	MAFNZ (2000b)	Yes (CSIRO/DAFF, 2005); (Mound, 2001)	-	-	-	No
Limothrips cerealium (Haliday) [Thysanoptera: Thripidae]	Cereal thrips	MAFNZ (1999a)	Yes (Mound, 1996); (Mound, 2001)	-	-	-	No
Macrophthalmothrips argus (Karny) [Thysanoptera: Phlaeothripidae]	Thrips	MAFNZ (1999a)	Yes* (Mound, 1996); (Mound, 2001)	Not likely Record is on dead wood, saprophytic (MAFNZ, 1999a)	-	-	No
Merothrips brunneus Ward [Thysanoptera: Merothripidae]	Thrips	MAFNZ (1999a)	Yes* (Mound, 1996); (Mound, 2001)	Not likely Fungal feeder on dead branches (Mound, 2001)	-	-	No
Nesothrips propinquus (Bagnall) [Thysanoptera: Phlaeothripidae]	Thrips	MAFNZ (1999a)	Yes* (Mound, 1996); (Mound, 2001)	Not likely Record is on dead wood and leaves, possibly saprophytic, associated with leaf litter, bases of grasses, sedges and tussocks, bird's nests (MAFNZ, 1999a). This species was assessed as "Not likely" to have the potential for being on mature apple fruit in the present document based on the revised criteria set out in the methodology section. It is treated as contaminant and will be dealt with based on the approach described in the pest risk management section	-	-	No
Sigmothrips aotearoana (Ward) [Thysanoptera: Thripidae]	Thrips	MAFNZ (2002b)	No (Mound, 2001)	Not likely Feeds on *Coprosma*, and some *Fuchsias* (MAFNZ, 2002b)	-	-	No

Scientific name	Common name/s	Reference for presence in New Zealand	Presence in Australia Reference	Potential for being on mature apple fruit Comments if applicable	Potential for establishment or spread	Potential for consequences Comments if applicable	Consider species further?
Thrips australis (Bagnall) [Thysanoptera: Thripidae]	Eucalyptus thrips	MAFNZ (1999a)	Yes (Mound, 1996); (Mound, 2001)	-	-	-	No
Thrips obscuratus (Crawford) [Thysanoptera: Thripidae]	New Zealand flower thrips	MAFNZ (2000b)	No (Mound, 1996); (Mound, 2001)	Not likely MAFNZ (2003a) states that *Thrips obscuratus* is "not attracted to apple fruit." "It is attracted to apple blossom but leave as soon as the blossom dries off. Records exist of the pest on apple fruit but these are of accidental contamination possibly from nearby stone fruit orchards." (MAFNZ, 2003a). This species was assessed as "Not likely" to have the potential for being on mature apple fruit in the present document based on the revised criteria set out in the methodology section. It is treated as contaminant and will be dealt with based on the approach described in the pest risk management section	-	-	No (was yes in the last revised draft IRA but see the revised criteria for being on pathway)
Thrips tabaci Lindeman [Thysanoptera: Thripidae]	Onion thrips	MAFNZ (1999a)	Yes (Mound, 1996); (Mound, 2001)	-	-	-	No
Xylaplothrips sp. nr *fuliginosus* (Schille) [Thysanoptera: Phlaeothripidae]	Thrips	Collyer (1976)	Uncertain	Not likely Collyer (1976) reported that this species is a predator of European red mite (*Panonychus ulmi* (Koch)). However, there are no records of this species associated with European red mite in HortResearch (1999b) indicating that this species is not an important natural enemy of pest mites in pipfruit orchards	-	-	No
Mites							
Aculus schlechtendali (Nalepa) [Acari: Eriophyidae]	Apple rust mite	CABI (2005)	Yes (Halliday, 1998)	Not likely Found on the undersurface of leaves (Manson, 1984a)	-	-	No
Agistemus longisetus González-Rodriguez [Acari: Stigmaeidae]	Stigmaeid mite	HortResearch (1999b)	Yes (Halliday, 1998) (Halliday, 2001)	-	-	-	No
Amblyseius harrowi Collyer [Acari: Phytosiidae]	Phytoseiid mite	Schicha (1980)	Yes (Halliday, 1998)	-	-	-	No

Scientific name	Common name/s	Reference for presence in New Zealand	Presence in Australia Reference	Potential for being on mature apple fruit Comments if applicable	Potential for establishment or spread	Potential for consequences Comments if applicable	Consider species further?
Amblyseius perlongisetus (Berlese) (Syn. = *Typhlodromus perlongisetus*) [Acari: Phytoseiidae]	Phytoseiid mite	Thomas and Chapman (1978)	No (Halliday, 1998)	Not likely Thomas and Chapman (1978) listed this species as a predatory mite that fed on phytophagous mites in commercial orchards. However, HortResearch (1999b) does not record this species in the key to pipfruit pests, indicating that this species is not an important natural enemy of pest mites in pipfruit orchards. In addition Collyer (1964) recorded this mite from many plant species including apple but did not mention whether this mite was actually found on the apple fruit. Zhang (2001) has since found this mite living in very specialised niches on the leaves of capsicum	-	-	No
Anystis baccarum L. [Acari: Anystidae]	Anystid mite, whirlygig mite	MAFNZ (1999a)	Yes (Halliday, 1998)	-	-	-	No
Bdellodes oraria Atyeo [Acari: Bdellidae]	Snout mite	MAFNZ (2000b)	No (Halliday, 1998)	Not likely Predatory upon other mites and small arthropods, found in leaf litter (MAFNZ, 2000b)	-	-	No
Brevipalpus obovatus Donnadieu [Acari: Tenuipalpidae]	Tenuipalpid mite	Manson (1987)	Yes (Halliday, 1998)	Not likely This species has been recorded from apple orchards in Auckland and Nelson (Manson, 1987; Collyer, 1973b). This species feeds on the ventral surface of the leaves and on stems and petioles (Jeppson et al., 1975)	-	-	No
Bryobia graminum (Schrank) (as *B. cristata* in (Manson, 1967a) on bark) [Acari: Tetranychidae]	Clover mite	Bolland et al. (1998)	Yes* (Bolland et al., 1998); (Halliday, 1998)	Not likely These mites are found on grass, clover and weeds along roadsides as well as on azalea, *Polyanthus*, vetch, *Tradescantia* pot plant and the bark of apple, pear and European plum in New Zealand (Manson, 1967a)	-	-	No
Bryobia praetiosa Koch [Acari: Tetranychidae]	Clover mite	Bolland et al. (1998)	Yes (Bolland et al., 1998); (Halliday, 1998)	-	-	-	No
Bryobia rubrioculus (Scheuten) [Acari: Tetranychidae]	Brown mite	MAFNZ (2000b)	Yes (Halliday, 1998)	-	-	-	No
Bryobia vasiljevi Reck (as *B. repensi* (Manson, 1967a:91) on clover under apple trees) [Acari: Tetranychidae]	Pasture mite	Bolland et al. (1998)	Yes* (Bolland et al., 1998); (Halliday, 1998)	Not likely This species found on clover, vetch, strawberry and *Passiflora mollissima* and clover under apple tree (Manson, 1967a)	-	-	No

Scientific name	Common name/s	Reference for presence in New Zealand	Presence in Australia Reference	Potential for being on mature apple fruit Comments if applicable	Potential for establishment or spread	Potential for consequences Comments if applicable	Consider species further?
Calepitrimerus baileyi Keifer [Acari: Eriophyidae]	Bailey's apple rust mite	Manson (1987)	No (Halliday, 1998)	Not likely On undersurface of apple leaves (Manson, 1984a)	-	-	No
Diptacus gigantorhynchus (Nalepa) [Acari: Diptilomiopidae]	Big-beaked plum mite	Manson (1984a)	Yes* (Knihinicki, 2003)	Not likely On the undersurface of apple leaves but causing no apparent damage (Manson, 1984a). Apple (*Malus pumila*) and ornamental apple species listed as alternate hosts (CABI, 2002; Becker et al., 1992)	-	-	No
Eotetranychus sexmaculatus (Riley) [Acari: Tetranychidae]	Six spotted mite	Bolland et al. (1998)	Yes* (Bolland et al., 1998); (Halliday, 1998)	Not likely It is very likely that the mite occurs on leaves of apple because on citrus the six-spotted mite feeds primarily on the lower leaf surface. Leaves are first attacked along the petiole and the midvein. The mite lives in localized colonies on the underside of interior leaves with heavy infestations spreading to the outer canopy leaves. Eggs are deposited on the lower leaf surface (Childers and Fasulo, 1995)	-	-	No
Eriophyes mali Nalepa [Acari: Eriophyidae]	Apple blister mite	MAFNZ (2000b)	No (Halliday, 1998)	Not likely In the draft IRA, '*Eriophyes mali'* was considered further and a full risk assessment was undertaken. This was because it was considered that the species is on the pathway based on the statement by MAFNZ (2000b) that the mite is 'Occasionally on fruit'. In their submission to the draft IRA, New Zealand Government provided further clarification about this statement: "*E. mali* occurs primarily on foliage and only occasionally on fruit. In the original data sheet prepared by Landcare Research it was noted that these mites were not likely to occur on fruit. Furthermore, the pest has never been found on harvested apples during the USDA pre-clearance program that has been running for over 20 years. The record on the New Zealand pest list is one from *Malus domestica*, with no part of the plant specified. This has been left on the pest list because of the "possibility" that it may also occur on fruit" (New Zealand Government, 2000). All the published references on this mite indicate that it is only found on leaves or buds. In addition, this mite was only recorded once on *Malus pumila* in Levin, New Zealand, and there are no subsequent records of this species in other localities in New Zealand	-	-	No

Scientific name	Common name/s	Reference for presence in New Zealand	Presence in Australia Reference	Potential for being on mature apple fruit Comments if applicable	Potential for establishment or spread	Potential for consequences Comments if applicable	Consider species further?
Eryngiopus nr. *nelsonensis* [Acari: Stigmaeidae]	Stigmaeid mite	HortResearch (1999b)	No (Halliday, 1998)	Not likely A predatory stigmaeid mite that feeds on a variety of species. They can be found amongst scale insect colonies on the bark of apple and pear trees (HortResearch, 1999b)	-	-	No
Galendromus occidentalis (Nesbitt) (Syn. = *Typhlodromus* or *Metaseiulus occidentalis*) [Acari: Phytoseiidae]	Predatory mite	Thomas and Chapman (1978)	Yes (Halliday, 1998)	-	-	-	No
Hemisarcoptes coccophagus Meyer [Acari: Hemisarcoptidae]	Hemisarcoptid predatory mite	Charles et al. (1998); HortResearch (1999b)	No (Gerson, 1994); (Halliday, 1998); (Halliday, 2001)	Likely A predatory mite of diaspidid scale insects, which can be found under the scale coverings. Introduced to control armoured scale insects (Diaspididae] (Charles et al., 1998). Introduction to the North Island has been successful but unsuccessful in the South Island. San Jose Scale infests mostly the bark on the stem and branches of the tree and very occasionally on the apple fruit. Oystershell scale and Apple mussel scale however infest the whole plant including the fruit (CABI, 2005)	Feasible	Not significant As this predatory mite is used as a biocontrol agent to control pest armoured scales (HortResearch, 1999b) and these pests are also present in Australia, it is expected that the mite would not have a negative impact in Australia	No
Neoseiulus cucumeris (Oudemans) [Acari: Phytosiidae]	Phytoseiid mite	Thomas and Chapman (1978)	Yes (Beard, 1999); (Halliday, 2001)	-	-	-	No
Neoseiulus fallacis (Garman) (Syn. = *Amblyseius fallacis*) [Acari: Phytoseiidae]	Phytoseiid mite	Penman and Chapman (1980)	Yes (Halliday, 1998)	-	-	-	No
Neoseiulus womersleyi (Schicha) (Syn. = *Amblyseius longispinosus*) [Acari: Phytoseiidae]	Phytoseiid mite	Thomas and Chapman (1978)	Yes (Halliday, 1998)	-	-	-	No
Oribatid mites [Acari: Oribatidae]	Oribatid mites	HortResearch (1999b)	Uncertain	Likely These algal and fungal feeding mites can also occur at the calyx of apples at harvest time (HortResearch, 1999b)	Feasible	Not significant No reports of oribatids as pests	No

Scientific name	**Common name/s**	**Reference for presence in New Zealand**	**Presence in Australia Reference**	**Potential for being on mature apple fruit Comments if applicable**	**Potential for establishment or spread**	**Potential for consequences Comments if applicable**	**Consider species further?**
Orthotydeus californicus (Banks) [Acari: Tydeidae]	Tydeid mite	MAFNZ (1999a)	Yes (Smith et al., 1997)	-	-	-	No
Orthotydeus spp. [Acari: Tydeidae]	Tydeid mite	MAFNZ (2000b)	Uncertain	Likely Secondary scavengers on honeydew, fungi (MAFNZ, 2000b)	Feasible	Not significant Secondary scavengers on honeydew and fungi (MAFNZ, 2000b)	No
Panonychus citri (McGregor) [Acari: Tetranychidae]	Citrus red mite	Bolland et al. (1998)	Yes* (Bolland et al., 1998); (Halliday, 1998)	Not likely The citrus red mite occurs in New Zealand and (Bolland et al., 1998) list apple as its host plant. However, there is no record of this species on apple in New Zealand (MAFNZ, 2003b). Limited distribution in NSW and under quarantine control (Smith et al., 1997)	-	-	No
Panonychus ulmi (Koch) [Acari: Tetranychidae]	European red mite	MAFNZ (2000b)	Yes (Halliday, 1998)	-	-	-	No
Tenuipalpus aberrans Collyer [Acari: Tenuipalpidae]	Tenuipalpid mite	Manson (1987)	No (Halliday, 1998)	Not likely Species with limited host plant range found on leaves of *Nothofagus menziesii*, *N. fusca*, *Dacrydium bidwilli*, *Sophora tetraptera*, *Phymatodes diversifolium*, *Astelia* sp. and roadside *Pyrus malus* in *Nothofagus* forest (Collyer, 1973a)	-	-	No
Tetranychus lambi Pritchard & Baker [Acari: Tetranychidae]	Spider mite	Manson (1987)	Yes (Halliday, 1998)	-	-	-	No
Tetranychus ludeni Zacher [Acari: Tetranychidae]	Bean spider mite	Bolland et al. (1998:191)	Yes (Bolland et al., 1998); (Halliday, 1998)	Not likely Although apple is not listed as a host in New Zealand by (Manson, 1967b), *Malus domestica* is listed as host of Bean spider mite in (Bolland et al., 1998). This mite feeds on leaves and it is not likely to be on fruit. Also gathers on twigs and branches and in autumn, under bark (Pritchard and Baker, 1952)	-	-	No
Tetranychus neocaledonicus (André) [Acari: Tetranychidae	Vegetable spider mite	Bolland et al. (1998)	Yes* (Bolland et al., 1998); (Halliday, 1998)	Not likely Bolland et al. (1998) list this species as present in New Zealand citing Manson (1967b). However there is no mention of this mite in New Zealand in this reference. This species has not actually been reported from New Zealand (Zhang, 2002)	-	-	No
Tetranychus urticae Koch [Acari: Tetranychidae]	Two spotted mite	MAFNZ (2000b)	Yes (Halliday, 1998)	-	-	-	No

Scientific name	**Common name/s**	**Reference for presence in New Zealand**	**Presence in Australia Reference**	**Potential for being on mature apple fruit Comments if applicable**	**Potential for establishment or spread**	**Potential for consequences Comments if applicable**	**Consider species further?**
Tuckerellid mites [Acari: Tuckerellidae]	Tuckerellid mites	HortResearch (1999b)	Uncertain	Not likely The family consists of 20 described species all in the genus *Tuckerella*. They are detritus feeding mites that occur on the bark of apple trees. Australian species of *Tuckerella* tend to be found on the stems of woody plants usually in the cracks on small twigs (Walter, 1999)	-	-	No
Typhlodromus pyri (Scheuten) [Acari: Phytoseiidae]	Predatory mite	MAFNZ (2000b)	Yes (Halliday, 1998)	-	-	-	No
Tyroglyphid mites [Acari: Acaridae]	Tyroglyphid mites	HortResearch (1999b)	Uncertain	Likely Detritus feeding mites that are usually found under the bark and sometimes in the calyx of apples at harvest time (HortResearch, 1999b)	Feasible	Not significant Normally detritus feeders feeding on moulds (HortResearch, 1999b)	No
Zetzellia ?subreticulata [Acari: Stigmaeidae]	Stigmaeid mite	HortResearch (1999b)	Uncertain	Not likely In New Zealand the feeding habits of *Zetzellia ?subreticulata* and its possible role as a predator of European red mite and twospotted spider mite are unknown (HortResearch, 1999b). These two pest mites are usually found on leaves and direct damage to the fruit rarely occurs (HortResearch, 1998). European red mite can also cause damage by infecting the fruit with (overwintering) eggs at harvest time (HortResearch, 1999b). However it is not known whether this predacious mite preys on the eggs of European red mite. Based on this evidence it is considered that the species is unlikely to be on the pathway	-	-	No
Snails							
Cochlicopa lubrica (Muller) [Gastropoda: Cochlicopidae]	Slippery moss snail	MAFNZ (2000b)	No (Smith, 1992)	Not likely Orchard or packing house contaminants, feeds on living and dead plant material, most common in wet, shaded areas (MAFNZ, 2000b)	-	-	No
Helix aspersa (Müller) [Gastropoda: Helicidae]	Common garden snail	MAFNZ (2000b)	Yes (CSIRO/DAFF, 2005)	-	-	-	No
Vallonia excentrica (Sterki) [Gastropoda: Valloniidae]	Eccentric grass snail	MAFNZ (2000b)	Yes* (Barker, 1999)	Not likely Orchard or packing house contaminants, polyphagous foliage feeder (MAFNZ, 2000b)	-	-	No
Spiders							

Scientific name	Common name/s	Reference for presence in New Zealand	Presence in Australia Reference	Potential for being on mature apple fruit Comments if applicable	Potential for establishment or spread	Potential for consequences Comments if applicable	Consider species further?
Ixeuticus martius (Simon) [Araneida: Amaurobiidae]	Spider	Baker (1983)	Yes (Main, 1976)	-	-	-	No
Mynoglenes sp. [Araneida: Linyphiidae]	Money spider	MAFNZ (2000b)	Uncertain	Not likely Orchard or packing house contaminants (MAFNZ, 2000b)	-	-	No
Poecilopachys australasia (Griffith & Pidgeon) [Araneida: Araneidae]	Two-spined spider	MAFNZ (1999a)	Yes (CSIRO/DAFF, 2005)	-	-	-	No
Trite spp. [Araneida: Salticidae]	Jumping spider	MAFNZ (2000b)	Uncertain	Not likely Orchard or packing house contaminants (MAFNZ, 2000b)	-	-	No

Appendix 3 – Data sheets – Apple scab

Venturia inaequalis (Cooke) G. Winter (1875) [Pleosporales: Venturiaceae]

Synonyms and changes in combination:

Endostigme inaequalis (Cooke) Syd. (1923), *Sphaerella inaequalis* Cook (1866), *Spilosticta inaequalis* (Cooke) Petr. (1940) [synonyms]; *Fusicladium pomi* (Fr.) Lind (1913), *Spilocaea pomi* Fr. (1825) [anamorphs] (CABI, 2005).

Common names:

Apple scab, black spot (CABI, 2005).

Hosts:

Cotoneaster spp. (Cotoneaster), *Crataegus oxyacantha* (Midland hawthorn), *Eriobotrya japonica* (loquat), *Malus* spp. (ornamental apple), *Malus domestica* (cultivated apple), *Pyracantha* spp. (firethorn), *Pyrus* spp. (pear), *Pyrus communis* (European pear), *Sorbus* spp. (Mountain ash), *Viburnum* spp. (arrow-wood) (MacHardy, 1996; CABI, 2005)

In pear (*Pyrus* spp.) scab is caused by *Venturia pirina* (Shabi, 1990). Several host specific forms referred to as 'formae speciales' of *V. inaequalis* on mountain ash (*Sorbus aucuparia*), hawthorn (*Crataegus oxycantha*) and cotoneaster (*Cotoneaster integerrma*) have been designated (Menon, 1956).

Based on a genetic and pathogenic study (Le Cam et al., 2002), proposed that pathogens responsible for scab on *Malus* spp. and *Pyracantha* spp. are considered as two 'formae speciales' belonging to *V. inaequalis*.

Plant part(s) affected:

Most commonly leaves, petioles, blossoms, sepals, fruits, pedicels, and less frequently on young shoots and bud scales. Most obvious symptoms occur on leaves and fruits (Biggs, 1990; MacHardy, 1996).

Distribution:

Afghanistan, Argentina, Australia (except Western Australia), Austria, Belgium, Bhutan, Bolivia, Brazil, Bulgaria, Canada, Chile, China, Colombia, Cyprus, Czechoslovakia (former), Denmark, Egypt, Ethiopia, Finland, France, Germany, Ghana, Greece, Guatemala, Hungary, India, Iran, Iraq, Ireland, Israel, Italy, Japan, Jordan, Kenya, Korea (Democratic Peoples' Republic of), Korea (Republic of), Lebanon, Libya, Malta, Mexico, Morocco, Netherlands, New Zealand, Norway, Pakistan, Peru, Poland, Portugal, Romania, Russian Federation, Saudi Arabia, Serbia and Montenegro, Serbia and Montenegro, South Africa, Sweden, Switzerland, Syria, Turkey, United Kingdom, USA, Uruguay, Zimbabwe (CABI, 2005).

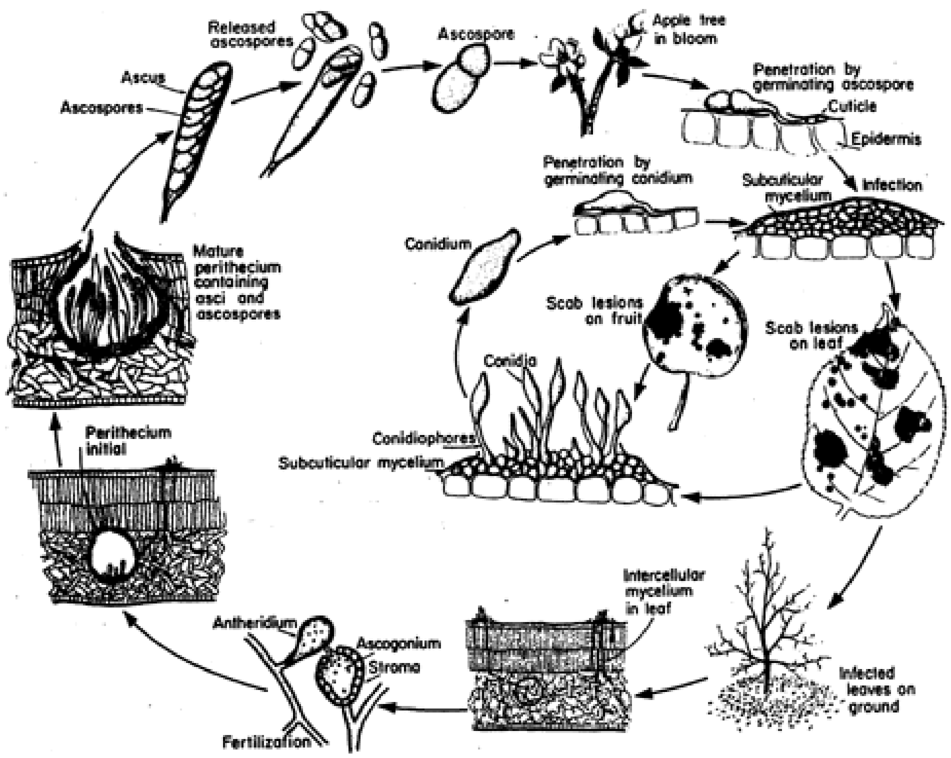
Since the first outbreak of apple scab in Western Australia (WA) in 1930 (Pitman, 1930), there had been five more outbreaks of scab between 1930 and 1996 (MacHardy, 1996).

Apple scab has been eradicated in WA and it is declared free of scab (McKirdy et al., 2001). In WA, the pathogen is under official control.

Biology:

Apple scab, caused by *V. inaequalis* (Cooke) G. Winter, is the most important disease of apple worldwide (MacHardy, 1996).(CABI, 2005) They have indicated that scab is a serious problem mainly in temperate regions with humid cool weather conditions in spring. In regions with semi-arid conditions such as western North America, Western Australia and parts of South Africa, the incidence of scab is less common (CMI, 1978).

Figure 1 Life Cycle of *Venturia inaequalis*, black spot fungus (Agrios, 1997)



The life cycle of the apple scab or black spot fungus is given Figure 1. The pathogen overwinters mainly in dead scabbed leaves and fruit on the ground as immature pseudothecia (Biggs, 1990). The fungus can also overwinter as mycelium in shoots (Moosherr and Kennel, 1995), in lesions on twigs (Stensvand et al., 1996) and bud scales (Salmon and Ware, 1931), or as dormant conidia in buds (Becker et al., 1992), but these are less common. Vegetative structures of *V. inaequalis* exposed to low temperatures in the winter rarely survive until the next growing season but an average of *c.* viable conidia per bud were detected inside buds (Becker and Burr, 1988; Becker et al., 1992). In regions where wood pustules are common conidia can be an important source of primary inoculum (Cook, 1974; Hill, 1975). Overwintering conidia in buds did not lead to more scab in orchards (Heijne and Anbergen, 1995).

Studies on overwintering of conidia of *V. inaequalis* associated with shoots and buds indicated that conidia are unlikely to overwinter on the surface of shoots or outer bud tissues, where they are exposed to fluctuating environmental conditions, and consequently were unlikely to play a role in initiating an early epidemic of apple scab in the spring. Initiating a scab infection from overwintered conidia in the inner bud tissues arising from a high level of scab in the previous autumn was much higher (Holb et al., 2004a). If the autumn scab incidence was above 40%, then the number of overwintered conidia markedly increased (Holb et al., 2005).

After leaf fall, the scab fungus continues to grow inside the infected leaves with the initiation of pseudothecia. Most pseudothecial initials are formed within 4 weeks after leaf fall (Biggs, 1990). The rate of further development of pseudothecia depends on temperature and moisture levels (MacHardy and Sutton, 1997). At least 20 min of exposure to light is required for pseudothecia to develop normally and that low or no light will reduce the number of pseudothecia produced (Holz, 1939). Leaves in lower layers of the leaf litter have fewer pseudothecia, and this was most likely due to less exposure to light (Hirst and Stedman, 1962). Moisture is a limiting factor in pseudothecial development (James and Sutton, 1982). Summarising the work of several researchers, MacHardy (1996) concluded that scabbed leaves must be wetted occasionally by rain or dew after leaf fall for pseudothecia to be produced and develop, but prolonged or continuous moisture can result in fewer pseudothecia, retard their maturation or lead to abnormal development.

Above a certain moisture threshold, the rate at which pseudothecia mature is determined primarily by temperature. Maturation accelerates with increasing temperatures in late winter and spring (CABI, 2005). The optimum temperature range for ascogonial development is 8°C–12°C (James and Sutton, 1982) and the temperature for ascospore maturation, i.e. 20°C (Wilson, 1928), corresponded very closely to ascospore germination in water reported by Keitt and Jones (1926). The maturation of pseudothecia, asci and the ascospores within them coincides mostly with bud break (CABI, 2005).

Two important factors likely to contribute to *V. inaequalis* inoculum density in spring are the incidence of black spot on leaves prior to leaf fall in the previous autumn and the density of leaf litter remaining in the spring (Horner and Horner, 2002). They found that blocks with high autumn black spot generally had high spring ascospore production. These two factors are important components of the Potential Ascospore Dose (PAD) prediction systems (MacHardy and Jeger, 1982) and it serves as a useful tool on the management of apple scab (MacHardy, 1998).

The cumulative ascospore discharge monitored by the volumetric traps always exceeded 98% at 600 degree days (base = 0˚C) after green tip stage. Estimating the relative quantity of the primary inoculum indirectly, by means of a degree-day model, was more closely aligned with the observed ascospore release measured by volumetric traps than the actual assessments of ascospore maturity and discharge obtained through squash mounts and discharge tests. The degree-day model, therefore, may be a more accurate predictor of ascospore depletion than squash mounts or discharge tests (Gadoury et al., 2004). Estimates of ascospore maturity generated by a model developed previously in the USA, were compared with the cumulative release of ascospores in Norway (Gadoury et al., 2004). In locations and years with frequent rain events, model-estimated ascospore maturity closely approximated observed ascospore release. However, in years with protracted dry periods of 1-3 weeks with little or no rain, not only was spore release delayed but release continued to lag behind predicted maturity even after several rain events subsequent to the dry interval. By halting degree day (base = 0˚C) accumulation if 7 consecutive days without rain occurred, accuracy of the model during “dry” years was greatly improved, without subsequently affecting the accuracy in “wet” seasons. This simple modification increased the accuracy of the model-derived estimates of ascospore maturity when lack of rain slows ascospore maturation (Stensvand et al., 2005).

When overwintered leaves on the orchard floor become wet in the spring, mature asci expand through the ostiole and forcibly discharge ascospores in the air (Biggs, 1990). Ascospores continue to mature and are discharged over a period of 5-9 weeks. The peak period of ascospore discharge usually occurs between the pink and full-bloom stages of bud development (Biggs, 1990). This period coincides with abundance of susceptible leaves. At least 0.2 mm rainfall per hour, lasting one to several hours, uninterrupted or interrupted by a maximum of 2 dry hours is needed for distinct ascospore ejection (Rossi et al., 2001). They also found that wetness caused by dew was insufficient to allow ascospores to disperse into the air. In contrast, ascospore release also occurred during periods of dew but it was triggered mainly by free moisture from rainfall and by light (Villalta et al., 2002). In all seasons, less than 17.5% of a season's ascospores were trapped during darkness. The airborne ascospores which serve as primary inoculum are disseminated by wind and carried to susceptible tissue on apple trees that have begun growth and flowering in spring.

Most ascospores are deposited in close proximity to their inoculum (CABI, 2005). Ascospores were released over distances ranging from 0.1 to 8.1 mm (one reached 13.2 mm) from the source, inside small chambers in still air (Aylor and Anagnostakis, 1991). These authors also showed that 75% of the ascospores were projected less than 4.1 mm from the source and only 1% were projected as far as 6.6 mm. The aerial concentration of ascospores decreased rapidly with height above the ground, and on average values of ascospores at 3 m height were only approximately 6% of ascospores measured at 0.15 m, the decrease in spore numbers was attributed to rapid increase of wind speed and turbulent eddydiffusivity with height above the ground (Aylor, 1995).

Nearly all ascospores are ejected less than 6 mm into still air, and with the water film on the leaf surface, the distance ascospores are propelled decreases to less than 0.25 mm and are seldom carried into the tree canopy under windless conditions. The ascospores ejected from leaf litter may get deposited on ground vegetation. Ascospores reaching the turbulent air must then pass through tree canopies and the surrounding boundary layer of the orchard (Frinking, 1993). It is generally accepted that most spores remain within a crop and fewer than 10% spores released in a crop are released beyond the crop boundary layer (Gregory, 1973). This author showed that ascospores are dispersed by wind, and the dispersal gradient from an inoculum source is steep.

Several researchers concluded that most airborne ascospores are deposited in close proximity (less than 100 m) to their source (MacHardy, 1996). Ascospores dispersed from a high-inoculum orchard during the production of primary inoculum, will not cause a detectable amount of scab in an orchard greater than 200 m downwind. It also appears that ascospores dispersed from a large inoculum source during a single rain event will cause a detectable increase in scab in an unprotected orchard 50-100 m down wind (MacHardy, 1996). Holb monitored the ascospore spread by Burkard spore traps and symptoms on susceptible and tolerant cultivars (Holb, 2002). This author found that the number of ascospores in the air and symptom production decreased with increasing distance of the spore trap and inoculum source, respectively. Ascospore concentration was reduced by half or one-third at 21 m and one-tenth at 45 m. The 15 to 21 m distance from the inoculum source can be considered as the upper limit of ascospore spread. Beyond 33 m, the number of infected trees decreased further and at 57 and 66 m, only a minimum number of trees with symptoms were reported. Cultivar susceptibility to apple scab markedly influenced incidence of infected clusters and disease gradients. The effect of the horizontal distance from the source was identifiable up to 18 m and 33 m for cv. Schone van Boskoop and cv. Jonagold, respectively, beyond which disease was negligible (Holb et al., 2004b).

After ascospores are ejected the temperature and moisture are the most critical determinants of ascospore viability and the rate at which ascospores germinate and grow. Germination and germ tube elongation occur over a wide temperature range (0.5°C–32°C) but these two processes are reduced greatly below 11°C and above 26°C, the optimum being 17°C (MacHardy, 1996). The minimum number of hours of continuous leaf wetness required for infection at various temperatures has been examined in detail (Mills, 1944; MacHardy and

Gadoury, 1989; Stensvand et al., 1997; Gadoury and Seem, 1997). In general, for infection to occur the ascospores must be continuously wet for 28 hours at 6ºC, for 14 hours at 10ºC, for 9 hours at 18°C–24ºC or for 12 hours at 26ºC (Agrios, 1997).

Ascospore germination and first infection is mostly on apple leaf or fruit, but initial infection can occur on sepals at 'bud break' stage which can then be a source of secondary inoculum for developing fruits. On germination the ascospore germ tube pierces the cuticle and grows between the cuticle and the outer wall of the epidermal cells and the initial hypha ramifies to form a subcuticular stroma. The mycelium produces conidiophores and large numbers of conidia, which push outwards, rupture the cuticle, and within 8-15 days of inoculation, form olive-green, velvety scab lesions. Although, the mycelium remains mostly as a subcuticular stroma, first the epidermal cells and later the palisade and mesophyll cells of the leaves show a gradual depletion of their contents, eventually collapsing and drying (Agrios, 1997). The viability of ascospores can last up to 19 days at 5°C (Boríc, 1985).

Production of conidia occurs mainly on the leaves, shoots, sepals, and fruit and less commonly on pustules that develop on bud scales. Conidia produced on these plant tissues increase the inoculum potential and contribute to the secondary spread of scab. Rarely, conidia present between bud scales constitute a part of the primary inoculum (MacHardy, 1996).

Conidia are disseminated mainly by rain-splash from scab lesions to other susceptible tissues within the canopy of the same tree (CABI, 2005; MacHardy, 1996). Rain accompanied by wind provides a means for conidial spread to a limited distance within an orchard. In exceptional circumstances conidia were caught by a spore trap in an aircraft flying at 610 m (Hirst and Stedman, 1961), presumably disseminated by high-altitude air currents. The distance conidia travel is dependent mainly on wind speed and the size of the water drops. Based on orchard and laboratory data, it appears highly unlikely that these conidia would cause an outbreak of scab at a location far way from the source (Hirst and Stedman, 1961) because of the steep gradient of dispersal of conidia within a few meters of the source and the vulnerability of detached conidia to dry conditions.

Several researchers concluded that free water is essential for conidial germination and they germinate over a wide range of temperatures from 0°C to 30°C–32°C, but 5°C–25°C is the most favourable range, with an optimal range of 16°C–20°C (MacHardy, 1996). The conidia germinated and developed appressoria within 12 h after inoculation. The germination percentages of conidia examined at 6 and 12 h after inoculation were 83% and 95% respectively. The frequencies of appressorium formation of the germinated conidia were 93% and 95% at 12 and 24 h after inoculation respectively (Huang et al., 2003). The rate of germination and appressorium formation of conidia was directly proportional to temperature from 5°C–20°C, but conidia germinated and formed appressoria more quickly than ascospores (Turner et al., 1986). Conidial viability is greatest when they are young, and desiccation and high temperature appear to have the greatest detrimental effect to conidia that remain attached to conidiophores in a lesion. Conidia germinate and cause further infection in the same way that ascospores do. The successive production of abundant conidia in each lesion may give rise to a scab epidemic.

Conidia sporulated at *c*. 70% to 100% relative humidity. It was optimal at 90% relative humidity, but reduced to approximately 50% at 80% and 100% relative humidity, and did not occur in dry atmosphere *c*. 60% relative humidity (Studt and Weltzien, 1975). Conidia sporulated over a wide range of temperature 4°C–28°C (optimum 10°C–20°C). Light has no discernable influence on sporulation. Up to 100000 conidia may be produced in each leaf lesion (Biggs, 1990).

Inoculum dose, host growth, and environmental conditions can all determine the severity of a scab attack. Susceptibility of leaves and fruit declines with age (Kollar, 1996). Infections are most abundant during cool, wet periods of summer, and autumn, while they are infrequent or absent in dry hot summer weather.

Apple scab attacks predominantly the leaves and fruit. As the leaves emerge, the lower surface in particular, and the surface adjacent to the midrib gets infected first and then the upper surface as the leaves unfold. Infected leaves usually become distorted as scab lesions enlarge (CABI, 2005).

Infection of sepals may serve as an important source of secondary inoculum for developing fruits (Kennel, 1987). Fruit is highly susceptible to infection through petal fall and fruit set (MacHardy, 1996). Lesions on young fruit are darker with distinct margins and these eventually become corky spots. When fruits enlarge, cracks appear in the skin and fruit flesh, but early-infected fruit usually drop prematurely. Apples become more resistant to scab as they approach maturity (Keitt and Jones, 1926). Lesions develop more slowly when infections occur late in the season particularly on the stem-end of fruit before cork formation restricts the fungal growth prior to harvest (Bratley, 1937). These ‘pin-head’ or ‘pin-point’ size lesions (0.1–4 mm diameter), appear shortly before harvest and they are frequently followed by ‘storage scab’, which may not appear until after 10–12 weeks in storage (MacHardy, 1996). ‘Storage scab’ is typically seen as shiny, black, sunken spots in contrast to velvety-like appearance of lesions that develop on fruit in the orchard (MacHardy, 1996). This author indicated that as lesions enlarge during cold storage, the cuticle is either broken or show alternate concentric bands of smooth and rough ridges on the cuticle.

A study was made of the conditions for scab development during fruit storage (Bratley, 1937). He identified several important factors, amongst them were, (i) presence of free moisture affected lesion size (ii) orchard conditions before picking influenced the number of lesions that developed in storage (iii) lesions size was smallest at 0°C but the lesion size and number increased at high temperature and high relative humidity and (iv) new lesions appeared at the stem-end of fruit. An investigation of the relationship between scab development on mature fruit (cv. Granny Smith) and temperature (1°C–2°C and 20°C) during storage after inoculation was carried out (Schwabe, 1982). It took 80 days for apples stored at 1°C–2°C to develop first lesions, but it took approximately 180 days for the greatest number of lesions to develop, compared to 35–45 days for first lesions to appear, with the highest number developing between 100 to 120 days at 20°C. It took 180 days for maximum lesion development for fruit stored at the lower temperature compared to *c*.100–120 days at the higher temperature. Lesions that appeared during storage developed from infections that occurred before harvest, and the number of infections that developed into lesions is directly related to temperature. At higher temperatures (and high relative humidity), lesions appear earlier and are more numerous.

Moisture is the most important factor affecting the size of lesions, particularly free moisture on apples packed tightly in storage cartons (Bratley, 1937). At a given temperature, increasing the relative humidity by 20% generally doubles the size of old lesions. He concluded that infections 1-2 weeks before harvest were unlikely to cause visible lesions during normal storage time (Bratley, 1937). Temperature determines how soon and at what rate lesions appear in storage. Apples were graded for scab severity before storage, at 0.5°C, 2.8°C or a cycle of 2.8°C and 0.5°C in a room held at *c*.80% relative humidity (Tomerlin and Jones, 1983). The increase in lesion diameter from one orchard was significantly greater at 2.8°C than at 0.5°C regardless of scab severity. Most new lesions that developed in storage were on apples that had visible lesions when stored. Of apples graded initially as scab-free, none from one orchard and 7% of fruit from the second orchard developed new lesions during storage.

A study conducted by inoculating 20 cultivars with *V. inaequalis* collected from natural infection in three locations widely separated geographically, not all cultivars were susceptible to all isolates (Palmiter, 1932; Palmiter, 1934). These results showed that natural populations of *V. inaequalis* included pathotypes that were unable to incite infection on some cultivars. In another study, the random amplified polymorphic DNA (RAPD) marker technique revealed that conidia collected from each cultivar caused lesions on that cultivar and not on another two cultivars (Sierotzki et al., 1994a; Sierotzki et al., 1994b). These authors interpreted this as indicating race-specific (major gene) response that can stop infection by *V. inaequalis* before symptom expression. They also found that there are other genes which condition a different level of parasitic fitness if the appropriate virulence is present. It follows, for example, that a mixed planting of apple cultivars with different levels of resistance to scab, the difference in scab incidence and severity among the cultivars would become less over time due to selection pressure for spores with genotypes best fit to attack each cultivar.

Natural genetic resistance to apple scab exists in some *Malus* species, the best known being *Malus floribunda* (designated as *Vf* from *Malus floribunda* 821), and used in breeding programs (Hough, 1944). Resistance to scab in *Malus atrosanguinea* 804 is similar to the resistance in *M. floribunda* and *M. micromalus* (Williams and Dayton, 1968; Williams et al., 1966). The resistance is determined after the cuticle is penetrated (Valsangiacomo and Gessleer, 1988) and involvement of phytoalexins (Hrazdina, 1998; Borejsza-Wysocki et al., 1999) and flavanols (Mayr et al., 1997; Feucht et al., 1998) has been proposed. The recent breakdown of *Vf*, a major resistance gene to apple scab, is an example of a founder effect in response to resistance gene breakdown (Guérin and Le Cam, 2004).

Different physiologic races are present in wild-type populations of *V. inaequalis*, which differ in pathogenicity to species and varieties of *Malus* (Parisi et al., 1993). Occurrence of 7 physiologic races of *V. inaequalis* is distinguished on the basis of pathogenicity to different *Malus* hosts (CABI, 2005). Testing 9 isolates of *V. inaequalis* obtained from three states in Australia, using five race differential selections of apple from the USA showed that they belong to race 1 (Heaton et al., 1991). There is a high degree of variation amongst the *V. inaequalis* population in New Zealand, but only one race (race 1) has been detected (Patterson et al., 2003). Race 1 isolates of *V. inaequalis* are avirulent on *Malus* hosts carrying the resistant gene *Vm*. This pathogen produced a proteinaceous elicitor that induced necrosis, similar to a hypersensitive response, when infiltrated into leaves of the resistant *Vm* host (Win et al., 2003).

Differential interactions in respect of virulence and aggressiveness were found between *V. inaequalis* isolates and apple varieties (Zhdanov, 1989). Based on genetic and pathogenic data, the pathogens responsible for scab on *Malus* spp. and *Pyracantha* spp. are designated as two formae speciales belonging to *V. inaequalis* (Le Cam et al., 2002).

Strains of *V. inaequalis* resistant or sensitive to fungicides have been reported from different countries. Benomyl tolerant strains have been isolated from commercial orchards in USA (Lalancette et al., 1987). Resistance to Dodine has been shown to be persistent (Köller et al., 1999). In some instances, 5%–30% of dodine-resistant strains have been detected in the population of *V. inaequalis* in majority of orchards investigated in Poland (Meszka and Bielenin, 2001). No dodine resistance was detected in New Zealand and it is still an effective fungicide (Bakker, 1999). Similarly, since the first report of tolerance to the sterol demethylation inhibitors (DMIs) (Stains and Jones, 1985), scab strains with reduced sensitivity to DMIs have been reported from several countries including New Zealand (Whelan et al., 1992). The strobilurine-analogues (beta-methoxyacrylates) after a few years of use have also shown a shift in sensitivity to *V.inaequalis* (Palm, 1999).

Economic impact:

Over a period, losses from scab far exceed those from any other disease or pest of apples (CABI, 2005). Crop losses can be severe (70% or more) when humid, cool weather occurs during the spring months (Biggs, 1990). The major economic loss to the grower is the reduction of fruit quality of scabbed apples. A severe attack on the leaves will cause mid-season defoliation and reduction of tree vigour, which in turn may lead to failure of fruit bud formation, and stunted and reduced growth. Young fruit affected by scab may be reduced in size and asymmetrical when it has matured, and the keeping quality of scabby fruit may be greatly impaired (MacHardy, 1996). In regions and years with favourable weather conditions for scab infection and with a high PAD, nearly all the fruit may be infected. In such regions, about 70% of the pesticides applied are used in relation to scab control (CABI, 2005).

In the early 1900's yield losses in unsprayed orchards in New York was estimated at around US $ 3.5 million (Warren, 1905; Wallace, 1913). More recently in 1983, nearly 10% of the apples in Himachal Pradesh in India were considered not marketable and were destroyed, resulting in a loss of US $ 1.5 million (MacHardy, 1996). Losses caused by 'storage-scab' were also common in several European countries in the late 1920's and early 1930's, but substantial losses are uncommon today (MacHardy, 1996). However, more recently, loss in yield due to fruit damage as a result of scab infection was reported at around 56-74% (Jurjevic et al., 2001).

Control:

The fungicides available to control scab can be divided into two different groups on the basis of their mode of action, the non-systemic multi-site fungicides and the specific uni-site inhibitors (CABI, 2005). Multi-site fungicides included several inorganic (for example, sulphur, copper) and organic chemicals (for example, thiram, ferbam, zineb, mancozeb) and are used as protective fungicides, applied before the initiation of infection. Captan, a class of organic fungicide remained one of the most widely used products in scab control. Together with dithianon, captan is often used as a partner for site-specific fungicides in an anti-resistance strategy (CABI, 2005). Intensive use of Dodine resulted in control failures due to resistance but it was persistent when treatments were interrupted over a number of years (Köller et al., 1991).

Single-site inhibitors include benzimidazoles (for example, carbendazim, benomyl and thiphanate-methyl); sterol demethylation inhibitors (DMIs) used in integrated fruit production (IFP) programs (for example, bitertanol, fenarimol, triflumizole); anilo-pyrimidines (for example, pyrimethanil, cyprodinil); and strobilurine-analogus derived from the natural antifungal antibiotic strobilurine A from the fungus *Strobilurus tenacellus* (for example, kresoxim-methyl and trifloxystrobin) (CABI, 2005). The most extensive group of fungicides is the DMIs and the mode of action is inhibition of fungal sterol biosynthesis (Scheinpflug and Kuck, 1987). Tolerance of *V. inaequalis* to DMIs has been reported from first in Germany (Stains and Jones, 1985) and later from several countries including New Zealand (Whelan et al., 1992). The primary target of anilino-pyrimidines in the infection process of *V. inaequalis* is just after the formation of primary stroma (Winter et al., 1994; Milling and Daniels, 1996). The mode of action includes inhibition of methionine biosynthesis and secretion of hydrolytic enzymes. Strobilurine-analogues strongly inhibit spore germination at very low dose rates, a higher retention after rainfall, and prevent the formation of conidiophores (CABI, 2005). A shift in the sensitivity of *V. inaequalis* to strobilurines has been reported (Palm, 1999). Resistance monitoring of orchard population of the pathogen in relation to the base line curves is needed to follow up the evolution of sensitivity and to warn of tolerant strains in different regions (Köller et al., 1991; Küng et al., 1999).

Strobilurine-analogues block electron transfer at the site of quinol oxidation (the Qosite) in the cytochrome bc1 enzyme in the respiratory chain of fungal mitochondria (Ammermann et al., 1992; Steinfeld et al., 2001). These fungicides are referred to as QoI (Quinone outside Inhibitors) fungicides. These are highly effective on spore germination at very low doses (Creemers et al., 1996) and are excellent preventive fungicides. The fungicides belong to this group used against scab include kresoxim-methyl and trifloxystrobin (Margot et al., 1998). The class of fungicides acting as respiration inhibitors by binding to the Qo centre of cytochrome b (QoIs) are in wide use for the management of apple scab. The response of *V.*

inaequalis populations to treatments with QoIs, sensitivities of isolates were determines for germinating conidia or for mycelial colonies developing from germinating conidia. Emergence of qualitative QoI resistance was documented for *V. inaequalis* in an orchard in North Germany, which had been treated intensively with a total of 25 QoI applications over four consecutive seasons. Isolates retrieved from the orchard were highly resistant to both kresoxim-methyl and trifloxystrobin and were characterised as G143A cytochrome b mutants (Köller et al., 2004).

Methods other than the use of chemicals are being tested to control scab. Field trials were conducted in New Zealand to evaluate methods of treating overwintering apples leaves to reduce ascospore production by *V. inaequalis*. Ascospore numbers were significantly reduced by the leaf amendment urea, which alone caused 73% reduction, but not with Bio-Start™ product. The effect of fungal isolates was not significant, although when combined with the water treatment, the isolates, *Chaetomium, Phoma, Epicoccum* spp. and *Trametes versicolor* reduced numbers of ascospores by 33, 27, 15 and 28% respectively, compared to no fungus control when combined with urea, the *Chaetomium* isolate reduced ascospore numbers by 92% and 82% compared to the nil fungus/water control treatments in Hawke's Bay and Lincoln respectively, indicating that the treatment has potential for reducing primary inoculum of apple scab (Tshomo et al., 2003).

Effect of the biological control agent *Microsphaeropsis orchracea* on the ejection pattern of ascospores by *V. inaequalis* and on apple scab development was studied in field and in vitro experiments. In the orchard, the greatest reduction in production of ascospores (94%–99%) occurred on leaves sprayed with *M. ochracea* in August. Further reductions in production of ascospores, to a lesser degree, were observed when *M. ochracea* was sprayed in September-October (Carisse and Rolland, 2004).

Appendix 3 – Data sheets – European canker

Neonectria galligena Bresadola (1901) Rossman & Samuels (1999). [Hypocreales: Nectriaceae]

Synonyms and changes in combination:

Nectria galligena (Bres.) [synonym]; *Cylindrocarpon heteronemum* (Berk. & Broome) Wollenweb.; *Cylindrocarpon mali* (Allesch.) Wollenweb; *Fusarium heteronemum* Berk. [anamorph]; *Nectria ditissima* Tul. & C. Tul. [teleomorph] (CABI, 2005).

Common names:

European canker, nectria canker, crotch canker, eye rot (CABI, 2005; Grove, 1990a).

Hosts:

Acer circinatum (vine maple); *Acer macrophyllum* (bigleaf maple); *Acer pensylvanicum*; *Acer rubrum* (red maple); *Acer saccharum* (hard maple); *Acer spicatum* (mountain maple); *Aesculus* sp. (horse-chestnut); *Alnus incana* (grey alder); *Betula papyrifera* (paper birch); *Betula pendula* (European white birch); *Betula lenta* (sweet birch); *Betula nigra* (river birch); *Betula populifolia* (grey birch); *Carpinus betulus* (common hornbeam); *Carya cordiformis* (Bitternut hickory); *Carya glabra* (pignut hickory); *Carya illinoinensis* (pecan); *Carya ovata* (shagbark hickory); *Carya tomentosa* (mockernut hickory); *Cornus nuttallii* (Pacific dogwood); *Corylus avellana* (hazel); *Fagus grandifolia* (American beech); *Fagus sylvatica* (European beech); *Frangula alnus* (Alder buckthorn); *Fraxinus excelsior* (common ash); *Fraxinus nigra* (black ash); *Juglans cinerea* (butternuttree); *Juglans nigra* (black walnut tree); *Liriodendron tulipifera* (yellow poplar); *Malus domestica* (apple); *Nyssa sylvatica* (blackgum); *Populus grandidentata* (bigtooth aspen); *Populus tremuloides* (trembling aspen); *Prunus serotina* (black cherry tree); *Pyrus communis* (pear); *Pyrus pyrifolia* var. culta (oriental pear tree); *Quercus alba* (white oak); *Quercus bicolor* (swamp white oak); *Quercus coccinea* (scarlet oak); *Quercus garryana* (Oregon white oak); *Quercus laurifolia* (laurel oak); *Quercus rubra* (Northern red oak); *Quercus velutina* (black oak); *Rosa* spp. (rose); *Rhus typhina* (staghorn sumac); *Salix alba* (white willow); *Salix amygdaloides* (peachleaf willow); *Sorbus aucuparia* (rowan tree); *Tilia americana* (American basswood); *Ulmus americana* (American elm); *Ulmus glabra* (mountain elm) (CABI, 2005).

Plant part(s) affected:

Stem, fruit.

Distribution:

Afghanistan; Argentina; Austria; Belgium; Bulgaria; Canada (British Columbia, New Brunswick, Nova Scotia, Ontario, Prince Edward Island, Quebec); Chile; China (Taiwan); Czechoslovakia (former); Denmark; Estonia; Faeroe Islands; France; Germany; Greece; Hungary; Iceland; India (Himachal Pradesh); Indonesia (Java); Iran; Iraq; Ireland; Italy; Japan; Korea (Republic of); Lithuania; Lebanon; Macedonia; Mexico; Netherlands; New Zealand; Norway; Poland; Portugal (Azores, Madeira); Romania; Russian Federation; Saudi

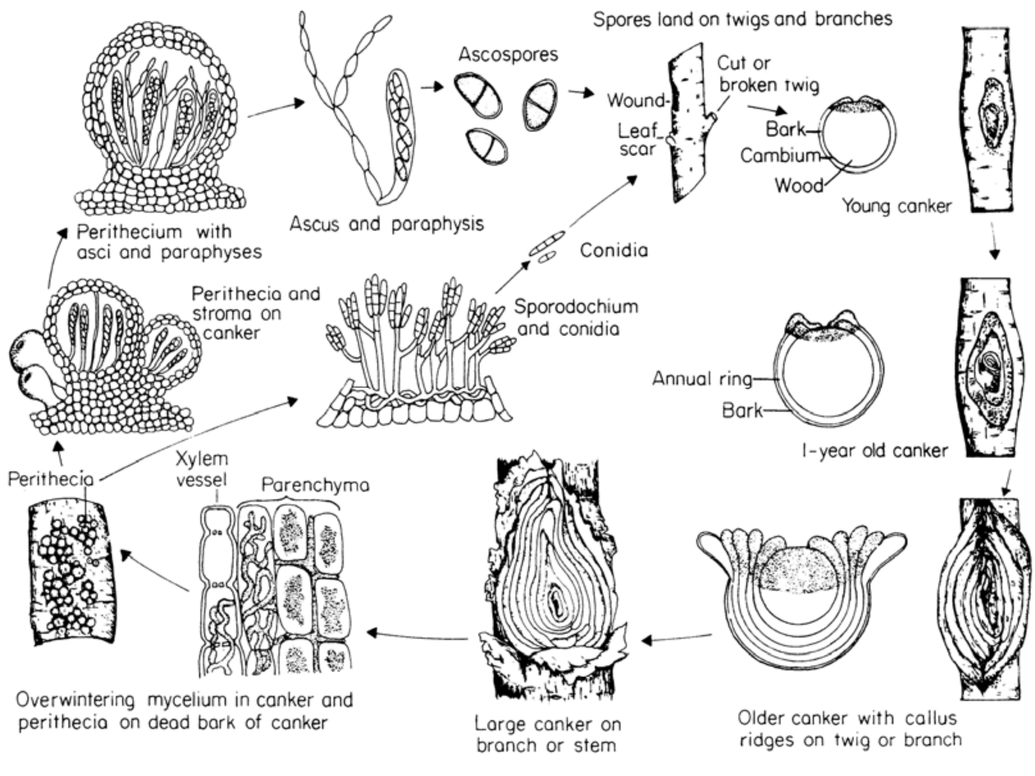
Arabia; Slovakia; South Africa; Spain (Canary Islands); Sweden; Switzerland; Syria; Ukraine; United Kingdom; USA (California, Connecticut, Florida, Illinois, Indiana, Maine, Maryland, Massachusetts, Michigan, Minnesota, Mississippi, New Hampshire, New York, North Carolina, North Dakota, Oregon, Pennsylvania, Rhode Island, South Dakota, Vermont, Virginia, Washington, West Virginia); Uruguay (CABI, 2005).

Note that the pathogen has been eradicated from Tasmania in Australia (Ransom, 1997).

Biology:

Nectria canker or European canker, caused by *Neonectria galligena*, is one of the most important diseases of apples and pears and many species of hardwood forest trees in most parts of the world (Agrios, 1997; Swinburne, 1975). The disease affects mostly trunks and branches of tree causing cankers but in apple and pear fruit that is also infected it causes rot. Foliage is not affected (Butler, 1949). The life cycle of the pathogen is given in Figure 2.

Figure 2 Life cycle of *Neonectria galligena* (Agrios, 1997)



On tree trunks and branches *Nectria* cankers usually develop around bud scars, wounds, twig stubs or in the crotches of limbs. In young trees cankers could girdle the trunks killing the whole tree. In older trees girdling kills only small branches but canker on main trunk or large branches reduce the vigour and value or productivity of the tree.

The fungus survives adverse environmental conditions as mycelium in twig and branch cankers and sporulates after the onset of moist conditions. It produces both the asexual stage, (creamy sporodochia producing conidia) and the sexual stage (bright red perithecia producing asci, each containing eight ascospores). Sporodochia and conidia generally form under cool moist conditions in spring, summer and autumn (Munson, 1939; Grove, 1990a). Conidia are commonly two- to four-celled macroconidia or rarely single-celled microconidia. Perithecia are formed on the cankers approximately one year after infection or on infected fruit that is left to mummify and overwinter on the tree. They form in autumn, mature in winter and spring (Munson, 1939; Grove, 1990a) releasing ascospores.

Spores are spread by wind and rain splash and perhaps by insects and birds (Munson, 1939; Butler, 1949; Agrios, 1997). Conidia are dispersed mainly by rain splash (Grove, 1990a). The most probable maximum distance for conidial dispersal is 10 m (Marsh, 1940; Taylor and Byrde, 1954) although under storm conditions this might extend to about 125 m (Swinburne, 1975; CABI, 2005). Ascospores are forcibly ejected and wind-disseminated or exuded in a gelatinous matrix and water dispersed (Munson, 1939; Grove, 1990a). Woolly aphids have been observed to carry conidia on their bodies (Munson, 1939). Birds are suspected to spread spores probably because they inhabit branches of trees. However, spread of the disease by insects and birds has not been demonstrated.

Known points of infection for tree trunks and branches are newly exposed leaf scars, cracks on leaf scars with onset of bud burst, scars left after the removal of fruit petioles, tree wounds, lesions caused by other pathogens such as *V. inaequalis* and *Myxosporium corticola*, pruning cuts, frost damage, bark fissures at branch crotches, burrknots, abnormal buds (Swinburne, 1975) and woolly aphid injury (Brook and Bailey, 1965).

Water is required for the germination of conidia and ascospores and their viability is affected by temperature, relative humidity and desiccation, it being sharply reduced when exposed to relative humidities between 85%–100% at 11°C and 19°C for 3–12 hours (Dubin and English, 1975a). Conidia and ascospores germinate over a wide range of temperatures from 2°C–30°C and optimum for the growth of the fungus is between 18°C–24°C (Munson, 1939; Butler, 1949). The disease becomes troublesome in regions where fog, moderate temperatures and annual mean rainfall exceeds 1000 mm (Grove, 1990a).

While spores and potential infection sites are available almost all through the year, the most important period for infection varies in different parts of the world (Swinburne, 1975). In Europe, autumn leaf fall is considered to be the most critical period. In Northern Ireland the critical period for infection in Bramley's seeding apple appears to be spring and summer, infection sites being scars of bud scales, distal leaf scars of previous year's that crack as stem growth increases and crotches that form as divergent buds elongate. In North West America and California, infection occurs during the dormant winter period between leaf fall and bud burst as it coincides with the distinct rainy season there.

Both ascospores and conidia act as inocula (Butler, 1949; Grove, 1990a). In California, where the main rainy period and infection is in winter, conidia are considered the major infective propagules, ascospores playing an insignificant role in infection (Dubin and English, 1975b). However, ascospores are considered an important epidemiological factor in disease development in Northern Ireland where summer infection is prevalent (Grove, 1990a).

Approximately 1000 conidia are required for leaf scar infection (CABI, 2005). In California five conidia were insufficient to initiate lesions at leaf scars but 50-500 did so readily (Dubin and English, 1974). In recent artificial inoculations in nursery plants during nursery practices such as de-feathering, budding and heading back, as few as 12 conidia have produced infection and these conidial numbers were considered to resemble natural situations (McCraken et al., 2003b).

The fungus exists in several strains differing in cultural characteristics, but they appear to be largely non-specific in their pathogenicity to different strains (Ng and Roberts, 1974; Flack and Swinburne, 1977). However it was found that the incitant of canker in ash (*Fraxinus* spp.) to be forma specialis, *N. galligena* f.sp. *fraxini* as distinct from the incitant of apple canker *N. galligena* f.sp. *mali* (Flack and Swinburne, 1977).

In apple, varieties vary in their susceptibility to the disease but none are immune (McKay, 1947). Cross-inoculation experiments found species such as poplar, hawthorn and beech common in hedgerows, windbreaks and woodlands to be external sources of inoculum for infection of apple plantations, with poplar being highly susceptible and unsuitable for use as a wind break (Flack and Swinburne, 1977).

Early studies on the origin of the inoculum responsible for initiation of epidemics in young orchards indicated that it might originate within nurseries (CABI, 2005). Reports from a recent study in UK, called the ‘Millennium project’ to understand the roles of nursery origin and spread from adjacent infected orchards towards canker development in young orchards (Berrie et al., 2000; Lovelidge, 2003; McCraken et al., 2003a; McCraken et al., 2003b) conclude that (a) approximately 5% of the infection in young orchards could be associated with nurseries but sometimes the problem could be bigger; this type of infection can become important in low rainfall areas; the disease that gets into trees through nurseries can remain symptomless for 3–4 years; there is no cost effective method for detecting the pathogen in symptomless wood which makes it difficult to get a handle on the size of the problem; and (b) in situations of high disease pressure inoculum movement from neighbouring sources is more important than nursery infection.

Contamination of the fruit occurs on the tree by spores emitted by the cankers and will depend essentially on whether the disease is present on the tree (Bondoux and Bulit, 1959). Excessive summer rains in Europe cause tree infection common in summer and hence more common fruit infection. Both North West America and California have suitable rainfall, and infection generally occurs during winter (Swinburne, 1975), therefore fruit infection is rare (Nichols and Wilson, 1956; McCartney, 1967). It only occurs when there is unusually high summer rain (McCartney, 1967).

Fruit infection typically takes place at the blossom end of the fruit; either through open-calyx, lenticels, scab lesions or wounds caused by insects and is called ‘eye rot’ (Swinburne, 1975). Fruit rot can also develop at the stem end (Swinburne, 1964; Bondoux and Bulit, 1959) and rarely on the general fruit surface when the skin is damaged (Bondoux and Bulit, 1959). In France, the rot was found to spread to the seed cavity where the fungus could be isolated from the mycelium that surrounds the seed (Bondoux and Bulit, 1959) but this was not observed in California (McCartney, 1967). In dessert varieties fruit infection generally leads to the development of a rot before harvest (Swinburne, 1964; Swinburne, 1975) but at times could remain latent and express only during storage (Snowdon, 1990a), especially if the contamination is towards the end of the season (Bondoux and Bulit, 1959). In cooking varieties rotting is rarely apparent until 3-7 months of storage (Swinburne, 1975).

The mechanism of latent infection has been attributed to the accumulation of benzoic acid in the fruit, a substance fungi-toxic to the pathogen in the acid condition in the unripe fruit (Swinburne, 1975). If an infection point starts in the young/immature fruit it will not grow due to high benzoic acid toxicity. As acidity decreases and sugar level increases with ripening, the toxicity of benzoic acid decreases and the fungus resumes growth.

Economic impact:

Cankers on branches and stems can necessitate tree replacement ranging from 10% of trees (Lovelidge, 1995) to whole plantations (Grove, 1990a). In Northern Ireland storage losses for fruit of the Bramley’s seeding variety varied from 3%–60% depending on the type of storage about half of these rots being attributed to *N. galligena*, (Swinburne, 1964; Swinburne, 1970a). Bramley’s seedling is more a cooking variety where losses before harvest are generally negligible (Swinburne, 1970a), rots appearing only after storage (Swinburne, 1971a). In France, 0.5% and 2% of stored apples of varieties *Reinettes du Mans* and *Rinettes blanches du Canada* respectively rotted in storage due to *Nectria* (Bondoux and Bulit, 1959). Economic damage to host species used for timber, through reduction in both quality and quantity of marketable logs, particularly in North America, has been reported (CABI, 2005) but there is no estimates of the magnitude of this loss.

Control:

Control of European canker in apple is by chemical and cultural control in orchards, development of resistance in host plants and preventing fruit rotting. Because epidemics of the disease are localised, control measures are not essential in every orchard. Chemical and cultural measures are applied only when an outbreak is detected. However, once the disease is established in young orchards it can be very difficult to control (CABI, 2005).

With the early recognition that leaf scars are a primary infection point in trees, chemical control uses copper based protectant fungicides to protect leaf scars during autumn leaf fall. In areas with significant summer rainfall fungicides used to control apple scab also provide good control of European canker (Swinburne, 1975). Protectant fungicides such as dodine and dithianon are recommended in integrated pest management programs to control both diseases (Cooke et al., 1993). Some fungicides such as carbendazim, although ineffective as a protectant at leaf fall effectively reduce sporulation of the fungus from canker lesions (Swinburne, 1975). Demethylation-inhibiting fungicides such as myclobutanil and penconazole have also been found to be effective against both scab and European canker. Paints containing fungicides are widely used to protect pruning scars from new infection.

Saure (1963) observed that infected branches removed during pruning continued to produce spores up to 2 years. This led to the recommendation to remove and destroy pruning material from the orchard. However because of the cost associated with this operation, pruned infected branches are now chipped and left in the orchards, with tests indicating that this does not increase the incidence of the disease in orchards.

Although all cultivars of apple are susceptible to European canker, prevalence and severity of the disease is much greater on some varieties. This knowledge is currently being used to develop resistant cultivars but these studies are still in early stages.

Pre-harvest application of fungicides to prevent fruit rot does not appear practical due to difficulties in providing adequate cover under commercial conditions. Further, because these fungicides are generally the same ones used to control apple scab it tends to increase the number of fungicide application per season. In order to reduce pre-harvest fungicide applications, predictive models based on meteorological data are being used to identify periods in the season when spore dispersal and infection are most likely in orchards. After harvest, in many countries fruit are dipped in a cocktail of compounds containing fungicides to control rots due to fungi including *N. galligena* (CABI, 2005).

Appendix 3 – Data sheets – Fire blight

Erwinia amylovora (Burrill 1882) (Winslow, Broadhurst, Buchanan, Krumwiede, Rogers and Smith, 1920) [Enterobacteriaceae: Enterobacteriales]

Synonyms and changes in combination:

Micrococcus amylovorus Burrill (1882); *Bacillus amylovorus* (Burrill) Trevisan, 1889; *Bacterium amylovorum* (*sic*) (Burrill) Chester (1897) (CABI, 2005).

Erwinia amylovora is a highly homogeneous species, but recent studies show that some differences exist at the molecular level between strains of different origins (Beer et al., 1996; Lecomte et al., 1997; Momol et al., 1997).

Pathovars have not been described in the species *E. amylovora*, but stable differences in virulence of some strains on certain genotypes (differential virulence) have been assessed on apple (Meijneke, 1974). The magnitude of these differences is not considered significant in the context of phytosanitary risk management.

Strains from Japan, isolated from Asian pear (*Pyrus pyrifolia*), taxonomically identical to *E. amylovora* showed limited range of pathogenicity on *Pyrus* and *Malus* cultivars (Beer et al., 1996).

Common names:

Fire blight.

Hosts:

Besides the species in genera *Malus* and *Pyrus*, there are 129 species of plants belonging to 37 genera of the family Rosaceae that have been reported to be susceptible to *E. amylovora* (van der Zwet and Keil, 1979). These authors showed that most of the hosts are susceptible only when inoculated artificially. The natural host range of *E. amylovora* is now generally considered to be restricted to genera of the sub-family Maloideae (formerly: Pomoideae) of the family Rosaceae (CABI, 2005), but a few belong to the sub-families Rosoideae and Amygdaloideae (Momol and Aldwinckle, 2000).

Primary hosts of economic and epidemiological significance are *Cotoneaster* spp. (cotoneaster); *Crataegus* spp. (hawthorn); *Cydonia oblonga* (quince); *Eriobotrya japonica* (loquat); *Malus* spp. (apple); *Pyracantha* spp. (firethorn); and *Pyrus* spp. (pear). Secondary hosts are *Amelanchier* spp. (serviceberry); *Chaenomeles* spp. (flowering quince) *Mespilus* spp. (medlar); *Photinia* spp. (photinia); *Rubus* spp. (blackberry, raspberry); and *Sorbus* spp. (mountain ash) (CABI, 2005; Deseö, 1970).

Of these, the most susceptible hosts are: *Cotoneaster bullatus*; *C. dammeri* (except cv. Eichholz No. 1); *C. lacteus*; *C. lucidus*; *C. microphyllus*; *C. moupinensis*; *C. salicifolius*; *C. watereri*; *Malus* (most species); *Crataegus* (most species); *Cydonia* (most species); *Pyracantha fortuneana* (cv. Orange Glow); *Pyrus* (most species); *Sorbus aria*; *Photinia* spp. Within each genus given as hosts of fire blight, there are species or cultivars that may show a high level of resistance under natural conditions or artificial inoculations (CABI, 2005; van der Zwet and Keil, 1979).

Occasionally fire blight symptoms have been described on plants not belonging to the sub-family Maloideae under natural conditions. For example, natural infections of *Rubus* spp. (raspberry and blackberry) plants, which belong to the Rosoideae sub-family have been reported (Starr et al., 1951). Strains of *E. amylovora* isolated from *Rubus* spp. are not pathogenic on pear (*Pyrus communis*) or apple (Starr et al., 1951; Ries and Otterbacher, 1977; Heimann and Worf, 1985). The distinct group of strains affecting *Rubus idaeus* (raspberry) and *Rubus* sp. (thornless blackberry) is presently described as *E. amylovora* f.sp. *rubi* (Starr et al., 1951). This disease may sometimes be destructive (Evans, 1996). It has not been described outside North America (USA, Canada). Strains of *E. amylovora* pathogenic to *Rubus* sp. were originally described as *E. amylovora* f.sp. *rubi* (Starr et al., 1951). These strains did not show cross pathogenicity with Maloideae strains. They were later shown to be more heterogeneous than strains from Maloideae, and to exhibit different profiles from these isolates in random amplified polymorphic DNA (RAPD) analysis (McManus and Jones, 1995). A subgroup within this group of *E. amylovora* f.sp. *rubi* strains seemed to be capable of cross-pathogenicity with Maloideae (Momol et al., 1997).

Natural infection of *Prunus salicina* (Japanese plum) belong to the Amygdaloideae (Prunoideae) sub-family, in close proximity to an active source of fire blight infection on Maloideae has been confirmed in Idaho in USA (Mohan and Thomson, 1996). Based on cultural and physiological and inoculation tests *Prunus* strains were not different from an apple strain (FB93-1) of *E. amylovora* (Momol and Aldwinckle, 2000). In Germany, *E. amylovora* was detected on young fruits of *P. domestica* (plum) (Vanneste et al., 2002b). These authors also confirmed natural infections on young fruit of *Rosa rugosa* (potato rose) (Rosoideae) in Germany.

Records on other rosaceous hosts are based on artificial inoculations and inconclusive evidence. Results from field inoculations showed varying degrees of susceptibility among several species to *E. amylovora*. In general, *P. salicina* (Japanese plum) and *P. armeniaca* (apricot) were most susceptible followed by *P. domestica* (European plums). Varieties of *P. persica* (peach), *P. persica* var. *nucipersica* (nectarine), *P. avium* (sweet cherry) and *P. cerasus* (sour cherry) were much less susceptible, while *P. dulcis* (almond) was the most resistant (Mohan et al., 2002). Confirmed and doubtful hosts of fire blight have been listed (Bradbury, 1986; van der Zwet and Keil, 1979).

There are several plant species belonging to the family Rosaceae in Australia. The major hosts include *Amelanchier* spp.; *Aronia* spp.; *Chaenomeles* spp.; *Cotoneaster* spp.; *Crataegus* spp.; *Cydonia* spp.; *Dichotomanthes* spp.; *Docynia* spp.; *Eriobotrya* sp.; *Heteromeles* sp.; *Malus* spp.; *Mespilus* sp.; *Osteomeles* sp.; *Peraphyllum* spp.; *Pyracantha* spp.; *Pyrus* spp.; *Rhaphiolepis* spp.; *Sorbus* spp.; and *Photinia* spp. (AQIS, 1998b).

The hosts in genera of *Aruncus* sp.; *Fragaria* spp.; *Prunus* spp.; *Rosa* spp.; *Rubus* spp. and *Spiraea* spp. are reported to be affected by fire blight bacterium under unusual conditions (AQIS, 1998a).

Plant part(s) affected:

Leaves, stems, flowers and fruits (CABI, 2005).

Distribution:

Albania; Armenia; Austria; Belgium; Bermuda; Bosnia and Herzegovina; Bulgaria; Canada (Alberta, British Columbia, Manitoba, New Brunswick, Newfoundland, Northwest Territories, Nova Scotia, Ontario, Prince Edward Island, Quebec, Saskatchewan, Yukon Territory); Croatia; Cyprus; Czech Republic; Czechoslovakia (former); Denmark; Egypt; France; Germany; Greece (Crete); Guatemala; Hungary; Iran; Ireland; Israel; Italy (Po Valley, Sicily); Jordan; Lebanon; Luxembourg; Macedonia; Mexico; Moldova; Netherlands; New Zealand; Norway; Poland; Romania; Serbia and Montengro; Slovakia; Slovenia; Spain; Sweden; Switzerland; Turkey; United Kingdom (England and Wales, Northern Ireland (eradicated), Scotland); USA (Alabama, California, Colorado, Connecticut, Georgia, Illinois, Louisiana, Maine, Maryland, Michigan, New Jersey, New York, North Carolina, Ohio, Oregon, Pennsylvania, Texas, Utah, Virginia, Washington, West Virginia, Wisconsin); (CABI, 2002; Bonn and van der Zwet, 2000).

In Japan, Goto (1992) described the disease affecting Asian pear (*Pyrus pyrifolia*) occurring in Hokkaido as 'bacterial shoot blight of pear (BSBP)'. The symptoms described by him were identical to those on fire blight and the causal agent as nearly identical to *E. amylovora*, except for some specific but unidentified properties. The causal agent affecting pear was identified as *E. amylovora* (Tanii et al., 1976), but later reported that several isolates showed limited range of pathogenicity on certain Asian pear cultivars. A study on the characterization of bacterial isolates (Beer et al., 1996) showed that irrespective of the host tree specificity or bacterial strain involved, BSBP is identical to fire blight.

Fire blight-like symptoms were detected on cotoneaster in the Royal Botanic Gardens in Melbourne in April 1997, and diagnostic tests confirmed that the causal organism was *E. amylovora* (Rodoni et al., 1999). National surveys conducted for three years following the detection of *E. amylovora* have confirmed the absence of the disease in Australia (Rodoni et al., 1999). Although the mode of introduction of fire blight into the Royal Botanic Gardens in Melbourne is unknown, it is unlikely this disease outbreak was associated with the introduction of planting material.

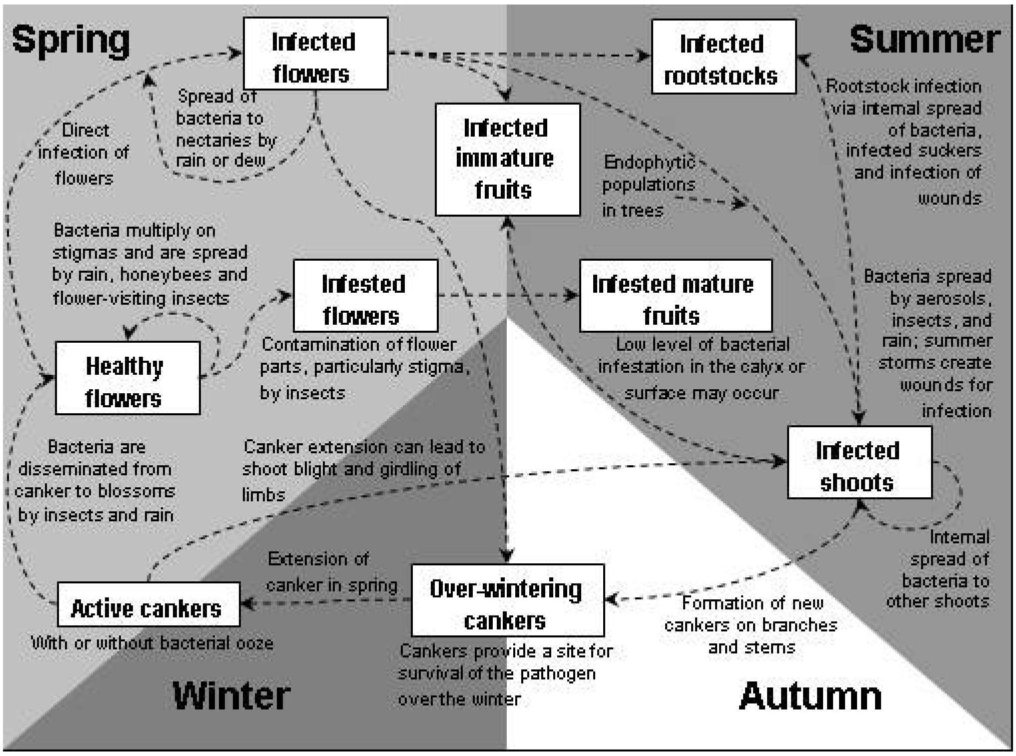
A disease affecting Asia pear (*Pyrus pyrifolia*) in the Republic of Korea that resembles BSBP in symptoms, host specificity and biology was reported (Kim et al., 1999b). The causal organism of this disease affecting Asian pear was designated as a new species of *Erwinia* (*E. pyrifoliae*) (Rhim et al., 1999).

Biology:

Disease cycle:

Figure 3 illustrates the key steps in the disease cycle of fire blight caused by *E. amylovora*. This bacterial pathogen overwinters almost exclusively along the margins of living bark tissues of overwintering (hold-over) cankers formed during the previous seasons in spurs, twigs and branches. The overwintering cankers with ill-defined margins ('indeterminate' cankers) are likely to provide inoculum in the spring as trees come out of dormancy. Under warm and humid conditions some of these cankers become active and exude bacteria-laden ooze that acts as the primary inoculum. Overwintering cankers are clearly visible on stems and large limbs but cankers on twigs and smaller limbs are not easily distinguished. The smaller cankers, especially those around cuts made in the previous season to remove blighted limbs are also important sources of inoculum. Bacteria may also move into the orchard from neighbouring infection sites, including ornamental and wild hosts.

Figure 3 Disease cycle of fire blight caused by *Erwinia amylovora* (adapted from Norelli et al. (2003)



The pathogen is disseminated by insects, rain, wind or wind-driven rain (as aerosols) to open blossoms, succulent shoot tips and tender leaves, where infection may occur. Open blossoms are the most susceptible tissues on the apple tree. Bacteria deposited on the stigmatic surface of blossoms multiply to very high numbers but usually do not cause disease (infestation); it is then in an epiphytic phase. Further spread of the pathogen occurs when pollinating insects (mainly bees) carry bacteria from infected/infested to non-infested (healthy) blossoms. Rain and dew wash the bacteria into the base of the hypanthium (floral cup) and gain entry through natural openings, mainly nectarthodes or wounds, resulting in symptom expression (infection) under conditions of warm temperatures and high humidity. Bacteria multiply intercellularly within floral tissues causing disease symptoms and infected blossoms eventually die. The spurs bearing the dead blossom clusters are retained on the tree and persist into the winter. Under suitable environmental and host conditions bacteria multiply rapidly and move intercellularly through succulent host tissues.

Secondary infections can occur throughout the growing season and develop as a result of the primary infections in blossoms, late blossoms (rat-tails) and shoots, as well as from oozing cankers. Pruning using contaminated tools can also hasten the spread of fire blight.

There are six distinct types of disease symptoms associated with fire blight infections. These are blossom blight, shoot blight, trauma blight, fruit blight, canker blight and rootstock blight. Blossom infection will result initially in producing water-soaked lesions on the sepals (outer most part of the blossom) and receptacle (expanded part of the flower stem) followed by wilting and browning or blackening. Droplets of bacterial ooze may sometimes be seen on the pedicel (flower stalk). Blossom infection may also lead to invasion of neighbouring spur leaves and eventually the twigs and branches. These infections may lead to the development of cankers.

After blossoms, succulent shoots, water sprouts and suckers are rapidly infected. Shoot blight symptoms are observed throughout the spring and summer often when blossom blight symptoms and active cankers are present. Tips of blighted shoots or suckers bend over, producing a characteristic symptom referred to as the shepherd's crook. As the bacteria move down the shoot, its tissues become discoloured (brown) and shrivelled. Older shoots that become infected after they develop about 20 leaves may not show the curling symptom at the tip. Bacterial exudation could occur on blighted shoots. As a result, petioles (leaf stalk) and mid-vein of leaves turn brown or black sometimes accompanied by bacterial ooze along the mid-vein. Dead leaves are attached to the shoot throughout the growing season and persist into the winter.

After blossom infection, immature fruitlets may be infected through internal invasion from an infected spur, through lenticels on fruit or through wounds caused by insects and mechanical damage (for example wind, hail) resulting in fruit blight. Infected fruitlets, appear shrivelled, dried, do not mature and appear mummified as they remain attached to the spur. Generally apple fruit exhibit a premature reddening of the area bordering the infection. Sometimes secretion of bacterial ooze from lenticels can occur on infected immature fruit. In some fruitlets flower parts may be infested with bacteria and these could get retracted into the calyx-end as the fruit matures. These bacteria in or on remnant flower parts remain protected in the calyx-end of mature fruit after harvest. Wounds caused by mechanical damage, especially hail storms, predispose mature fruit to infection. Such infections are easily recognisable. Although uncommon endophytic (internal) fruit infection may occur when fruit is located close to severely blighted shoots. Surface infestation of mature fruit may also occur as a result of bacteria spreading with rainwater splashed from infected sources present within the tree canopy and neighbouring infected trees.

Fire blight spreads from infected sites in blossoms, shoots or fruit through twigs to branches causing localised stem cankers causing canker blight. During rain or humid periods bacterial ooze could be seen on the surface of the cankers. When dry it remains as a hardened gummy substance on canker surfaces for several months. Bacteria may be spread by visiting insects , splashing rain or pruning tools. Two types of cankers are formed; 'determinate' and 'indeterminate'. In 'determinate' cankers (rough margins) the infected area is surrounded by callus tissue, these cankers generally become inactive and seldom serve as sources of inoculum the following spring. In contrast, the bacteria in most 'indeterminate' cankers (smooth margins) overwinter successfully to cause renewal of bacterial activity in the spring to continue the disease cycle. Canker blight may develop before, during or shortly after bloom depending on spring orchard temperature. Under favourable conditions the infection may spread into adjacent water spouts, the scaffold limbs and the main stem killing the tree.

Trauma blight develops as a result of infection following injuries associated with spring frosts, hail storms or damage to leaves, shoots and fruit by winds.

Rootstock blight can occur in most rootstocks but especially M.9 and M.26 dwarfing rootstocks on apples. Invasion of *E. amylovora* into the rootstock may occur through infected suckers or water sprouts, bacteria washed down from infected blossoms and twigs into the soil containing roots or internal translocation from infected scion wood. Rootstock blight often occurs at ground level below the graft union in the rootstock part of the tree. This type of blight frequently kills trees.

Survival:

In order to continue the disease cycle, *E. amylovora* must survive the winter on dormant host plants. *E. amylovora* survives almost exclusively in living bark tissues along the margins of overwintering (hold-over) cankers on hosts that have been infected in previous growing seasons (Brooks, 1926; Miller, 1929; Rosen, 1933; Parker, 1936; Schroth et al., 1974; Eden-Green and Billing, 1974; Beer and Norelli, 1977).

Survival of the pathogen in a proportion of cankers usually stops or is reduced during the period after leaf fall, when the temperature is low (Billing, 1974a). Often a corky layer is formed on cankers which arrests the spread of the pathogen into healthy tissue (Hockenhull, 1974). The activity of the bacterium was completely suppressed in symptomless woody stem tissues 11 weeks and 9 weeks after stem and root inoculation, respectively (Gowda and Goodman, 1970). This has been attributed to the defence mechanisms operating in the plant during the growing season and especially during dormancy. The host defence reactions have been identified as the reason for the failure to isolate *E. amylovora* from majority of cankers after the winter (Schroth et al., 1974). These cankers are likely to develop into inactive 'determinate' cankers. Cankers with 'indeterminate' margins are more likely to become active sources of infection than those with 'determinate' margins (van der Zwet, 1969; Beer and Norelli, 1977).

Cankers initiated earlier in the season were more likely to be 'determinate', and late-season infections on susceptible cultivars may carry-over inoculum to the following season as 'indeterminate' cankers (Biggs, 1994; Beer and Norelli, 1977). Earlier workers noted that a higher percentage of cankers were hold-over cankers on susceptible than on resistant cultivars (Brooks, 1926). Susceptible cultivars are more likely to develop cankers with 'indeterminate' margins (Biggs, 1994). The bacteria do not overwinter in the dead tissue of 'indeterminate' cankers but in living bark that surrounds them (Steiner, 2000a). Most, but not all cankers with 'determinate' margins are benign (Beer and Norelli, 1977).

Majority of cankers formed in one season do not become active hold-over cankers the following season (Thomson et al., 1975). Usually only a small proportion of cankers formed in the current season become active overwintering cankers and produce visible ooze the following year (Brooks, 1926; Miller, 1929; van der Zwet, 1969). Estimates of the proportion of active overwintering cankers are reported to vary from 2%–46% (Miller, 1929; Tullis, 1929) to 2%–11% (Brooks, 1926; Rosen, 1929; Pierstorff, 1931; Goodman, 1954; van der Zwet, 1969). Survival of *E. amylovora* has been demonstrated up to 2 years in healthy buds and tissues adjacent to old cankers in a controlled greenhouse experiment. The bacteria isolated were virulent on pear shoots (Keil and van der Zwet, 1972). The fire blight bacterium has also been isolated from cankers that were 1 and 1.5–2 years-old (Nachtigall et al., 1985), from wood in at least four year-old 'indeterminate' cankers (Beer and Norelli, 1977) or even from six-year old cankers (van der Zwet, 1969). Several investigators have indicated that cankers on older and larger trees are more important as potential sources of inoculum (Schroth et al., 1974; Beer and Norelli, 1977). However, the pathogen can also overwinter in twigs 3−13 mm in diameter and serve as important sources of inoculum (Parker, 1936), but detection of active cankers is sometimes complicated by the absence of definite margins (Tullis, 1929) and therefore are less likely to be removed during pruning (Beer and Norelli, 1977). The number of cankers required to initiate a fire blight outbreak may be as few as 1–4 per ha (Brooks, 1926; Tullis, 1929).

The multiplication of inoculum from overwintering cankers is influenced by environmental and host factors (Beer and Opgenorth, 1976). These authors indicated that in general, the canker activity is preceded by warm and moist conditions and that the number of bacteria increased at temperatures greater than 17°C and with rainfall. Few cankers were active immediately following very cool temperature (less than 5°C) or frost (Beer and Opgenorth, 1976). Exudation of ooze by new infections and hold-over cankers was favoured by relative humidity greater than 80% and temperature between 18.3°C–29.5°C (Brooks, 1926).

In spring, bacteria multiply at the margins and adjacent bark tissues of 'indeterminate' hold-over cankers that are active, often exuding drops of ooze containing viable bacteria that serve as the most important source of primary inoculum to start the disease cycle at blossoming (van der Zwet, 1969; Schroth et al., 1974; Beer and Norelli, 1977). The bacteria in ooze are usually virulent (van der Zwet, 1994). Bacterial ooze containing up to 10^{10} viable

E. amylovora cells/mL have been detected from host tissue, especially during warm humid periods (Beer, 1979).

The isolation of *E. amylovora* from overwintering canker surfaces 1–3 weeks before the occurrence of blossom infection has been confirmed (Beer and Opgenorth, 1976). The bacteria could sometimes multiply before the detection of bacterial ooze (Thomson et al., 1975) or even before the appearance of fire blight symptoms (Schroth et al., 1974; Thomson et al., 1975). Beer and Opgenorth (1976) reported that *E. amylovora* may be present on the surface of cankers apparently free from ooze (Beer and Opgenorth, 1976). They were able to detect *E. amylovora* sporadically throughout the growing season on cankers that were formed in the previous year. These authors also found that some cankers were active for most of the spring, others were temporarily active and in still others the bacterium was not isolated from the surface.

The pathogen can survive in dried ooze on host plants. Its survival in this state is strongly influenced by moisture status. Bacteria can survive in the dry exudate for over a year at low relative humidity (Rosen, 1938). Under dry conditions the pathogen survived in the ooze for more than two years (Hildebrand, 1939). The non-bacterial components of the ooze, which includes a polysaccharide (Beer, 1979), assist the pathogen to survive (Reinhardt, 1958; Beer, 1979). However, Hildebrand (1939) showed that the survival time of the pathogen was much shorter in the field under humid conditions. In general, survival of epiphytic *E. amylovora* is likely to be limited to a few weeks (Dueck and Morand, 1975; Maas Geesteranus and de Vries, 1984). Failure of *E. amylovora* to survive in ooze in the orchard may be attributed to the combination of high relative humidity and fluctuating temperatures (Rosen, 1938).

Blighted twigs can also serve as important sources of inoculum (Miller, 1929). Their size could vary. However, the majority of twigs that served as overwintering sites averaged 6 mm in diameter (Brooks, 1926; Miller, 1929). Bacteria were found in cankers formed on twigs as small as 0.4 cm diameter without the presence of visible ooze (Brooks, 1926; Ritchie and Klos, 1975). Bacteria have been recovered from non-oozing cankers (Miller and Schroth, 1972; Beer and Norelli, 1977).

The pathogen also survives as latent infections (Schroth et al., 1974; van der Zwet and van Buskirk, 1984) primarily in overwintering shoots (Gowda and Goodman, 1970; Keil and van der Zwet, 1972), which are likely to initiate cankers to serve as primary inoculum (Aldwinckle and Preczewski, 1976).

Survival of *E. amylovora* in hibernating shoots in the absence of disease symptoms has been reported by Crepel et al. (1996). These authors have detected fire blight bacteria in variable concentrations (10^3 and 10^7 cfu/mL of plant extract) in 30% of artificially inoculated and overwintered shoots. There is no consensus about the primary pathway for migration of the pathogen in plant tissues. Most studies indicate that there is rapid movement through xylem vessels (Rosen, 1929; Shaw, 1934; Crosse et al., 1972; Eden-Green and Billing, 1974; Aldwinckle and Preczewski, 1976; Huang and Goodman, 1976). Distinctive xylem streaking in advance of visible external symptoms have been observed (Aldwinckle and Preczewski, 1976). Other studies have detected the movement of *E. amylovora* in the phloem (Lewis and Goodman, 1965; Gowda and Goodman, 1970). Bacteria have been observed in phloem sieve tubes near canker margins (Miller, 1929). Where the pathogen persists in tissues as a latent infection, cutting-off of such tissues during the growing season could induce the formation of overwintering cankers that provide inoculum for the next season (Steiner and Suleman, 1993). Migration of the bacterium in the cortical paraenchyma has also been observed (Nixon, 1927; Eden-Green and Billing, 1974).

Systemic movement of bacteria has been recorded in excess of 15 cm in 7 h (Lewis and Goodman, 1965) and symptom development is reported to be up to 30 mm per day. When infected shoots were pruned at the base of visible symptoms, 57% of the stumps remaining on the tree developed fire blight symptoms (Clarke et al., 1991). They also demonstrated that pruning 20–25 cm beyond visible symptoms still produced disease symptoms in 12% of the cut stubs.

Erwinia amylovora is not a strict phylloplane epiphyte (Leben, 1965) but can only be present after blossom infection has occurred in the orchard (Miller and Schroth, 1972; Miller and van Diepen, 1978). Bacterium on apple leaves was not detected before infection (Crosse et al., 1972). However, the presence of *E. amylovora* epiphytically on apparently healthy leaves has been reported (van der Zwet and van Buskirk, 1984; Sholberg et al., 1988) who showed that 100% of the apple leaves sampled were contaminated with *E. amylovora* even after the fruit harvest in September. *E. amylovora* is a competent epiphyte capable of colonizing and multiplying on the surface of plants and it makes little difference whether the plants colonized are susceptible or resistant to fire blight (Steiner, 2001). Plant trash has the potential to be a source of inoculum, if present as a contaminant with apple fruit.

Erwinia amylovora has been isolated from buds during the winter and spring (Baldwin and Goodman, 1963). The role of buds as a source of primary inoculum is uncertain (Beer, 1979) but current scientific opinion is that buds are unlikely to be an important source in the transmission of the pathogen in orchards.

Early attempts to isolate *E. amylovora* from soil were negative (Pierstorff, 1931). The ability of *E. amylovora* (as *Bacillus amylovorus*) to survive in the orchard soil for a limited period during the growing season (up to 10 November) was demonstrated in Utah (Ark, 1932). However, when the soil was artificially inoculated with *E. amylovora*, viable bacteria were recovered from soil up to a maximum 54 days (Ark, 1932). Studies conducted later in Utah showed that up to 44% of isolates recovered from soil near blighted trees in the spring were *E. amylovora* (Thomson, 1969). The decline in *E. amylovora* cells is much higher in non-sterile than in sterile soil, where the number of living bacteria was stable over 11 weeks (Hildebrand et al., 2001). They showed that in untreated field soil *E. amylovora* declined rapidly, and the pathogen was no longer detected 5 weeks after inoculation. Bacteriophages that lyse *E. amylovora* are readily isolated from soil beneath apples and pears (Baldwin and Goodman, 1963; Vanneste and Pauline, 1990) but they are not specific to *E. amylovora* and often have a host range that includes several species (Hendry et al., 1967; Vanneste and Pauline, 1990). Resting spores are not produced by *E. amylovora*, and its survival in soil is not considered epidemiologically significant (Roberts et al., 1998). However, soil cannot be totally overlooked as a source of inoculum and suggested that bacteria are likely to be splashed on to foliage of nursery plants but are unlikely to contaminate flowers and shoot tips of plants in the orchard (Thomson, 2000).

The ability of *E. amylovora* to survive in bee hives for a limited period has been demonstrated but the transfer of bacteria from the hives to flowers is considered unlikely (Pierstorff and Lamb, 1934; de Wael et al., 1990). There is no evidence that *E. amylovora* overwinters in hives, but bees are important agents in the primary spread of inoculum (Pierstorff and Lamb, 1934; Hildebrand and Phillips, 1936).

Dissemination:

There are four principal forms in which *E. amylovora* occurs: ooze, strands, epiphytic bacteria, and endophytic bacteria (van der Zwet, 1994). (i) Bacterial ooze or exudate, originating mostly from active cankers in the spring, but also later from infected blossoms and shoots (Schroth et al., 1974). (ii) Dry bacterial strands on shoots and fruit (Keil and van der Zwet, 1972b) and strands in the form of thicker tendrils have been reported from lenticels of apple and pear (van der Zwet et al., 1988). (iii) Bacteria are present epiphytically on the surface of various host tissues including cankers, blossoms especially on stigmas, leaves, buds and fruits as well as in the calyx-end of fruit (Keil and van der Zwet, 1972). (iv) Endophytic bacteria present inside the xylem vessels (Aldwinckle and Preczewski, 1976) and in the phloem (Gowda and Goodman, 1970).

Several mechanisms are involved in the medium- to short-range dissemination of bacteria to blossoms, fruitlets, young leaves and actively growing shoots. They include crawling and flying insects (van der Zwet and Keil, 1979), wind (van der Zwet and Keil, 1979), rain (Thomson and Gouk, 1992), wind-driven rain (Bauske, 1967), aerosols (Southey and Harper, 1971) and aerial strands (Keil and van der Zwet, 1972b; Deckers and Heggen, 1989). Long-range spread of the pathogen occurs through contaminated propagative material (van der Zwet and Keil, 1979), possibly by aerial strands (dried ooze that consist of linear arrays of bacterial cells embedded in an ooze matrix) transported in air currents (Eden-Green and Billing, 1972) and by birds (Mazzucchi, 1994).

Although specific insects have not been identified in the primary spread of fire blight, several are definitely involved in the secondary spread. Insects are the most important agents of dissemination of *E. amylovora* (van der Zwet and Keil, 1979). These authors listed 77 genera of insects associated with the spread of the disease within and between orchards. Several crawling, browsing, flying insects or other animals have been identified as potential agents to spread ooze of *E. amylovora* from overwintering cankers to open blossoms (Schroth et al., 1974). Muscoid flies in large numbers have been detected in traps adjacent to ooze cankers, with a significant increase in the muscoid fly population on the traps a few days before the colonisation of flowers (Thomson et al., 1999). Ooze can contain 10^{10} cells per mL (Beer, 1979) and in this situation, insects are very efficient inoculating agents carrying up to 10^5 cells per insect (Miller and Schroth, 1972).

Pollinating insects are the most effective carriers of *E. amylovora* from infected or infested blossoms to non-infested blossoms. Honey bees (*Aphis mellifera* L.) because of their importance as pollinators have been intensively studied with regard to disease transmission (Keitt and Ivanoff, 1941; van Laere et al., 1981). Bees are recognised as important agents of disease transmission from flower to flower but not from overwintering cankers to flowers (van der Zwet and Keil, 1979; Thomson et al., 1992). Foraging bees visited about 400 blossoms per hour (Johnson et al., 1993). The estimated efficiency of bees to disperse *E. amylovora* from infested hives to pome fruit blossoms averaged 20 blossoms per hour of foraging activity (Johnson et al., 1993).

The flight range of bees in each foraging area is quite variable and is influenced primarily by the resource distribution, population levels of bees that are competing in the respective areas and the productivity of the plant (Gray, 1992). In general, bees have a strong tendency to forage at the nearest source for each floral species in the area (Gray, 1992). It has been observed that honey bees can readily fly 4 km in all directions of their hive (Hoopingarner and Waller, 1992). These authors also refer to the possibility of in-hive pollen transfer from bee to bee that has implications in the transfer of *E. amylovora* from contaminated pollen in the hive to blossoms. Experiments have demonstrated that honey bees were able to disseminate *E. amylovora* from beehives to healthy pear flowers for less than 48 h after initial contamination of the beehives with10^8 cfu per mL (Alexandrova et al., 2002). Bees from hives in a desert will fly as much as 13.7 km to a food source, if no other sources are closer to the hive (Eckert, 1933).

Some investigators (for example, (Brooks, 1926) consider water to be another important agent for spread of fire blight. Rain disseminates primary inoculum within orchards (Parker, 1936) from overwintering cankers to blossoms and young vegetative shoots (van der Zwet, 1994). Bacteria present at the top of the canopy were responsible for cone-shaped downward spread of the pathogen during rain (Miller, 1929). It also facilitates the movement of bacteria from the stigma to the hypanthium (floral cup) of blossoms, where infection generally occurs (Thomson, 1986). Dispersion of *E. amylovora* bacteria in water droplets has been demonstrated for short-distance (1 m at a wind velocity of 22 km per h, the maximum distance attempted) spread in wind-borne rain (Bauske, 1971). Air movement of 7 and 14 mph is capable of moving water droplets at least 40 inches, the usual distance between two rows (Bauske, 1971). Air samples collected during rain near active shoot infections with conspicuous ooze always contained *E. amylovora* (McManus and Jones, 1994) but only a few during dry periods. The dried ooze rehydrated quickly during rain and is splashed-dispersed during rain (Eden-Green and Billing, 1972).

Wind dissemination of bacteria could occur as tiny ooze droplets or strands over short- to medium-distances which have not been specified (van der Zwet and Keil, 1979). Wind acts primarily as a means of transport for insects, contaminated pollen (Hildebrand and Phillips, 1936), dry bacterial clumps, water-borne bacteria (Bauske, 1971) and aerial strands (Ivanoff and Keitt, 1937).

Infected plant tissues exude aerial strands of *E. amylovora* cells embedded in an ooze matrix (Eden-Green and Billing, 1972), which could serve as short-range inoculum sources under dry conditions (Ivanoff and Keitt, 1937) but the role of aerial strands as a source of inoculum is yet to be demonstrated (Ivanoff and Keitt, 1937). Aerial strands are readily broken off the plant surfaces and transported by wind currents (Bauske, 1967; Bauske, 1971). Bacterial strands are easily rehydrated in water (Keil and van der Zwet, 1972b). Once the strands are rehydrated, the bacteria are only viable for a few days (Eden-Green and Billing, 1972). The importance of bacterial strands in dissemination of the pathogen is still conjectural (Schroth et al., 1974).

Long-range dissemination could be over land or sea (van der Zwet, 1994). Most important factors that contribute to this method of spread are infected or infested nursery or propagative material (Schroth et al., 1974; van der Zwet, 1994). *E. amylovora* was isolated from buds of apple scion wood imported into Italy from The Netherlands (Calzolari et al., 1999). Birds have been implicated in the spread of fire blight (Norelli et al., 1984) but circumstantial evidence to correlate the distribution of the fire blight disease to the feeding and roosting habits of migratory starlings (Billing, 1974b) is not supported by scientific evidence. Deposition of solid aerosols transported by high altitude air currents (Mazzucchi, 1994) has also been implicated in long-range spread. These methods of spread of fire blight bacteria, except for movement through propagation material, are more difficult to study and conclusive evidence is lacking for several proposed means (Roberts et al., 1998).

Inoculum potential:

Epiphytic populations of *E. amylovora* were found predominantly on the stigmatic surfaces of pistils in blossoms, with populations often reaching 10^6-10^7 colony-forming-units (cfu) per healthy flower (Tomkins et al., 2000). The population of *E. amylovora* on the stigmas was usually greater than the population on the remaining flower parts by a magnitude of one to six log units (Thomson, 1986).

There is no accepted threshold number of bacteria that will cause infection. Research shows that the threshold may vary with environmental conditions (temperature, humidity, competitive ability etc.). A single cells could not cause infection on pear flowers in the greenhouse unless the blossoms were maintained at high humidity (Hildebrand, 1937). However, Hildebrand (1937) successfully inoculated receptacles of excised apple blossoms in moist chambers at 24°C. Inoculation with 1 bacterium per blossom resulted in 60% infection, the success rate with two bacteria per blossom was also 60% but with 5 or more than 10 bacteria per blossom infection rates increased to 80% and 100%, respectively (Hildebrand, 1937). Artificial inoculation of blossoms of pears in the greenhouse using 10^1 cfu per blossom was effective in 66% of tests vs. 91% effective for inoculations using 10^2 cfu per blossom (Ivanoff and Keitt, 1941).

Pear flowers inoculated with 10^2 cfu per blossom did not develop symptoms frequently, but symptoms are likely to develop in 5 days when inoculated at 10^7 cfu per blossom (Beer and Norelli, 1975). These authors also showed that the rate of disease development was slower when blossoms were inoculated with *c.* 10^4 cfu per blossom than with 10^6 cfu per blossom, but there was little difference in the rate of disease development between 10^5 cfu per blossom and 10^6 cfu per blossom. Similar observations were made when blossoms were inoculated with a bacterial concentration of 10^4 than with 10^6 cfu per blossom (Thomson, 1986). Only concentrations at 10^5 cfu per mL caused significantly greater blossom and cluster infection than the control treatment (van der Zwet et al., 1994).

Natural bacterial populations of 10^3 to 10^7cfu per blossom were detected on stigmas of pear blossoms of several rosaceous hosts in California and Utah, often without causing disease symptoms (Thomson, 1986). Low populations of *E. amylovora* inoculated on to healthy stigmas can multiply rapidly to high populations (up to10^5–10^6cfu/blossom) under optimum temperature (Thomson, 1986; Thomson et al., 1999). They showed that flowers were colonised rapidly over a period of 2–6 days but the incidence of blossom infection increased from 0%–100% usually in only 2 days. In contrast, infections were likely to occur when epiphytic population of *E. amylovora* in flowers reached 10^6–10^7cfu under high relative humidity and not at 10^2cfu (Beer and Norelli, 1975). These authors also showed that blossoms from orchards with populations of 10^7cfu generally developed into apparently healthy fruit. Rain and dew facilitates the transfer of bacteria from the stigma to the hypanthium or to the flower parts where infection may occasionally occur (Thomson, 1986; Thomson and Gouk, 1992), resulting in infection when the temperature is right. The movement of high populations of epiphytic bacteria from the stigma of apparently healthy blossoms to hypanthia explains in part how severe outbreaks develop following a rain storm (Thomson, 1986).

Severe fire blight symptoms (blackening of flower parts) were only seen in apple blossoms when stigmas of individual blossoms were inoculated with 10^7 and 10^8 cfu per blossom (Hale et al., 1996). Hale and Clark (1990) detected the pathogen from infected tissues in the blossoms using the DNA hybridization method and confirmed by a polymerase chain reaction (PCR) test. However, these authors found that with 10^5 cfu per blossom only slight browning of apple pedicels was observed but the bacterium was not detected. When blossoms were inoculated with 10^0–10^4cfu there were no disease symptoms and the pathogen was not detected in blossoms (Hale et al., 1996). When inoculated with 10^2–10^4cfu, *E. amylovora* was detected in blossoms and fire blight symptoms were not seen. The rate of development of fire blight was slower when blossoms were inoculated with 10^4 than with 10^6 cfu per blossom (van der Zwet et al., 1988).

Epiphytic populations of *E. amylovora* from 10^5–10^7cfu per healthy blossom have been detected on fire blight hosts in western United States (Thomson et al., 1982), but only a small percentage of blossoms developed fire blight symptoms and only very seldom did disease result in fruit infestation (Thomson, 1986). Although more than 50% of healthy flowers in some orchards were infested with *c.* 10^6 cells of *E. amylovora* per blossom, subsequent disease incidence was only 1–3 strikes per (Thomson et al., 1975). In New Zealand, epiphytic populations of *E. amylovora* in healthy flowers reached 10^4–10^6cfu per blossom during full bloom, but fire blight infection was less than 1 strike per tree (Thomson and Hale, 1987). The incidence of fire blight was always significantly less than the percentage of blossoms colonised (Thomson, 1986). This author showed that in many cases, 90%–100% of the blossoms were colonised, but less than 1% of the blossoms were infected. This author also showed that even with populations of 10^7cfu per blossom, these blossoms generally developed into apparently healthy fruit.

Several reasons have been attributed to the absence of blossom blight and these include insufficient inoculum to initiate an infection (Hildebrand, 1937), unfavourable environmental conditions prior to bloom (Powell, 1965) or during and after bloom (Mills, 1955), nonsusceptibility of blossoms (Thomson et al., 1975) or a combination of these factors. The age of flowers had an influence on the growth and establishment of *E. amylovora* (Gouk and Thomson, 1999). They showed that under New Zealand conditions 1-3 day-old blossoms supported exponential growth of *E. amylovora*, but the bacterial populations did not increase on blossoms older than 3 days.

Fruit infestation/infection:

Epiphytic survival of *E. amylovora* on symptomless immature apple fruit has been reported (Schroth et al., 1974; Hale et al., 1987). *E. amylovora* was detected in calyces of immature fruit sourced from orchards with no fire blight symptoms or with less than 1-2 strikes per tree, but with infected alternative hosts present in the vicinity of these orchards (Clark et al., 1993). These authors detected *E. amylovora* in 8.7% and 7% of fruit sourced from two orchards with no fire blight symptoms in one season. *E. amylovora* was detected in 50% of immature fruit sampled from orchards with severe blight (75 strikes per tree) (Hale et al., 1987). These authors showed that the fire blight bacterium was only occasionally detected in immature fruit from orchards with a low level of infection (1–2 strikes per tree). In New Zealand, a close correlation between results of orchard inspections for fire blight and the results of DNA testing of *c.* 60000 immature fruit for the presence of *E. amylovora* over three seasons has been demonstrated Clark et al.(1993).

Erwinia amylovora was detected from apple fruit harvested from infected orchards or trees which had fire blight infections (Goodman, 1954; Sholberg et al., 1988; Janisiewicz et al., 1986; Clark et al., 1993; Hale et al., 1987; Hale and Clark, 1990; van der Zwet et al., 1990). Isolation of *E. amylovora* from healthy mature apple fruit from trees in close proximity with severely blighted pear trees has been demonstrated (Sholberg et al., 1988). Recovery of *E. amylovora* from the calyx of two cultivars (cvs. Delicious and York) from a blight-free orchard in West Virginia has been reported (van der Zwet et al., 1986). *E. amylovora* was detected from 3% of mature fruit when the bacterium was detected in 50% of the immature fruit (Hale et al., 1987). These authors frequently isolated the pathogen from the calyx-end of fruit and rarely from washings from the main portion of the fruit. Hale et al. (1987). These authors indicated that the DNA technique used for testing could have detected both dead and live bacterial cells. *E. amylovora* was not detected in any fruit, even when harvested from trees with or directly adjacent to fire blight (Roberts, 2002).

Three DNA techniques were used to assess the calyx infestation of symptomless mature apple fruit (McManus and Jones, 1995). *E. amylovora* was detected in 4% of fruit in first round PCR (detection level 200 cfu), 27% of the fruit infestation using PCR-dot-blot hybridization test (detection level 20 cfu) and 75% infestation with nested PCR (detection level less than 1 cell), but these techniques did not allow the differentiation of DNA of dead cells from DNA in live cells. McManus believed that DNA came mostly from dead cells (AQIS, 1998a).

Erwinia amylovora was recovered from about 8% of apple fruit sampled from orchards in four growing regions in America and Canada (van der Zwet et al., 1986). These authors showed that of the fruit sampled, 7% had been harvested from severely blighted trees in an orchard and 1% from apparently healthy trees in another orchard. These authors (van der Zwet et al., 1986) have also found that the bacterial numbers exceeded 10^3cfu/fruit in the calyces of fruit harvested from blight-free orchards, when severe fire blight was present in the area (distances have not been specified).

Naturally infested apple fruit at harvest were contaminated with an average of $10^{3.3}$ cfu/mL of *E. amylovora* (Sholberg et al., 1988). The literature on the presence of *E. amylovora* on apple fruit in Canada, the USA, New Zealand was reviewed and it showed an average of 4.9% and 0.35% fruit infestation on apples drawn from orchards with active fire blight and without any consideration for fire blight, respectively (Roberts et al., 1998). The lower value reflects that only a proportion of orchards are likely to have active fire blight at any one time (AQIS, 1998a).

Erwinia amylovora was not detected in core tissues or washings from 1,555 mature symptomless fruit harvested from blighted trees of seven apple cultivars grown in five locations in Washington State (Roberts et al., 1989). The detection sensitivities for these tests were about 20 and 30 bacterial cells per fruit for external and internal assays, respectively. Similarly, epiphytic populations of *E. amylovora* were not found on mature symptomless apple fruit (cv. Wealthy) harvested from naturally infected trees in Canada (Dueck, 1974a).

The calyces of apple were inoculated with *E. amylovora* with *c.* 10^6 cfu per mL and hung in orchard trees at flowering (Taylor et al., 2002). These authors showed that the bacterial population declined to 10^2 cfu per mL during the 20-day sampling period and they could not detect the pathogen either in rainwater or on insects trapped and tested. The bacterial population in calyces infested with 10^3 cfu per mL were reduced to 10^3 cfu per mL (Taylor et al., 2002) and they concluded that *E. amylovora* in calyces of apple were not transferred to susceptible hosts even under conditions conducive for infection.

Recovery of endophytic populations of *E. amylovora* has been reported from fruit harvested close to visibly blighted shoots (van der Zwet et al., 1986). These authors reported that fruit from which the pathogen was recovered were attached within 30 cm of severely blighted shoots but the pathogen could not be isolated from fruit picked 60 or 200 cm away from the same source of infection. These authors showed that fire blight bacterium was not detected from core tissues of apple fruit of four cultivars harvested from apparently healthy trees grown in four regions of North America (Utah, West Virginia, Washington, Ontario). In West Virginia, none of the fruit harvested from apparently healthy trees (cvs. York and Delicious) in blighted orchards contained internal populations of the pathogen (van der Zwet et al., 1990). These authors could not recover the bacterium from 100 fruit of four resistant cultivars grown in West Virginia and 210 fruit (cv. Delicious) collected in Washington State. *E. amylovora* could not be detected in fruit harvested from blighted trees of seven apple cultivars grown in five locations in Washington State (Roberts et al., 1989).

Erwinia amylovora was not recovered from internal tissues of mature apples harvested from trees with or without fire blight in Ontario (Canada), West Virginia or Washington (van der Zwet et al., 1990). *E. amylovora* was not detected in washings of fruit harvested from orchards with low level (1–2 strikes per tree) or no infection (Hale et al., 1987). *E. amylovora* could not be detected either from calyces of immature and mature fruit or on the surface of mature fruit sampled from within 5 cm even after heavy inoculation of open blossoms in adjacent blossom clusters (Hale et al., 1996). *E. amylovora* was not detected in calyces of either immature or mature apple fruit even from within 20 cm of inoculated sites (Clark et al., 1993).

The role of fruit as a vector of fire blight disease has been questioned (Schroth et al., 1974). The Ministry of Agriculture and Fisheries and Food in UK (Ministry of Agriculture, Fisheries and Food, United Kingdom, 1969) considered that fruit is unlikely to spread the fire blight bacterium, *Erwinia amylovora*. Mature healthy fruit harvested from blighted trees do not appear to be a suitable substrate to carry *E. amylovora* (Roberts et al., 1989). It has also been shown that *E. amylovora* was not present on mature fruit harvested from blighted trees in Canada (Dueck, 1974a; McLarty, 1923).

Survival of *E. amylovora* in mature apples has been reported after a period of cold storage, when high inoculum doses were injected into the apple cortex (Anderson, 1952; Goodman, 1954; Dueck, 1974a; Nachtigall et al., 1985). Populations of surface bacteria declined to a non-culturable level on artificially-infested and naturally contaminated apples after five months in cold storage at 2ºC (Sholberg et al., 1988). The culturability of *E. amylovora* in calyces of apple fruit was lost during cold storage and the bacterium could not multiply to culturable levels when the temperature is increased to *c.* 20ºC (Hale and Taylor, 1999). Fruit harvested from blighted and blight-free orchards adjacent to infected orchards developed rots in storage (van der Zwet et al., 1986). However, they could not isolate *E. amylovora* and found it difficult distinguish the symptoms from other rots. Storage of apple fruit (*c.* 30,000) sourced from trees adjacent to infected trees when cold stored for 2-3 months did not develop external and internal disease symptoms and *E. amylovora* was not isolated (Roberts, 2002). Population levels of *E. amylovora* on apple calyces decreased from 10^6 cfu to 10^2 per fruit over a 20-day period in cold storage (Taylor and Hale, 2003). These authors also observed that *E. amylovora* on apple calyces infested with 10^4 cfu per fruit decreased to non-culturable levels after 14 days. Similarly, calyces infested with 10^2cfu per fruit decreased to non-culturable levels after eight days in cold storage. The PCR assay detected *E. amylovora* in calyces infested with 10^6 cfu and 10^4cfu per fruit after 20-day period of cold storage but not in calyces infested with 10^2cfu per fruit (Taylor and Hale, 2003).

Control:

Routinely most orchardists remove as much infected limbs as possible during the dormant season with the aim of reducing the primary inoculum and also to maintain a high proportion of fruiting wood and to control the tree size and shape. This is followed by an early-season copper spray, at the green tip stage of bud development, to reduce the efficacy of any remaining inoculum (van der Zwet and Keil, 1979). To enhance the efficacy of copper and also to improve the overall efficacy of the orchard pest control program, oil is usually added to copper. It is aimed at reducing the inoculum or multiplication of *E. amylovora*, thus preventing the development of new blossom infections (Psallidas and Tsiantos, 2000).

Application of chemicals during the blossoming period aimed to protect flowers from infection and prevent a build up of inoculum for shoot infections. In New Zealand antibiotics such as streptomycin are used at blossoming. These applications are based on computer forecasting programs. In Europe, other chemicals such as flumequin (Firestop™, Fructil™) which is a non-antibiotic are used (Deckers et al., 1990). Other chemical that have been tried are oxytertracycline, Kasugamycin, Oxolinic acid, Fosetyl-aluminium (fosetyl-Al) (Psallidas and Tsiantos, 2000). Development of strains resistant to some chemicals have caused problems in the management of fire blight. Streptomycin resistant *E. amylovora* strains have been detected in USA (Shaffer and Goodman, 1985) and in New Zealand (Thomson et al., 1993). The development of oxolinic acid resistant *E. amylovora* strains have been reported in several sites in northern Israel. However, the persistence of these populations depends on the fire blight management measures undertaken by growers (Kleitman et al., 2005).

Prohexadione-calcium (Apogee™) suppresses both shoot growth and fire blight in young apple orchards when fewer high doses (125 or 250 mg/litre) than multiple low doses of the chemical are applied (Norelli and Miller, 2004). In indoor experiments involving artificial inoculation, pre-treatment with Prohexadione-calcium (2 applications of 125ppm, 32 and 22 days before inoculation) effectively controlled fire blight blossom infections to the same degree as streptomycin (100 ppm). In trials on shoot infections, Prohexadione-calcium (Pro-Ca) treatment (100 or 200g Regalis per 100 litres) 15 days before inoculation resulted in better control of fire blight compared to streptomycin (streptomycin 20 wp at 0.5 kg/ha) or Kasugamycin (Kasumin 2 l at 4 litres/ha) treatment applied several hours before inoculation (Rubán et al., 2003). Although Pro-Ca is inactive as a bactericide or fungicide, it acts primary by inducing the formation of flavonoids (Roemmelt et al., 2003) in particular luteoforol, with phytolexin-like properties (Rademacher, 2003).

Biological control of fire blight occurs when bacterial antagonist establishes and develops a large population on the stigmatic surface prior to the establishment of *E. amylovora* (Wilson and Lindow, 1993). Some of the antagonistic strains are commercially available and some others are in experimental stage. The bacterial species *Pseudomonas fluorescens* A 506

(*Pf*A506) and *Erwinia herbicola* strain C9-1 (*Eh*C9-1) (syn. *Pantoea agglomerans* strain C9-1) have been widely tested to suppress floral infection by *E. amylovora* (Vanneste, 1996). Competition for nutrients or sites (Wilson and Lindow, 1993) and antibiosis (Vanneste et al., 1992) are the mechanisms involved in the antagonism. *P. fluorescens* A506 suppresses fire blight through competitive exclusion of *E. amylovora* on the surfaces of blossoms, the primary infection court, whereas Eh252 and C9-1 produce antibodies that are toxic to *E. amylovora*. A506 produced an extracellular protease [proteinase]. A partially purified extracellular protease inactivated the antibiotics mccEh252 and herbicolin O, which are produced by Eh252 and C9-1 respectively (Anderson et al., 2004). *Pf*A506 is available commercially as BlightBan A506™ (Johnson and Stockwell, 2000). A new strain of *Pantoea agglomerans* (P10c) isolated from pears in New Zealand has shown to be the most effective for control of fire blight (Vanneste et al., 2002a). It is the major component of a commercial product now on sale in New Zealand.

In Germany, three bacterial antagonists, strain Pa21889 of *Pantoea agglomerans*, strain BsBD170 of *Bacillus subtilis* and strain Ra39 of *Rahnella aquatilis* were tested against blossom blight (*E. amylovora*) under artificial and natural conditions and compared with streptomycin. All the antagonistic strains gave a significant reduction (43–81%) of the disease (Laux et al., 2003). A newly registered biocontrol product Biopro®, based on the antagonist *Bacillus subtilis* strain BD170, is being used in Switzerland. A specific molecular marker used for monitoring the spread of this agent on blossoms indicate efficient primary colonisation of pistils of flowers by foraging honey bees. Secondary colonisation was found to be dependent on the timing of treatments relative to bloom stage in the orchard (Broggini et al., 2005).

Apple scion and rootstock breeding programs have been initiated (Lespinasse and Aldwinckle, 2000). Four resistant rootstocks have been released from this program (Robinson et al., 1997).

Quantitative detection:

A method of sampling pear blossoms and estimation of the incidence of blossom colonisation by *E. amylovora* has been developed using a coliform agar (Kritzman et al., 2003). This medium enabled the diagnosis to be completed within 36 h and was used to determine the spatial distribution of colonised blossoms in the orchards.

Real-time PCR could be useful for quantitative detection (50 cells per assay) and therefore mass screenings of *E. amylovora*. Neither the presence of other bacteria nor low amounts of tissue extracts from bark or leaves changed the signal threshold (Salm and Geider, 2004).

The electronic nose uses an array of chemical sensors, where each sensor has only fractional specificity to a wide range of odour molecules, connected with a suitable pattern recognition system. In this, the electronic nose with 12 polymer sensors discriminated between plant pathogenic bacteria belonging up to 7 species from 7 different genera including *E. amylovora*. It was successful in correct classification (90%) of the 7 bacterial species. Thus, the electronic nose is considered a rapid, sensitive, specific, non-destructive and easy-to-use technique for detection and identification of plant pathogenic bacteria (Momol et al., 2004).

Appendix 3 – Data sheets – Apple leafcurling midge

Dasineura mali Kieffer (1904) [Diptera: Cecidomyiidae]

Synonyms and changes in combination:

D. mali (Kieffer) was originally described in the genus *Perrisia*; *Dasyneura mali* (*sic*, misspelling of *Dasineura*); *Cecidomyia mali* (Kieffer, 1904).

Common name(s):

Apple leafcurling midge (ALCM), Apple leaf-curling midge, Apple leaf midge.

Host(s):

Malus domestica (apple). Apple trees are the only host of the apple leaf-curling midge, infestation can differ between apple cultivars, although this can vary through the season depending on the availability of shoots suitable for oviposition however, no apple cultivar has been found to be free from infestation (CABI, 2005).

Plant part(s) affected:

Leaves, terminal shoots, larvae can pupate on fruit.

Distribution:

Austria, Belgium, Bulgaria, Canada (New Brunswick), Central Russia, Czechoslovakia (former), Finland, France, Germany, Hungary, Italy, Macedonia, Netherlands, New Zealand, Norway, Poland, Romania, Russian Far East, Siberia, Sweden, Switzerland, USA (Massachusetts, New York), Yugoslavia (former) (CABI, 2005).

D. mali is presumably native to the Palaearctic region, where it will have originally adapted to cultivated apple (CABI, 2005). Country records for the Palaearctic were summarized by (Skuhrava, 1986). *D. mali* has been accidentally introduced into North America; Massachusetts in 1928 and was recorded in New Brunswick in 1964 (MacPhee and Finnamore, 1978; Gagné, 1989) and New Zealand in about 1950 (Berry and Walker, 1989; Gagné, 1989). Apple leafcurling midge has been recorded in New Zealand apple orchards from Clyde to Auckland and is probably found wherever apple trees can be grown (Tomkins, 1998).

Biology:

The following biological data is taken from several sources, most notably (Allison et al., 1995; CABI, 2005; Harris et al., 1996; HortResearch, 1999b; Todd, 1959; Tomkins, 1998).

(Harris et al., 1996; HortResearch, 1999b; Todd, 1959; Tomkins, 1998)Apple leafcurling midge is a gall midge, a fly with four life stages: adult, egg, larva (or maggot) and pupa. The larvae cause severe distortion (galling) of young leaves.

The adult apple leafcurling midge is a small fly, 1.5 to 2.5 mm long, with dusky wings 1.5-2 mm long covered in fine dark hairs. Female midges have a characteristic red abdomen, and the antennae of male and female adults can be used to distinguish the sexes. The adult females are very docile when approached, and can be readily observed laying eggs on the apple shoots. Although leaves are the preferred site for oviposition (egg-laying), eggs may also be laid under the bracts of buds and on developing flowers in spring, when fewer leaves are available. Eggs are transparent pink to orange-red in colour and cigar-shaped, approximately 5 times as long as wide. They are sometimes laid singly but are usually in groups (sometimes large groups) on the margin or upper side of unfolding leaves. Their bright colour makes them easily visible on shoot tips using a hand lens, and this is used when monitoring populations. A maximum of 500 eggs per leaf has been recorded, although 30-40 eggs per leaf is more typical. Eggs take 3-10 days to hatch depending on prevailing temperatures. Larvae are legless maggots. They are red-coloured when they hatch from the eggs, then change to clear-white until the final instar (stage), when they become a bright orange/red colour. They need about 20 days to reach maturity in summer. The larvae spend most of their life within a rolled leaf that typically contains 20-30 larvae, with the number varying from 1-500. Often both margins of infested leaves are rolled towards the midvein but sometimes only one margin is rolled. The edges of two leaves may also be rolled together, especially on spur growths where leaves are clustered. Larval feeding prevents the opening leaf from unfolding, with the roll becoming tighter as the leaf growth continues.

Once larvae mature, they leave the leafroll and crawl or fall to find a site to pupate. Most descend to the ground and crawl under the soil surface. The largest numbers of larvae escape from rolled leaves when they have been thoroughly soaked by rain. A few larvae may remain inside their rolled leaf to pupate, while a larger proportion (10% or possibly higher) may crawl down the trunk of the tree and pupate under the loose bark or around pruning cuts. Some mature larvae, dispersing from their leaf rolls, get caught up on and use apple fruit as a cocooning and pupation site. They construct and firmly attach their cocoons to the fruit skin, at the stalk or calyx ends. Only a single cocoon contaminates most fruit, although up to 40 cocoons per fruit have been found under extreme populations. The larvae spin tough, white silken cocoons which are mainly just beneath the surface of the ground, among debris or loose pebbles of earth, or fastened to bark. The pre-pupa (the stage between larva and pupa) has the same orange colour as mature larvae and is clearly visible inside the cocoon.

The larva transforms to an orange pre-pupa inside the white cocoon. During the summer generations, the pupal stage lasts 13-18 days. For the overwintering generation, the midges remain as mature larvae or pre-pupae inside their cocoons over the winter and then pupate in spring. The fully developed mature brown-coloured pupa works its way partially out from the cocoon before the adult fly emerges.

Damage

Apple leafcurling midge larvae can feed on apple leaves, flowers, and young fruits. Flower and fruit damage occurs when high populations of apple leafcurling midge occur in early spring during flowering. Larvae developing from the eggs laid on flowers can affect developing fruitlets resulting in fruit whose skin is distorted by bumps. The flower stems and petals can also be distorted. Feeding on shoots and leaves is the most common form of damage. The larvae attack the edges of the young unfurling leaves of apple shoots and tight rolls (galls) develop containing the larvae. It is the tightness of the rolls that distinguishes them from the loose leaf-rolls made by leafroller caterpillars. There is also a reddening, and later browning, of the midge leaf rolls as the larvae mature and the leaves age. Old rolls are dry and brittle and may break up. At the tips of the shoots, two or more young leaves may become rolled together resulting in major shoot distortion. This rolling may prevent the leaves from fully expanding and they may drop prematurely. Leaf and shoot damage to young trees and grafts can be very severe, resulting in poor shoot development, and distorting the shape of the developing tree. On the other hand, mature trees can tolerate the shoot damage encountered with normal populations of the midge. It is only where there are extremely high populations, that crop yields may be affected. Leaf and shoot damage may affect crop yields, with field trials conducted overseas showing that where insecticide applications reduced tree infestation by apple leafcurling midge, an average yield increase of 10% occurred on apple trees (Kolbe, 1982). Apple leafcurling midge has been shown to reduce photosynthesis in damaged leaves and has also been implicated in the incidence of fire blight in apples however they do not vector fire blight (Gouk and Boyd, 1999).

Life cycle

The number of generations of apple leafcurling midge completed each year decreases from north to south in New Zealand. There are 6-7 generations annually in the north of New Zealand. Populations in the north reach particularly high levels in the wetter regions (for example, the Waikato), whereas dry weather and the cessation of terminal shoot growth often prevents population build up during mid- and late-summer on the east coast (for example, Hawke's Bay). Only the first two generations in spring are discrete, and there is considerable overlap in the later generations. This overlapping of later generations also occurs in Palmerston North, Nelson and Marlborough in central New Zealand, where there are usually 5 generations per year. Further south in Canterbury and Otago, the 4 generations are more discrete, although this varies from season to season and the timing of generations is influenced by temperature, drought conditions, and rainfall episodes. Summer droughts can have a major influence on both the abundance and phenology (life cycle timing) of apple leafcurling midge. Rainfall softens the leafrolls and makes it easier for mature larvae to escape; delays of up to 10 days can occur in this process in the absence of rainfall. Studies in the southern North Island have shown that the length of a generation cycle varies from over 50 days in spring to 35-40 days in summer. In the southern South Island, the equivalent periods are from over 60 days to about 40 days.

Life history

The apple leafcurling midge overwinters as a dormant, cocooned larva in the top 7.5 cm of surface soil and in debris beneath apple trees, with some also cocooned on the bark. The larvae pupate in spring and the adults of the first generation lay eggs from pre- to post-flowering depending on temperatures and latitude. Pupation occurs from budburst in the north, from just pre-flowering in central New Zealand, to flowering in the south. This discrete adult emergence and associated egg-laying is completed over the flowering/post flowering period. The eggs are laid in batches mainly on the edges of unfurling leaves in the tips of growing shoots, although this spring generation also uses bracts and flowers for egg laying. Like the first generation, the second is also discrete in all regions, but overlapping of generations increases subsequently, particularly in the north.

Studies have shown that volatile chemicals released by apple foliage are important in host-finding behaviour of female apple leafcurling midges. The female selects very young leaves for egg laying, normally only those leaves, which are just beginning to unfold in the shoot tips, or are up to about two-thirds unfolded. She also prefers undamaged shoots that are growing vigorously. However, on heavily infested trees, a few eggs may be laid on older leaves with existing larval infestations. Females also share the same shoot when egg-laying with individual females ovipositing on several leaves. Young foliage is more attractive to the females than mature foliage, and the response is greater in the afternoon than the morning. This appears compatible with a daily pattern in which mating dominates in the morning and oviposition later in the day. The ability to see the apple foliage plays a much lesser role in host finding than the chemical cues. Unlike the females, male apple leafcurling midges do not respond to the odour of apple foliage.

Field evidence indicates that adult midges live only a few days (perhaps up to a week). Swarming of adults has been observed to precede egg laying by the females, and mating is assumed to occur in these swarms. The female produces a pheromone that attracts the males for mating (Harris et al., 1999). Most eggs are laid in groups and on the upper edges of the unfurling leaves; one female may lay up to 200 eggs. Depending on temperatures, the eggs require 3-10 days for development, and the larvae take a further 20-30 days to reach maturity, when they start leaving the ends of their leaf rolls to seek cocooning sites. This is usually beneath the trees on which they developed and population dispersal is mainly achieved by the winged adult flies. Laboratory studies indicate that the pupal stage is completed in 13-18 days, and that adults live 2-6 days. Adults in the field or in breeding cages have also been observed to live only a few days.

Adult eclosion showed a diel periodicity, peak eclosion occurring between 06:00 and 10:00 hours. Within this period, peak male eclosion typically occurred 1-2.5 hours earlier than peak female eclosion. No adults emerge after noon. For males, wing fanning, mating and flight first occurred, on average 30, 32 and 41 minutes after eclosion, respectively. For virgin females, calling behaviour and mating first occurred, on average 16 and 38 minutes after eclosion, respectively. Calling events were of variable duration (0.3-55 minutes) and occurred most frequently between 09:00 and 15:00 hours. The sex pheromone of apple leafcurling midge has not been identified. Males of apple leafcurling midge do not respond to calling virgin females of pear leafcurling midge. Males mated many times, whereas females mated only once or twice. After mating, females sat for approximately 1hour before taking their first flight. Males are most active or abundant in the area under the tree canopy rather than in the canopy itself. This is probably linked to the emergence of females from the soil (Harris et al., 1999).

A series of 4-7 generations are completed over the summer, the number again depending on latitude and temperature. Female midges seek out actively-growing shoots to lay their eggs, and the numbers of available healthy shoots has a major impact on the success of each generation. The surge of new growth in early summer is particularly suitable for rapid population increase in the second and third generations, while the cessation of growth in mid- to late-summer often helps to reduce late season populations. This effect is most pronounced in dry seasons and regions. In addition, adult females lay few eggs on shoots already damaged by the midge. The larval stages cause tight curling of the edges of leaves, with from 1-500 larvae on a single leaf.

Reproduction

Sexual reproduction is obligatory in apple leafcurling midge. Virgin females produce a sex pheromone that attracts males for mating, and swarming of males has been observed around virgin female midges. Males are not attracted to mated females, including those mated just 1-2 hours previously. Females mate once or twice, whereas males mate many times. For example, males have been observed to mate an average of 11 times in 30 minutes.

Rainfall is important in the emergence of the fully developed midge larvae from their tightly-rolled leaf galls. Under drought conditions, larvae are unable to leave the rolls and the delay in this process limits the numbers of generations of midge that can be completed in summer. Drought conditions also limit the production of new shoot growth essential for egg laying by female midges. However, the level of mortality, which can be attributed to drought, has not been determined.

Population dynamics

The apple leafcurling midge has not been studied in detail in New Zealand or any other country. Research in Palmerston North in the 1950s showed that the greatest population increase of apple leafcurling midge occurred in the second and third generations. This was mainly attributed to the abundance of growing shoots at this time available for egg laying by females, which have a strong preference for vigorous undamaged shoots. Later generations of the midge suffer from a lack of undamaged vigorous terminal shoots, and populations often decline in late summer under these conditions. This is strongly affected by the level of rainfall. Where this is abundant and terminal growth continues, the later generations can be devastating, as has occurred in the Waikato in the 1990's and 2000's. Apart from providing abundant egg-laying sites through terminal growth, rainfall also softens the leaf galls and allows undelayed emergence of fully-developed larvae. The abundance of vigorous shoots on young trees and grafts are a further demonstration of the importance of this factor. Very high populations and damage can occur on these trees.

Research in the 1990's and 2000's has generally confirmed these findings. However, another major factor affecting midge populations today is the apple cultivar. Modern cultivars vary considerably in their susceptibility to damage, with Gala types and cultivars with Gala parentage associated with highest midge populations. Major varietal differences in susceptibility have also been reported from the U.S.A. The mechanism causing this effect is unknown.

Dispersal

The dispersal of apple leafcurling midge has been little studied. Both adult male and female are winged. Maximum flight activity has been observed under warm, calm conditions, although small numbers have been seen on the wing even when the weather is cool, overcast, and windy. The adult life of both sexes is only a few days (range 2-6 in laboratory studies), limiting long distance migration. Nevertheless, some researchers consider them strong fliers able to disperse well in wind, and apple leafcurling midge has a history of rapid spread when introduced to new areas.

Long distance movement of apple leafcurling midge has been achieved by a mixture of adult flight and the transportation of infested apple trees. The latter is particularly likely given the frequent infestation of nursery trees by the midge and its liking for spinning cocoons in the soil beneath the trees. This is a favoured overwintering site and midges could readily be associated with nursery trees being despatched for planting in winter. Apple leafcurling midge is reported to have arrived in the North Island of New Zealand on apple stocks shipped from the Netherlands (1950), and was probably transported to other parts of New Zealand on nursery trees in the years following its introduction. By 1956, it was already present in many North Island locations.

Natural enemies

A small complex of natural enemies is known to attack apple leafcurling midge in New Zealand. In the absence of insecticides, these natural enemies combine with other factors (for example, dry conditions, cultivar 'resistance') to often maintain midge populations below economic damage levels. In wet warm seasons, when there is abundant shoot growth for the midges to lay eggs, the populations may increase to damaging levels despite the activities of natural enemies. This is particularly likely on some susceptible cultivars (for example, Gala and Gala types), and on young apple trees and grafts producing numerous growing shoots. The contributions of the different predators and parasites in reducing apple leafcurling midge numbers are not well understood but the most important natural enemy both here and in

Europe is the wasp *Platygaster demades* (Walker). Parasitism in New Zealand ranges from 40% in the first generation of the midge to >90% in the final summer generation. However, lack of synchronisation with the second generation of the midge results in low parasitism (1-3%) in early summer which allows rapid population increase at that time.

Larvae of apple leafcurling midges are susceptible to predation when seeking cocooning sites, by spiders, predatory beetles, predatory bugs, and ants. Similarly, the cocooned larvae may be susceptible to attack by ground predators, particularly through the long overwintering period. This natural mortality of apple leafcurling midges has not been studied.

In New Zealand, other predators of the apple leafcurling midge include a native dolichopodid fly, *Chrysosoma mobile* (Hutton), and a native damsel fly, *Australestes colensonis* (White). In addition, the whirligig mite, *Anystis baccarum* (L.), is a general predator, which is abundant in apple orchards feeding on a range of insect eggs and young larvae including apple leafcurling midges.

The known natural enemies of apple leafcurling midge in New Zealand are: birds (unspecified), European earwig, *Forficula auricularia* L., an introduced predatory anthocorid bug (pirate bug) *Orius vicinus* (Ribault), a small black parasitoid wasp *Platygaster demades* (Walker), an introduced predatory and plant-feeding mirid bug *Sejanus albisignata* (Knight), and a predatory phytoseiid mite *Typhlodromus pyri* Scheuten.

Control

There are several cultural factors that can contribute to the management of apple leafcurling midge. The selection of apple scion varieties, soil cultivation, mulching and ensuring the planting of midge-free stock, can all play a part. Tree training, irrigation, and nutrition may also affect midge abundance.

There is strong evidence that apple scion cultivars differ in their susceptibility to apple leafcurling midge. Among modern cultivars, 'Braeburn', 'Gala' and 'Royal Gala' types are particularly prone to infestation, as are other varieties, which include 'Gala' in their parentage (for example, 'Pacific Rose') (Smith and Chapman, 1997). The timing of peak egg laying has also been found to vary between cultivars, such as being earlier on 'Royal Gala' than on 'Braeburn'. Major varietal differences in susceptibility have been reported from U.S.A. (HortResearch, 1999b) and Germany (Kolbe, 1982). Early studies in the U.S.A. of 12 varieties ranked 'Delicious' as prone to severe infestation, 'Gravenstein' and 'Red Gravenstein' as only moderately affected, and infestation of 'Wealthy' as minimal (HortResearch, 1999b). Cox’s Orange Renette, Frieherr von Berlepsch, Golden Delicious, Karmjin de Sonnaville, Melrose and Roter Boskoop were heavily infested in 1982 while there were no signs of infestation on other (unspecified) cultivars (Kolbe, 1982). The mechanism causing this effect is unknown. In New Zealand apple leafcurling midge infestation can also differ between apple cultivars, although this can vary through the season depending on the availability of shoots suitable for oviposition.

Soil cultivation just prior to the emergence of adult midges from pupation sites in the soil has been shown to reduce midge populations by up to 99%. This may be an option of special value in young blocks of trees, which are particularly susceptible to structural damage by the midge affecting terminal growth. Addition of mulches that result in the midge cocoons being buried at greater depth is also reported to reduce adult emergence.

One of the primary methods of dispersal of apple leafcurling midge in the past has been through midge-infested stock from nurseries. Care should be taken to ensure that young trees are free of infestation when despatched from the nursery.

Other cultural techniques, which might be used to influence apple leafcurling midge populations, are tree training, irrigation, and nutrition. The success of this pest is strongly influenced by the numbers of vigorous growing shoots and the duration of new growth. Over vigorous vegetative growth that favours the midge should not be encouraged at the expense of efficient fruit production. An increase in the abundance of apple leafcurling midge in Switzerland was attributed in part to increased fertilization with nitrogen.

Biological control of apple leafcurling midge is usually very effective, provided chemicals toxic to its natural enemies are avoided. Within the complex of natural enemies, the most important is *Platygaster demades*, a parasitoid wasp that causes high mortality of midge larvae. *P. demades* is today common in organic orchards and in orchards practising IFP. Care should be exercised to avoid toxic pesticides. This parasitic wasp and other natural enemies are susceptible to organophosphates.

There are some natural enemies of apple leafcurling midge overseas which are not present in New Zealand. These include an egg parasitoid (*Torymus* sp., Torymidae), an unnamed larval ectoparasitoid, a eulophid, *Eulophus nebulosus* and several predatory anthocorid bug species.

Since the 1960's, chemical control of apple leafcurling midge has been based on the use of organophosphates. These highly toxic chemicals have provided effective control of apple leafcurling midge and other pests but they have had the disadvantage of toxicity to many natural enemies. More recently, insect growth regulator compounds have been developed for insect control. These are more selective chemicals usually allowing survival of many natural enemies. Unfortunately, there is no insect growth regulator yet developed which is effective against apple leafcurling midge, and chemical control still relies on organophosphates. The apple leafcurling midge parasite, *Playgaster demades*, is so important for control of this pest in IFP and organic production that every effort is now being made to eliminate the use of chemical control, and to rely instead on biological control for this pest.

Where organophosphate sprays are still required for the control of apple leafcurling midge in summer (for example, use of diazinon based on monitoring), these uses must be efficiently integrated with the control of other pests, such as Woolly Apple Aphid and scale insects. Organophosphate spraying may be especially required to protect young apple trees and young grafts from damage by apple leafcurling midge. A major increase in the pest status of apple leafcurling midge in the 1990's was thought at first to be related to insecticide resistance. However, tests showed that this was not the case and there are no reports of apple leafcurling midge in New Zealand developing resistance to insecticides (HortResearch, 1999b).

Appendix 3 – Data sheets – Brown-headed leafroller

Ctenopseustis herana (Felder and Rogenhofer, 1875) [Lepidoptera: Tortricidae]

Ctenopseustis obliquana (Walker, 1863) [Lepidoptera: Tortricidae]

Adapted from HortResearch (1999b).

Synonyms and changes in combination:

Ctenopseustis herana: Cacoecia charactana Meyrick, 1881; *Tortrix herana* Felder & Rogenhofer, 1875; *Cacoecia inana* Butler, 1877; *Ctenopseustis herana* (Felder & Rogenhofer); *Ctenopseustis obliquana* Type II of Foster et al. (1986), Foster and Dugdale (1988) (Dugdale, 1990; MAFNZ , 1999b)

Ctenopseustis obliquana: Teras obliquana Walker, 1863; *Sciaphila transtrigana* Walker, 1863; *Sciaphila turbulentana* Walker, 1863; *Teras spurcatana* Walker, 1863; *Tortrix ropeana* Felder & Rogenhofer, 1875; *Cacoecia charactana* Meyrick, 1881; *Ctenopseustis obliquana* Types I and III of Foster et al. (1986); *Ctenopseustis obliquana* Types I of Foster and Dugdale (1988) (Dugdale, 1990; MAFNZ , 1999b).

Common name(s):

Brown-headed leafroller (BHLR).

Host(s):

Brownheaded leafroller caterpillars have been recorded on more than 200 plant species. While many of these are true host plants, which enable the insect to complete its full life cycle, others may be only temporary hosts for the caterpillars, which move off onto other host plants. Some of the more important and common hosts are: kiwifruit, apples, pears, grapes, citrus varieties, stone fruits, feijoa, and berry fruits. Other host plants include pohutakawa, karaka, mahoe, poroporo, coprosma, willow, honeysuckle, privet, poplar, eucalyptus, ivy, cyclamen, orchids, roses, and clover. Many shelter species are excellent hosts of leafrollers. Wherever possible, new plantings should use non-hosts, such as *Casuarina* spp. (sheoke) and bamboo.

The following plant species contain plants on which caterpillars of brownheaded leafroller have been recorded. Most of these are known to be true host plants on which brownheaded leafroller is able to complete its life cycle. The caterpillars of the two *Ctenopseustis* species cannot be separated in the field. It is not known, therefore, whether they occur equally frequently on the host plants listed below, or whether there are different host plant preferences of the two species. In addition to recent species-specific records, analysis of past records in relation to the known distribution of the two species has been done to give the underlined coded information. Plant species not underlined refer to both species of brownheaded leafroller. Where only one species was likely to be present in the area sampled, the text is underlined as follows: *Ctenopseustis herana* and *Ctenopseustis obliquana*.

Common hosts include *Acacia* spp. (wattle), *Acmena smithii, Actinidia deliciosa* (*chinensis*) (kiwifruit), *Aucuba japonica, Berberis darwinii, Berberis glaucocarpa* (barberry), *Chaenomeles speciosa*, *Choysia ternata*, *Citrus grandis*, *Citrus limonia*, *Citrus sinensis, Citrus* spp., *Cotoneaster frigidis, Cotoneaster lacteus, Crataegus monogyna, Crataegus oxycantha*, *Cryptomeria japonica*, *Cyclamen persicum* (Cyclamen), *Cydonia oblonga*, *Duchesnea indica*, *Eriobotrya japonica, Eucalyptus* spp., *Fagus sylvatica, Feijoa sellowiana, Forsythia intermedia, Forsythia suspense, Fragaria moschate, Fragaria xananassa, Fuchsia magellenica, Fuchsia* sp. (fuchsia), *Hedera helix* (ivy), *Hedera* sp., *Hypericum androsaemum, Hypericum calycinum*, *Hypericum humifusum*, *Hypericum perforatum, Jasminium mesnyi*, *Jasminium officinale, Kerria japonica*, *Laurus nobilis*, *Ligustrum vulgare* (privet), *Lonicera japonica, Lonicera periclymenum* (honeysuckle), *Lonicera* sp., *Malus baccata, Malus* x *domestica* (apple), *Persea americana, Phebalium squameum, Photinia glabra, Populus alba* (poplar), *Populus deltoides, Populus nigra, Primula vulgaris, Prunus amygdalus, Prunus armeniaca* (apricot), *Prunus avium* (cherry), *Prunus campanulate, Prunus cerasifera, Prunus cerasus, Prunus laurocerasus, Prunus persica* (peach), *Prunus persica* (var. nectarina), *Prunus serrulata*, *Prunus* sp., *Prunus* x *domestica* (plum), *Pyracantha angustifolia, Pyrus communis, Pyrus pyrifolia*, *Pyrus ussuriensis*, *Quercus ilex, Quercus robur, Quercus* spp. (oaks), *Quercus suber*, *Rhaphiolepis umbellate, Ribes nigrum* (blackcurrant), *Ribes rubrum, Ribes sanguineum, Ribes uva-crispa* (gooseberry), *Rosa* sp. (rose), *Rubus fruticosus* (blackberry), *Rubus idaeus* (dewberry), *Rubus occidentalis*, *Rubus* spp., *Salix alba* (willow), *Salix babylonica, Salix fragilis, Salix matsudana, Salix* x *reichardtii, Sambucus nigra, Spiraea argula*, Syringa vulgaris, *Viburnum* sp., *Vitis vinifera* (grapevine), *Vitis* sp.

Occasional hosts include *Acer nigrum, Aesculus hippocastanum, Amaranthus retroflexus, Antirrhinum majus, Aquilegia vulgaris*, *Arctotis stoechadifolia, Aster lanceolatus*, *Aster* sp., *Betula pendula*, *Brassica oleracea*, *Buddleia davidii, Camellia japonica, Camellia reticulata*, *Camellia saluenensis*, *Camellia sasangua*, *Carduus nutans*, *Ceanothus papillosus*, *Chamaecyparis lawsoniana*, *Chimonanthus praecox, Chrysanthemum* sp., *Cirsium arvense*, *Clematis tangutica*, *Clematis vitalba, Clethra arborea, Cucurbita maxima*, *Cytisus multiflorus*, *Cytisus scoparius* (Scotch broom), *Dahlia* sp., *Daphne* sp., *Deutzia scabra*, *Diospyros khaki* (persimmon), *Escallonia* sp. (escallonia), *Euonymus japonicus*, *Ficus carica*, *Garrya elliptica*, *Geranium pratense*, *Hypochaeris radicata*, *Ilex aquifolium* (holly), *Juglans regia, Liquidamber styraciflua, Lotus pedunculatus*, *Lupinus albus, Lupinus arboreus, Lupinus luteus*, *Lupinus* sp. (lupin), *Magnolia liliflora*, *Magnolia stellata*, *Malva parviflora, Mentha spicata*, *Pelargonium* sp., *Phaseolus vulgaris*, *Pieris japonica, Pinus muricate, Pinus nigra (cv austriaca)* (Austrian pine), *Pinus nigra* (*laricio*) (Corsican pine), *Pinus patula*, *Pinus radiata* (Monterey pine, radiata pine), *Pinus strobes, Plantago lanceolata* (plantain), *Podranea ricasoliana*, *Pseudotsuga menziesii* (Douglas fir), *Racosperma longifolium, Rhododendron* sp., *Rumex obtusifolius* (Dock), *Rumex* sp., *Salvia* sp., *Sequoia sempervirens* (Coast redwood), *Sonchus oleraceus*, *Thuja orientalis*, *Thuja plicata, Tilia cordata*, *Trifolium pratense*, *Trifolium repens* (clover), *Ulex europaeus*, *Ulma* sp., *Vaccinium corymbosum*, *Verbena* sp., *Veronica* sp., *Vicia faba*, *Vinca major*, *Weigela florida*, *Wisteria sinensis, Wisteria* sp.

Native New Zealand hosts include *Aristotelia serrata, Carmichaelia* sp., *Carpodetus serratus* (marble-leaf, putaputaweta), *Clianthus puniceus* (kaka beak), *Coprosma australis*, *Coprosma repens*, *Coprosma rotundifolia*, *Coprosma* sp., *Corynocarpus laevigatus* (karaka), *Fuchsia excorticata, Griselinia littoralis*, *Griselinia lucida, Hebe speciosa, Hebe* spp., *Hoheria populnea*, *Leptospermum scoparium, Leptospermum* sp. (tea-tree), *Lophomyrtus bullata* (ramarama), *Macropiper excelsum* (kawakawa), *Melicytus ramiflorus, Metrosideros excelsa* (pohutakawa, rata), *Muehlenbeckia* sp., *Olearia rani, Olearia* sp., *Parahebe catarractae*, *Pittosporum crassifolium, Pittosporum eugenoides, Pittosporum* sp., *Pittosporum tenuifolium* (kohuhu), *Pseudopanax arboreum, Pseudowintera colorata*, *Solanum aviculare*.

Plant part(s) affected:

Mainly leaves, sometimes buds, stems and fruits.

Distribution:

Ctenopseustis herana is found on both North and South Islands of New Zealand. It is absent from the Auckland, Bay of Plenty, Gisborne, Hawke's Bay, Wellington, Manawatu-Wanganui and Taranaki regions of the North Island. It is a pest species mainly in Nelson, Canterbury and the Waikato.

Ctenopseustis obliquana is also found in both the North and South Islands but is less frequent on the east coast of the South Island where it may be replaced by *C. herana*. *C. obliquana* is a major pest of apples in Hawke's Bay, Gisborne, Waikato, and Nelson.

Biology:

There are two species of brownheaded leafroller, *Ctenopseustis obliquana* and *Ctenopseustis herana*. Their appearance is identical at all stages - adult moths, eggs, larvae, or pupae. The two species produce different pheromones, and pheromone trapping enables the populations of each species to be monitored independently. In addition, the distribution of the species varies in different parts of New Zealand.

Adult brownheaded leafrollers are extremely variable in colour and forewing pattern. In both sexes the forewings are often walnut brown, but vary from dark brown (almost black) to a pale fawn, and have a variety of colour combinations. Females have a characteristic darker oblique mark halfway down the edge of each forewing. The body length is generally 8-12 mm and the wingspan 20-28 mm. Males too have an oblique forewing mark, plus a characteristic dark, transverse stripe (often black) across the front part of the folded wings about 2 millimetres behind the head. Their body length is generally 8-11 mm, and wingspan 17-24 mm. Adults often have other darker areas that vary in position, and in shade from pale to dark brown. Males have a 'fan' of large scales at the tail end of the abdomen whereas the brown ovipositor can be seen when viewing the tip of the female abdomen from below. Hindwings of both sexes are a uniform or mottled, pale brown, but are hidden beneath the folded forewings when the adult is at rest. The length of the resting moth is about half the wingspan.

Eggs of all leafroller species are laid in rafts or batches of 2 - 216, usually on the upper surface of host plant leaves. The eggs are flat, and with a pebbled surface. They overlap each other within the raft to form a smooth mass. This makes it difficult to distinguish the eggs from the surrounding leaf surface. Eggs are approximately 0.7 mm by 1.0 mm and the batches have a sparse coating of particles over the surface. They are initially pale green and change to a more yellow green as they develop. Prior to hatching the dark head of the developing caterpillar is visible through the egg wall, giving the egg batches a blotchy or speckled appearance. Eggs parasitised by minute wasps (for example, *Trichogramma* spp.) are black just prior to wasp emergence.

Larvae of BHLR are difficult to distinguish from the larvae of lightbrown apple moth and greenheaded leafrollers, when occurring together in the same habitat. However, their colour, markings and size provide some distinguishing features. There are five or six larval instars (stages) in all species. The first larval instar is about 1.5 to 2.0 mm long and has a pale brown head with a dark mark on each side and the body is often pale green. The head becomes strikingly black in the second instar, and changes again, through subsequent instars, from dark brown to reddish or pale brown. Body colour varies. The mature larva may have faint red or red-brown stripes on its head, and is up to 20 mm long.

The pupa (chrysalis) is at first green, but soon becomes brown after rapidly hardening, and then darkens during development. The pupa is typically found in a thin-walled silken cocoon between two leaves webbed together, and is usually 10-15 mm long; the female pupae are larger than those of the male. Males and females can be distinguished by examining the pupa from the lower surface. In the female, three dark segmental bands are visible beyond the tip of the wing cases whereas there are four in the male. At the end of the abdomen, two prominent broad-based laterally-projecting spines and a number of hooks support the pupa in its cocoon. Each abdominal segment also has a series of short, backward-projecting spines that are used by the pupa to move partially out of its cocoon prior to moth emergence.

Female *Ctenopseustis obliquana* lays egg-masses of 30 or more eggs on leaves of the host-plant. The mass is covered with a translucent pale green secretion. Larvae feed between leaves spun together with silk, and may also feed on shoots, buds, stems or the surface of fruits. Full grown larvae are about 20 mm long, greenish or yellowish and with the head and prothoracic plate shining dark brown. They usually pupate within the larval shelter. There are several generations per year, and in summer a generation from egg to adult can be completed in 4-6 weeks.

Damage

All five species of leafroller larvae (for example, BHLR, GHLR and lightbrown apple moth) cause similar damage to foliage and fruits; there is no way of distinguishing the damage of different species. Early instars often settle on the under surface of leaves close to the main veins, where they construct silken shelters and feed on the leaf tissue; this feeding typically creates small windows in the leaves. Other young larvae are commonly found on the shoot tips or areas of new growth, where they web the leaves together with silk. A third settlement site is the calyx of fruits such as apple, where their presence is detected only from observing the fine silken webbing among the sepals. Larger larvae migrate from these settlement positions to construct feeding niches between adjacent leaves, between a leaf and a fruit, in a developing bud, or on a single leaf, where the leaf roll develops. The late stage larvae feed on all leaf tissue except main veins. Buds of deciduous host plants are especially vulnerable to attack in the winter and early spring, when the interior of the buds may be eaten.

Surface fruit damage is common in short-stemmed apple varieties, which form compact fruit clusters. Leaves are webbed to the fruit and feeding injury takes place under the protection of the leaf; or larvae spin up between fruits of a cluster. Small, circular 'stings' are caused by young larvae biting through the skin. This is typically on the green side of the apple (such as where a leaf and fruit have come in contact), in contrast to codling moth stings which are on the ripe side of the fruit. In crops such as kiwifruit, plum, grapefruit, and apple, the maturing fruit produces a layer of corky tissue over the damage by leafrollers; this helps prevent secondary infection by pathogens. Internal damage to apple, and pear fruits is much less common than surface damage, but a young larva may enter the interior of an apple or pear through the calyx. The presence of extensive silk distinguishes this damage from that of codling moth. In addition, the excreta (frass) of leafrollers occur as distinct pellets and are usually ejected and scattered on to the outside of the fruit. In contrast, codling moth frass is pushed to the surface in a sticky mass where it is often seen at the entry hole. Leafrollers can cause internal damage to apricots, peaches, and walnuts as well as apples.

Life cycle

The life cycle of brownheaded leafroller is different in different parts of New Zealand and similar to that of lightbrown apple moth. Brownheaded leafroller passes through three generations annually in the central New Zealand region and has no winter resting stage. There is considerable overlap in the generations, especially in late summer, although development is driven by temperature. In northern New Zealand three generations and partial fourth generation are completed annually, with major flight periods in Auckland hard to distinguish because of the continuous overlapping of generations. In Canterbury, the number of complete generations is reduced to two due to the cooler climatic conditions. Brownheaded leafroller also completes two generations in Otago (at the same time as greenheaded leafroller flights) but these species occur at extremely low levels in apple orchards, even though common on other host plants.

Life history

In central regions, adults produced by the overwintering larval generation emerge during October and November (November/January in the south). Eggs are laid in clusters of 2-216 on the upper surface of leaves, and take about 9 days at 20° to hatch (longer at cooler temperatures). These give rise to the first summer generation, in which final instar larvae mature between January and mid-February (January to March in the south). Second generation larvae reach maturity during March and April, and the adults from this generation provide third generation eggs in central regions. Normally, the rate of larval development is slowed considerably during the winter; thus the majority of larvae over-winter in the prolonged early juvenile phases of the second, third, and fourth instars. During this period they normally feed on herbaceous plants, although some feed on the buds of deciduous trees and shrubs. Re-invasion of apple trees takes place during October-December, when moths from the overwintered generation start laying eggs again on the apple leaves. In the north of the North Island, flights of adults occur during the winter, which is warmer than further south.

Most of the brownheaded leafroller population spends the winter as young (2nd to 4th stage) caterpillars on ground cover plants, on fallen leaves, in fruit buds, or occasionally under the bark. There is no true dormancy and the caterpillars feed on warm winter days. The caterpillars complete their development, spin a loose silken cocoon, and change to pupae in the spring and early summer before emerging as adult moths. In southern areas with two generations per year, emergence begins in mid November and is spread over December and into January. Males emerge a short time ahead of females. The second generation emerges from February to May. In northern areas, the emergence of the overwintered generation is completed by December, the second generation of adults occurs over January/early March, and overlapping third or partial fourth generations occurs through to July. However, all stages are present at most times in the north making it difficult to distinguish generations. Females are normally mated only once and egg laying usually begins on the following day, reaching a peak after a few days. They mature and lay a series of egg batches on the upper surface of leaves during their lifetimes, which is about 3-4 weeks at 20ºC. The caterpillars hatch within 1-2 weeks and disperse to settle on the lower surfaces of leaves, often against the midrib and main veins. As the caterpillar grows, it moves to new sites, such as between two leaves, between leaf and fruit, or within a roll created by folding the edge of a leaf. Larval development is completed on apple leaves in about 30 days at 20ºC (*Ctenopseustis obliquana*). Prior to pupation, the majority of larvae leave their feeding sites and prepare new rolls or spin up specially for pupation and emergence. The threshold temperature for development has been determined as 4.8ºC.

Reproduction

The two pest species of brownheaded leafrollers produce distinct female sex pheromones for long-range communication with males seeking a mate. Pheromone traps exploit this by being baited with the distinct pheromone of each species; this enables each species to be monitored separately. The main pheromone components are: *Ctenopseustis obliquana*: (Z)-8-

tetradecenyl acetate, (Z)-5-tetradecenyl acetate; *Ctenopseustis herana*: (Z)-5-tetradecenyl acetate.

The ratios of Z5-14:OAc to Z8-14:OAc in *C. obliquana* vary in different parts of the country. The pheromones are released in the evening and night, but particularly around dusk, and attract males over long distances. Females are normally mated once, although both sexes are capable of mating more often. The male passes sperm to the female in a sac (spermatophore), which the female stores in the bursa copulatrix. Most mating occurs 1-4 days after adult emergence.

The female lays a series of egg batches, averaging on apples in the field about 56 per batch (range 2 - 216), almost exclusively on the upper leaf surface. Fecundity is highly variable between individual females and is determined primarily by weather conditions, and probably the quality and succession of host plants. Females fed by freeze-dried apple leaves as larvae produced an average of 193-429 eggs at 11.5ºC, an average of 58-143 eggs at 18ºC, and an average of 69-182 eggs at 22.5ºC. Higher average fecundities were obtained at 11.5ºC than at 18 or 22.5ºC. Egg infertility in New Zealand under natural conditions is rare at <1%. Egg mortality from other causes is also low with inviability (failure to hatch) averaging only 2% of eggs. New Zealand lacks many of the predators, which feed on leafroller eggs overseas. High mortality of (neonate) caterpillars occurs when they disperse after hatching from their egg batch.

Population dynamics

The population dynamics of brownheaded leafrollers have not been investigated. Those ecological studies that have been carried out suggest that some of the factors, which are known to be important for lightbrown apple moth populations, are also probably key factors affecting the populations of brownheaded leafrollers. These include high mortality of young caterpillars after hatching from the eggs and wide variation in fecundity (the total numbers of eggs laid) between females, generations, and host plants. Predation by a wide variety of predators plays the key role in the mortality of young caterpillars of lightbrown apple moth in Australia and it is likely that a similar complex of predators (for example, spiders) occurs in New Zealand and feeds on young brownheaded leafrollers. Many of the parasitoids which attack brownheaded leafroller eggs and caterpillars cause only minor mortalities but there is circumstantial evidence of leafroller population decline following the introduction of *Trigonospila brevifacies* and *Xanthopimpla rhopaloceros* from Australia, particularly in populations outside orchards.

Dispersal

The dispersal ability of brownheaded leafrollers has very important implications for management. With high levels of control achieved by insecticides or *Bacillus thuringiensis*, the resident population of brownheaded leafrollers in most orchards is extremely low. As a result, the immigration of adult moths into orchards is often greater than the resident population, and the removal of outside sources (for example, weeds like blackberry and honeysuckle) can contribute to control. There have been no mark-recapture studies of the dispersal of brownheaded leafrollers. Like lightbrown apple moth, brownheaded leafrollers also have numerous alternative host plants in the environment of orchards and immigration of wild moths into orchards can be very high. This can be both a problem for control of brownheaded leafroller damage and a benefit for resistance management by diluting the effects of insecticidal selection. Immigrant moths from wild host plants normally contain a high proportion of insecticide-susceptible individuals.

Brownheaded leafrollers are predominantly nocturnal fliers, with maximum activity 2-6 hours after sunset. The lower temperature threshold for flight in Auckland has been estimated at 7-8ºC but further data is required in this and other regions.

Another important aspect of movement is the dispersal ability of larvae, especially 1st stage caterpillars hatching from their egg batches. This has been detected in water traps placed alongside apple trees. Major mortality occurs during this process but the caterpillars are able to spread out and reduce competition for food, as well as move to new host plants. Caterpillars may disperse into apple crops from surrounding shelter, such as Acmena spp. and Populus spp.

Natural enemies

The natural enemies of the brownheaded leafroller species have not been studied as much as those of lightbrown apple moth in apple orchards. However, they have many natural enemies in common and much of the description and pictures provided for the natural enemies of lightbrown apple moth are also applicable to brownheaded leafrollers. The following information is based on that for lightbrown apple moth but contains adjustments where differences have been shown from specific studies on brownheaded leafrollers. Brownheaded leafrollers in New Zealand are attacked by a range of parasites and by predators and diseases, which make a major contribution to control, particularly if broad-spectrum insecticides are avoided. With the introduction of selective insect growth regulator chemicals and organic production methods for leafroller control, these natural enemies are now playing a greater part in leafroller management in orchards. Biological control by the introduction of natural enemies from overseas has never been specifically undertaken for brownheaded leafrollers. However, some parasitoids introduced from Australia for the control of lightbrown apple moth have also attacked brownheaded leafrollers and are now found in their populations.

The greatest mortality occurs to young larvae hatching from egg batches and before they have settled (spun shelters) on the leaves. These losses are probably due to a number of predators, including spiders and predatory bugs, as occurs in lightbrown apple moth.

Natural enemies and diseases include (this is not an exhaustive list): parasitic or predatory wasps - *Ancistrocerus gazella*, *Brachymeria phya* (Walker) and *Brachymeria teuta* (Walker), *Diadegma* sp., *Dolichogenidea tasmanica, Dolichogenidea carposinae* and *Dolichogenidea* sp. 3 formerly referred to as *Apanteles sicarius*, *Sympiesis* sp. and *Zealachertus* sp., *Eupsenella* spp., *Goniozus jacintae*, *Glabridorsum stokesii* (Cameron), *Glyptapanteles demeter* (Wilkinson), *Trichogramma* sp., *Trichogramma (Trichogrammanza) funiculatum* and *Trichogrammatoidea bactrae fumata*, *Vespula* spp. and *Xanthopimpla rhopaloceros* Kreiger; common earwig *Forficula auricularia* L., predatory bugs - *Orius vicinus* (Ribault), *Oechalia schellenbergii* (Guerin Meneville) and *Cermatulus nasalis* (Westwood), and *Sejanus albisignata* (Knight); parasitic flies - *Pales funesta* (Hutton), *Pales feredayi* (Hutton), and *Trigonospila brevifacies* (Hardy); whirligig mite *Anystis baccarum* (L.); a number of bird species including the silvereye *Zosterops lateralis;* a range of spider species (including theridiid *Achaearanea veruculata*, *Achaearanea veruculata*, *Ixeuticus martius* (Amaurobiidae), *Trite planiceps* and *Trite* sp. (Salticidae), several *Diaea* spp. (Thomisidae) and *Clubiona* sp. (Clubionidae)).

Control

Brownheaded leafrollers are attacked by a wide range of predators, and parasitoids. However, these beneficial species have never been the primary method of control in commercial orchards. This is because brownheaded leafrollers are quarantine pests and must be controlled to extremely low levels. Natural enemies are rarely effective in controlling pest populations at these low densities. However, with the introduction of more selective insecticides, such as insect growth regulators, and the increase in organic production, the natural enemies of brownheaded and other leafrollers have become more important. Classical biological control of brownheaded leafrollers, which are native New Zealand insects, has never been attempted. However, parasitoids introduced for control of lightbrown apple moth (an Australian species) have been found parasitising brownheaded leafrollers. These are contributing to reducing pest populations of brownheaded leafrollers not only in orchards but also on their many host plants in the surrounding environment. This could minimise immigration of moths into orchards and reduce the need for chemical control.

Insect pathogens, such as bacteria and viruses, offer an alternative method of biological control. The bacterium *Bacillus thuringiensis* is widely used for control of leafrollers.

Another biological method of controlling brownheaded leafrollers is mating disruption, which uses high concentrations of the insect pheromone to prevent mating.

The same insecticidal chemicals are used to control the whole complex of five leafroller species on apples. There are three main approaches to chemical control. Since the 1960s, chemical control has been based on the use of broad-spectrum insecticides, such as organophosphates, carbamates, and to a limited extent, synthetic pyrethroids. These highly toxic products have provided very effective control of leafrollers and other pests but they have had the disadvantage of wider toxicity to many natural enemies. More recently, the chemical industry has developed effective insect growth regulator compounds, which combine high toxicity to leafrollers with safety to many important beneficial species, such as predators and parasitoids. These selective qualities are also present in a new group of natural insecticidal products, the first of which is Success Naturolyte™.

IFP aims to eliminate the use of organophosphate and carbamate chemicals in apple orchards and replace these with selective chemicals. At present, all three groups of chemicals are permitted in IFP but with a strong preference for the use of insect growth regulators and the other selective materials. Organophosphates or carbamates may still be required for the control of some pests (for example, woolly apple aphid) and these uses must be efficiently integrated with the control of leafrollers. Several leafroller species in New Zealand have developed resistance to insecticides.

Pheromone trapping can be used to monitor leafroller populations and trap catches provide action thresholds for guiding spray decisions.

All the pest leafroller species have many host plants. A valuable measure which can greatly assist with control is the destruction, mowing or grazing of host plants of leafrollers outside or within the orchard. Annual weeds and ground covers (dock, plantains, clovers) in the orchard are especially important for overwintering by the leafroller caterpillars. Mowing in summer and grazing in winter and early spring can substantially reduce leafroller populations on the ground cover plants. Similar benefits can be obtained by topping shelter trees which host leafrollers (for example, willow, poplar, alder) to a manageable height; caterpillars may descend from these shelter trees onto the crop prior to harvest.

The short-stemmed (for example, Cox's Orange Pippin, Sturmer Pippin) and late season apple varieties have the greatest risk of infestation by leafrollers. Short stems and large fruit bunches create well protected feeding niches for leafroller caterpillars. Careful pruning and thinning can help to achieve good spray penetration of the trees and the fruit clusters, as well as reducing the number of feeding niches, particularly on the short-stemmed varieties. Mummified fruits are used by leafrollers for overwintering and their removal can help to reduce overwintering populations.

Appendix 3 – Data sheets – Codling moth

Cydia pomonella Linnaeus [Lepidoptera: Tortricidae]

Adapted from Poole et al. (2001).

Synonyms and changes in combination:

Carpocapsa pomonella Linnaeus; *Carpocapsa pomonana* Treitschke; *Enarmonia pomonella* Linnaeus; *Laspeyresia pomonella* Linnaeus; *Phalaena pomonella* Linnaeus.

Common name(s):

Codling moth.

Host(s):

Castanea dentata (chestnut) (Hely et al., 1982), *Citrus sinensis* (orange), *Crataegus laevigata* (hawthorn), *Cydonia oblonga* (quince), *Diospyros kaki* (persimmon), *Juglans regia* (walnuts), *Malus domestica* (apple), *Malus sylvestris* (crab apple), *Prunus armeniaca* (apricot), *Prunus avium* (cherry) (Moffitt et al., 1992), *Prunus damson* (plum), *Prunus domestica* (plums) (Yokoyama and Miller, 1988a), *Prunus persica* (peaches), *Prunus persica* var. *nucipersica* (nectarines), *Punica granatum* (pomegranate), *Pyrus communis* (pear).

Plant part(s) affected:

Fruit.

Distribution :

Africa, Asia, Australia, Europe, New Zealand, North and South America (CABI, 2005). In Australia this species occurs in New South Wales (Vickers, 1993), Queensland (Swaine et al., 1991), South Australia (Wicks and Granger, 1989), Tasmania (Hely et al., 1982), and Victoria (Vickers, 1993).

Biology:

The life cycle of codling moth consists of four life stages: adult, egg, larva, and pupa.

The adult is a small grey-brown tortricid with a wingspan of approximately 18 mm. Forewings have a large coppery circular marking near the tip and the hind wings are brown. Eggs are flattened and oval in shape and translucent when first laid, measuring about 1.0 mm in size. About 250-300 eggs are laid singly on or near developing fruits or on leaves and twigs near the fruit. Eggs hatch in 10-15 days depending on temperature. First instar larvae are whitish, developing later to appear pale pink. The head and prothoracic plate are brown. Accurate identification of codling moth larvae depends on setal characteristics. Larvae can measure up to 20 mm in length. Pupae are 8.0-11.5 mm long and dark brown in colour. Life cycle development varies seasonally but is an average of 68 days.

Codling moths overwinter as cocooned larvae and can be found on the host in cracks and under bark. Cocoons can also be found in fruit containers and other equipment (Hely et al., 1982). Overwintering larvae usually emerge from mid-October to early January, with second generation larvae emerging from mid-December to mid-February (Hely et al., 1982). Codling moth can disperse within an orchard by flight, but as tortricid moths are not strong fliers, dispersal between orchards is most likely to be attributed to infested fruit and infested equipment such as picking boxes (Hely et al., 1982).

Appendix 3 – Data sheets – Garden featherfoot

Stathmopoda horticola Dugdale, 1988 [Lepidoptera: Oecophoridae]

Adapted from Landcare Research (1999).

Synonyms or changes in combination:

Stathmopoda horticola Dugdale, 1988; *Stathmopoda skelloni* in the sense of authors, but not of Butler, 1880.

Common name(s):

Garden Featherfoot.

Host(s):

Probably polyphagous on fruits of a wide range of trees. Hosts include *Actinidia deliciosa* (kiwifruit), *Malus domestica* (apple), *Prunus persica* (peach).

Plant part(s) affected:

May be found feeding at the calyx or stem end of apples (HortResearch, 1999b).

Distribution:

New Zealand.

Biology:

The garden featherfoot (GFF), *Stathmopoda horticola* Dugdale, has four life stages: adult, egg, larva (or caterpillar) and pupa.

Very little has been published on the life history of this species, but on orchard trees, the larvae are known to feed on the surface of fruit from a silken shelter under the dying calyces.

Larvae are dark purplish brown, with a dark reddish brown head and paler intersegmental divisions. They are about 8 mm long when full grown. They form a white silken cocoon, often on the surface of the fruit; when on kiwifruit the larva incorporates fruit hairs which camouflage the cocoon. Larvae diapause over winter in the cocoon, and pupate in the spring.

According to HortResearch (1999b), caterpillars of *Stathmopoda* spp. are occasional pests of apples in the north of New Zealand. They may be found feeding at the calyx or stem end of apples. The fruits of kiwifruit are more often attacked by this pest and, after they have completed feeding, the caterpillars may spin their cocoons on the bark of the vine.

Appendix 3 – Data sheets – Green-headed leafroller

Planotortrix excessana (Walker, 1863) [Lepidoptera: Tortricidae]

Planotortrix octo Dugdale, 1990 [Lepidoptera: Tortricidae]

Adapted from HortResearch (1999b).

Synonyms or changes in combination:

Planotortrix excessana: Teras excessana Walker, 1863; *Teras biguttana* Walker, 1863; *Cacoecia excessana* (Walker, 1863); *Tortrix excessana* (Walker, 1863); *Planotortrix excessana* Type B of Foster et al. (1986); *Planotortrix excessana* Types B and C of Foster and Dugdale (1988) (Dugdale, 1990).

Planotortrix octo: Planotortrix excessana Type A of Foster et al. (1986), Foster and Dugdale (1988), *Planotortrix octo* (Dugdale, 1990).

Common name(s):

Green-headed leafroller (GHLR).

Host(s):

Greenheaded leafroller caterpillars have been recorded on more than 200 plant species. While many of these are true host plants, which enable the insect to complete its full life cycle, others may be only temporary hosts for the caterpillars, which move off onto other host plants. Some of the more important and common hosts are: apples, pears, grapes, citrus varieties, stone fruits, kiwifruit, walnut, lupin, tree lupin, ivy, camellia, laurel, hebe, polyanthus, coprosma and young conifers. Many shelter species are excellent hosts of leafrollers. Wherever possible, new plantings should use non-hosts, such as *Casuarina* spp. (sheoke) and bamboo.

The following plant species contain plants on which caterpillars of greenheaded leafroller have been recorded. The caterpillars of the two *Planotortrix* species cannot be separated in the field. It is not known, therefore, whether they occur equally frequently on the host plants shown below, or whether there are different host plant preferences of the two species. In addition to recent species-specific records, analysis of past records in relation to the known distribution of the two species has been done to give the underlined coded information. Plant species not underlined refer to both species of greenheaded leafroller. Where only one species was likely to be present in the area sampled, is underlined as follows: <u>*Planotortrix excessana*</u> and <u>*Planotortrix octo.*</u>

Common hosts include: *Acacia* spp., *Achillea millefolium*, <u>*Acmena smithii*</u>, *Actinidia deliciosa (chinensis), Aesculus hippocastanum*, <u>*Aquilegia vulgaris*</u>, *Arctotis stoechadifolia, Boronia ledifolia*, <u>*Boronia megastigma*</u>, *Carduus nutans*, <u>*Cassia corymbose*</u>, <u>*Cedrus deodara*</u>, *Chaenomeles speciosa, Chamaecyparis lawsoniana, Choysia ternata, Chrysanthemum* sp., *Cirsium arvense, Cirsium vulgare, Citrus grandis, Citrus limonia*, <u>*Citrus sinensis*</u>, *Citrus* spp., *Clematis tangutica, Clematis vitalba, Cotoneaster frigidis, Cotoneaster lacteus, Crataegus monogyna*, <u>*Crataegus oxycantha,*</u> *Cupressus sempervirens, Cupressus* spp., *Cydonia oblonga*, *Cydonia speciosa*, *Cytisus multiflorus, Cytisus scoparius, Dahlia* sp., *Eriobotrya japonica*, *Eucalyptus* spp., *Fagus sylvatica*, *Feijoa sellowiana*, *Fragaria moschate, Fragaria xananassa*, *Fuchsia magellenica, Hedera helix, Hedera* sp., *Kerria japonica, Laburnum anagyroides, Laurus nobilis, Lupinus albus, Lupinus arboreus, Lupinus luteus, Malus baccata, Malus* x *domestica*, *Prunus persica* (var. *nectarina*), *Persea americana*, *Persea gratissima*, *Phaseolus vulgaris*, *Phebalium squameum*, *Photinia glabra, Picea abies, Picea* spp., *Pinus muricate, Pinus nigra* (cv austriaca), *Pinus nigra* (laricio), *Pinus patula, Pinus radiata, Pisum sativum, Polygonum persicaria, Populus alba, Populus deltoides, Populus nigra, Prunus amygdalus, Prunus armeniaca, Prunus avium, Prunus campanulate, Prunus cerasifera, Prunus cerasus, Prunus laurocerasus, Prunus persica, Prunus serrulata, Prunus* x *domestica, Pseudotsuga menziesii, Pyracantha angustifolia, Pyrus communis, Pyrus pyrifolia, Pyrus ussuriensis, Quercus ilex, Quercus robur, Quercus* spp., *Quercus suber, Racosperma longifolium, Rhaphiolepis umbellate, Ribes nigrum, Ribes rubrum, Ribes sanguineum, Ribes uva-crispa* (includes many fruit crops), *Rosa* sp., *Rubus fruticosus, Rubus idaeus, Rubus occidentalis, Rubus* spp., *Rumex acetosa, Rumex acetosella, Rumex crispus, Rumex obtusifolius, Rumex pulcher, Salix alba, Salix babylonica, Salix fragilis, Salix matsudana, Salix* spp., *Salix* x *reichardtii, Solidago canadensis, Sonchus kirkii, Sonchus oleraceus, Thuja orientalis, Thuja plicata, Trifolium pratense, Trifolium repens, Trifolium subterraneum, Ulma* sp., *Verbena* sp., *Vicia faba, Vicia sativa, Vitis* sp., *Vitis vinifera, Wisteria sinensis, Wisteria* sp.

Occasional hosts include: *Acer nigrum, Amaranthus retroflexus, Antirrhinum majus, Arbutus unedo, Aucuba japonica, Begonia corallina, Berberis darwinii, Berberis glaucocarpa, Beta vulgaris, Betula pendula, Brassica oleracea, Brassica rapa, Brassica* spp., *Buddleia davidii, Camellia japonica, Camellia reticulata, Camellia saluenensis, Camellia sasangua, Camellia* spp., *Campanula medium, Capsella bursa-pastoris, Capsicum frutescens, Carpobrutus edulis, Ceanothus papillosus, Chimonanthus praecox, Chimonanthus* spp., *Clethra arborea, Cucurbita maxima, Cucurbita pepo, Daphne* sp., *Daucus carota, Deutzia crenata, Diospyros khaki, Erica lusitanica, Erodium cicutarium, Escallonia* sp., *Euonymus japonicus, Ficus carica, Forsythia intermedia, Forsythia suspense, Garrya elliptica, Geranium pratense, Hypericum androsaemum, Hypericum calycinum, Hypericum humifusum, Hypericum perforatum, Ilex aquifolium, Iris germanica, Jasminium mesnyi, Jasminium officinale, Juglans regia, Lampranthus spectabilis, Lavandula dentata, Ligustrum vulgare, Lilium auratum, Liquidamber styraciflua, Lonicera japonica, Lonicera periclymenum, Lycopersicum esculentum, Magnolia liliflora, Magnolia stellata, Malva parviflora, Mentha spicata, Myosotis sylvatica, Opuntia* spp., *Paeonia officinalis, Passiflora edulis, Passiflora mollissima, Pastinaca sativa, Pelargonium* sp., *Physalis peruviana, Plantago lanceolata, Plantago major, Plumbago capensis, Podranea ricasoliana, Primula vulgaris, Rhododendron* sp., *Sambucus nigra, Solanum nigrum, Solanum tuberosum, Syringa oblata, Syringa vulgaris, Tilia cordata, Urtica urens, Veronica arvensis, Veronica* sp., *Viburnum* sp., *Vinca major, Weigela florida, Zygocactus* spp.

Native New Zealand hosts include: *Agathis australis, Aristotelia serrata, Carmichaelia* sp., *Carpodetus serratus, Clematis paniculate, Clianthus puniceus, Coprosma australis, Coprosma repens, Coprosma* sp., *Coriaria arborea, Coriaria sarmentosa, Corynocarpus laevigatus, Fuchsia excorticata, Griselinia littoralis, Griselinia lucida, Hebe speciosa, Hebe* spp., *Hoheria populne, Leptospermum scoparium, Leptospermum* sp., *Macropiper excelsum, Melicytus ramiflorus, Metrosideros excelsa, Muehlenbeckia* sp., *Myoporum laetus, Mysine australis, Olearia* sp., *Parahebe catarractae, Pittosporum crassifolium, Pittosporum eugenoides, Pittosporum tenuifolium, Pseudopanax arboreum, Pseudowintera inserta, Rubus parvus, Urtica ferox.*

Plant part(s) affected:

Leaves and fruit (HortResearch, 1999b).

Distribution:

Greenheaded leafrollers, *Planotortrix excessana* and *P. octo* only occur in New Zealand, including some offshore islands. They inhabit most lowland forest margins and horticultural areas (Thomas, 1998).

Planotortrix excessana is rare or infrequent in the eastern regions of the country. It is a major pest of apples in Nelson and the Waikato. *Planotortrix octo* is found in both the North and South Islands and is particularly important in the eastern apple growing regions of Poverty Bay, Hawkes Bay, Marlborough, Canterbury, and Central Otago. It is also a pest in the Waikato (HortResearch, 1999a).

Biology:

There are two species of greenheaded leafroller, *Planotortrix excessana* and *Planotortrix octo*. Their appearance is identical at all stages - adults, eggs, larvae, or pupae. The two species produce different pheromones, and pheromone trapping enables the populations of each species to be monitored independently. In addition, the distribution of the species varies in different parts of New Zealand.

Note that, as presented in HortResearch (1999b), many aspects of the biology of green-headed leafrollers are either very similar to or the same as the ones for the brown-headed leafrollers. However, for the completeness, such information is also repeated below although it has been stated under BHLR and this information is underlined.

Greenheaded leafroller moths are larger than the other leafroller species. The body length of female moths is 8-14 mm and the wingspan 22-30 mm; males tend to have a smaller body length, 7-12 mm, and a wingspan of 18-25 mm. Females are normally pale to dark brown, often with a series of broad, darker-brown, variable zig-zag bands across the forewings. A prominent, dark-brown spot is almost always present about one-third the distance in from the tip of the forewing. The male forewings are a uniform medium to dark coppery brown (often darker than the female), sometimes with a distinct greyish surface sheen. Markings are indistinct compared to those of females, but colour varieties are common. One variety has a conspicuous white or pale area centrally on the forewings, about one-third the distance from the base. Males have a 'fan' of large scales at the tail end of the abdomen (body) whereas the brown ovipositor can be seen when viewing the tip of the female abdomen from below. Hindwings of both sexes are a uniform or mottled, pale brown, but are hidden beneath the folded forewings when the adult is at rest. The length of the resting moth is about half the wingspan.

Eggs are laid in rafts or batches of 3 - 186, usually on the upper surface of host plant leaves. The eggs are flat, and with a pebbled surface. They overlap each other within the raft to form a smooth mass. This makes it difficult to distinguish the eggs from the surrounding leaf surface. The greenheaded leafroller egg batch is densely coated with characteristic white particles deposited during egg laying and this makes it difficult to see individual eggs. This enables egg batches of these species to be distinguished from the other leafrollers. Eggs are approximately 1.3 by 1 mm. They are initially blue-green and change to a paler yellow green as they develop. Prior to hatching the dark head of the developing caterpillar is visible through the egg wall, giving the egg batches a blotchy or speckled appearance. Eggs parasitised by minute wasps (for example, *Trichogramma* spp.) are black just prior to wasp emergence.

Larvae of GHLR are difficult to distinguish from the larvae of lightbrown apple moth and brownheaded leafrollers, when occurring together in the same habitat. However, their colour, markings and size provide some distinguishing features. There are five or six larval instars (stages) in all species. The first larval instar is about 1.5 to 2.0 mm long and has a pale brown head capsule with a dark mark on each side. During development, the head and the plate behind it become paler and almost transparent, until in the final instar they appear shining green. At this stage the body is up to 25 mm long and is pale bluish-green with diffuse, white, longitudinal bands.

The pupa (chrysalis) is at first green, but soon becomes brown after rapidly hardening, and then darkens during development. The pupa is typically found in a thin-walled silken cocoon between two leaves webbed together, and is usually 10-15 mm long; the female pupae are larger than those of the male. Males and females can be distinguished by examining the pupa from the lower surface. In the female, three dark segmental bands are visible beyond the tip of the wing cases whereas there are four in the male. At the end of the abdomen, two prominent broad-based laterally projecting spines and a number of hooks support the pupa in its cocoon. Each abdominal segment also has a series of short, backward-projecting spines that are used by the pupa to move partially out of its cocoon prior to moth emergence.

Damage

All five species of leafroller larvae (for example, BHLR, GHLR and lightbrown apple moth) cause similar damage to foliage and fruits; there is no way of distinguishing the damage of different species. Early instars often settle on the under surface of leaves close to the main veins, where they construct silken shelters and feed on the leaf tissue; this feeding typically creates small windows in the leaves. Other young larvae are commonly found on the shoot tips or areas of new growth, where they web the leaves together with silk. A third settlement site is the calyx of fruits such as apple, where their presence is detected only from observing the fine silken webbing among the sepals. Larger larvae migrate from these settlement positions to construct feeding niches between adjacent leaves, between a leaf and a fruit, in a developing bud, or on a single leaf, where the leaf roll develops. The late stage larvae feed on all leaf tissue except main veins. Buds of deciduous host plants are especially vulnerable to attack in the winter and early spring, when the interior of the buds may be eaten.

Surface fruit damage is common in short-stemmed apple varieties, which form compact fruit clusters. Leaves are webbed to the fruit and feeding injury takes place under the protection of the leaf; or larvae spin up between fruits of a cluster. Small, circular 'stings' are caused by young larvae biting through the skin. This is typically on the green side of the apple (such as where a leaf and fruit have come in contact), in contrast to codling moth stings which are on the ripe side of the fruit. In crops such as kiwifruit, plum, grapefruit, and apple, the maturing fruit produces a layer of corky tissue over the damage by leafrollers; this helps prevent secondary infection by pathogens. Internal damage to apple, and pear fruits is much less common than surface damage, but a young larva may enter the interior of an apple or pear through the calyx. The presence of extensive silk distinguishes this damage from that of codling moth. In addition, the excreta (frass) of leafrollers occur as distinct pellets and are usually ejected and scattered on to the outside of the fruit. In contrast, codling moth frass is pushed to the surface in a sticky mass where it is often seen at the entry hole. Leafrollers can cause internal damage to apricots, peaches, and walnuts as well as apples.

Hatching leafroller caterpillars settle mainly on the lower surfaces of leaves where they feed near the main veins or in shoot tips. Some settle at the calyx or stem end of fruit and may cause stings on the surface. Leaf feeding and shoot damage often include leaf folding and rolling. The fruit surface is eaten and some caterpillars bore into the fruit, particularly through the calyx. Faecal pellets (frass) are often found with damage. Leafroller damage is characterised by silken webbing on both fruits and foliage, and even bud damage in winter/spring. Shoot distortion is caused by feeding and the tying of the young leaves and growing point with silk.

Life cycle

The life cycle of greenheaded leafroller is different in different parts of New Zealand and similar to that of lightbrown apple moth. Greenheaded leafroller passes through two to three generations annually in the central New Zealand region, and has no winter resting stage. There is some overlap in the generations, especially in late summer, although development is driven by temperature. In northern New Zealand three overlapping generations are completed annually, with major flight periods in Auckland occurring during November-December, February-March, and May-July. In Canterbury, and particularly in Otago and Southland, the number of complete generations is reduced to two due to the cooler climatic conditions.

Life history

In central regions, adults produced by the overwintering larval generation emerge during October and November (November/January in the south). Eggs are laid in clusters of 3-186 on the upper surface of leaves, and take about 8 days at 20° to hatch (longer at cooler temperatures). These give rise to the first summer generation, in which final instar larvae mature between January and mid-February (January to March in the south). Second generation larvae reach maturity during March and April, and the adults from this generation provide third generation eggs in central regions. Normally, the rate of larval development is slowed considerably during the winter; thus the majority of larvae over-winter in the prolonged early juvenile phases of the second, third, and fourth instars. During this period they normally feed on herbaceous plants, although some feed on the buds of deciduous trees and shrubs. Re-invasion of apple trees takes place during October-December, when moths from the overwintered generation start laying eggs again on the apple leaves. In the north of the North Island, flights of adults occur during the winter, which is warmer than further south.

Most of the greenheaded leafroller population spends the winter as young (2nd to 4th stage) caterpillars on ground cover plants, on fallen leaves, in fruit buds, or occasionally under the bark. There is no true dormancy and the caterpillars feed on warm winter days. The caterpillars complete their development, spin a loose silken cocoon, and change to pupae in the spring and early summer before emerging as adult moths. In southern areas with two generations per year, emergence begins in mid November and is spread over December and January. Males emerge a short time ahead of females. The second generation emerges from February to May. In northern areas, the emergence of the overwintered generation is completed by December, the second generation of adults occurs over February/March, and overlapping with the third generation occurs through to July in the north. Females are normally mated only once and egg laying usually begins on the following day, reaching a peak after a few days. They mature and lay a series of egg batches on the upper surface of leaves over a period of up to three weeks. The caterpillars hatch within 1-2 weeks and disperse to settle on the lower surfaces of leaves, often against the midrib and main veins. As the caterpillar grows, it moves to new sites, such as between two leaves, between leaf and fruit, or within a roll created by folding the edge of a leaf. Larval development is completed on apple leaves in 26-30 days at 20ºC (*Planotortrix octo*). Prior to pupation, the majority of larvae leave their feeding sites and prepare new rolls or spin up specially for pupation and emergence. The threshold temperature for development has been determined as 6.1ºC.

The two pest species of greenheaded leafrollers produce distinct female sex pheromones for long range communication with males seeking a mate. Pheromone traps exploit this by being baited with the distinct pheromone of each species; this enables each species to be monitored separately. The main pheromone components are: *Planotortrix excessana*: (Z)-5-tetradecenyl acetate, (Z)-7-tetradecenyl acetate, (Z)-9-tetradecenyl acetate; *Planotortrix octo*: (Z)-8-tetradecenyl acetate, tetradecyl acetate

The ratios of Z5-14:OAc to Z7-14:OAc in *P. excessana* vary in different parts of the country. The pheromones are released in the evening and night, but particularly around dusk, and attract males over long distances. Females are normally mated once, although both sexes are capable of mating more often. The male passes sperm to the female in a sac (spermatophore) which the female stores in the bursa copulatrix. Most mating occurs 1-4 days after adult emergence.

The female lays a series of egg batches, averaging on apples in the field about 54 per batch (range 3 - 186), almost exclusively on the upper leaf surface. Fecundity is highly variable between individual females and is determined primarily by weather conditions, and probably the quality and succession of host plants. Greenheaded leafroller females which had been fed freeze-dried apple leaves as larvae produced an average of 52-87 eggs at 11.5ºC, an average of 53-282 eggs at 18ºC, and an average of 84-141 eggs at 22.5ºC. Egg infertility in New Zealand under natural conditions is rare at <1%. Egg mortality from other causes is also low with inviability (failure to hatch) averaging only about 2% of eggs. New Zealand lacks many of the predators, which feed on leafroller eggs overseas. High mortality of newly emerged (neonate) caterpillars occurs when they disperse after hatching from their egg batch.

Population dynamics

The population dynamics of greenheaded leafrollers have not been investigated. Those ecological studies, which have been carried out, suggest that some of the factors that are known to be important for lightbrown apple moth populations are also probably key factors affecting the populations of greenheaded leafrollers. These include high mortality of young caterpillars after hatching from the eggs and wide variation in fecundity (the total numbers of eggs laid) between females, generations, and host plants. Predation by a wide variety of predators plays the key role in the mortality of young caterpillars of lightbrown apple moth in Australia and it is likely that a similar complex of predators (for example, spiders) occurs here and feeds on young greenheaded leafrollers. Many of the parasitoids which attack greenheaded leafroller eggs and caterpillars cause only minor mortalities but there is circumstantial evidence of leafroller population decline following the introduction of *Trigonospila brevifacies* and *Xanthopimpla rhopaloceros* from Australia, particularly in populations outside orchards. This requires investigation.

The dispersal ability of greenheaded leafrollers has very important implications for management. With high levels of control achieved by insecticides or *Bacillus thuringiensis*, the resident population of greenheaded leafrollers in most orchards is extremely low. As a result, the immigration of adult moths into orchards is often greater than the resident population, and the removal of outside sources (for example, *Pittosporum* spp.) can contribute to control. There have been limited mark-recapture studies of the dispersal of greenheaded leafrollers. Preliminary results indicate that this is similar to lightbrown apple moth with most male moths recaptured within 100 m of their release point and a maximum dispersal of 400 m. Like lightbrown apple moth, greenheaded leafrollers also have numerous alternative host plants in the environment of orchards and immigration of wild moths into orchards can be very high. This can be both a problem for control of greenheaded leafroller damage and a benefit for resistance management by diluting the effects of insecticidal selection. Immigrant moths from wild host plants normally contain a high proportion of insecticide-susceptible individuals.

Greenheaded leafrollers are predominantly nocturnal fliers, with maximum activity 2-6 hours after sunset. The lower temperature threshold for flight in Auckland has been estimated at 10-12ºC but further data is required in this and other regions.

Another important aspect of movement is the dispersal ability of larvae, especially 1st stage caterpillars hatching from their egg batches. This has been detected in water traps placed alongside apple trees. Major mortality occurs during this process but the caterpillars are able to spread out and reduce competition for food, as well as move to new host plants. Caterpillars may disperse into apple crops from surrounding shelter.

The natural enemies of the greenheaded leafroller species have not been studied as much as those of lightbrown apple moth. However, they have many natural enemies in common and much of the description and pictures provided for the natural enemies of lightbrown apple moth are also applicable to greenheaded leafrollers. The following information is based on that for lightbrown apple moth but contains adjustments where differences have been shown from specific studies on greenheaded leafrollers. Greenheaded leafrollers in New Zealand are attacked by a range of parasites and by predators and diseases, which make a major contribution to control, particularly if broad-spectrum insecticides are avoided. With the introduction of selective insect growth regulator chemicals and organic production methods for leafroller control, these natural enemies are now playing a greater part in leafroller management in orchards. Biological control by the introduction of natural enemies from overseas has never been specifically undertaken for greenheaded leafrollers. However, some parasitoids introduced from Australia for the control of lightbrown apple moth have also attacked greenheaded leafrollers and are now found in their populations.

The greatest mortality occurs to young larvae hatching from egg batches and before they have settled (spun shelters) on the leaves. These losses are probably due to a number of predators, including spiders and predatory bugs, as occurs in lightbrown apple moth.

Natural enemies and diseases include (this is not an exhaustive list): parasitic or predatory wasps - *Ancistrocerus gazella*, *Brachymeria phya* (Walker), *Brachymeria teuta* (Walker), *Diadegma* sp., *Dolichogenidea tasmanica, Dolichogenidea carposinae*, *Dolichogenidea* sp. 3 (formerly referred to as *Apanteles sicarius*), *Eupsenella* sp., *Glabridorsum stokesii* (Cameron), *Glyptapanteles demeter* (Wilkinson), *Goniozus jacintae*, *Goniozus* sp., *Sympiesis* sp., *Trichogramma* sp., *Trichogramma (Trichogrammanza) funiculatum*, *Trichogrammatoidea bactrae fumata, Vespula* spp., *Xanthopimpla rhopaloceros* Kreiger and *Zealachertus* sp.; common earwig *Forficula auricularia* L.; predatory bugs - *Cermatulus nasalis* (Westwood), *Oechalia schellenbergii* (Guerin Meneville), *Orius vicinus* (Ribault), and *Sejanus albisignata* (Knight); parasitic tachinid flies - *Pales funesta* (Hutton), *Pales feredayi* (Hutton), and *Trigonospila brevifacies* (Hardy); predatory mite *Anystis baccarum* (L.); a range of spider species - such as *Achaearanea veruculata*, *Ixeuticus martius* (Amaurobiidae), *Trite planiceps* and *Trite* sp. (Salticidae), several *Diaea* spp. (Thomisidae) and *Clubiona* sp. (Clubionidae); birds including the silvereye *Zosterops lateralis;* Eugregarine (protozoan) parasites. Note that many of these natural nenemies are originally introduced from Australia to New Zealand to control lightbrown apple moth.

Control:

Greenheaded leafrollers are attacked by a wide range of predators, and parasitoids. However, these beneficial species have never been the primary method of control in commercial orchards. This is because greenheaded leafrollers are quarantine pests and must be controlled to extremely low levels. Natural enemies are rarely effective in controlling pest populations at these low densities. However, with the introduction of more selective insecticides, such as insect growth regulators, and the increase in organic production, the natural enemies of greenheaded and other leafrollers have become more important. Classical biological control of greenheaded leafrollers, which are native New Zealand insects, has never been attempted. However, parasitoids introduced for control of lightbrown apple moth (an Australian species) have been found parasitising greenheaded leafrollers. These are contributing to reducing pest populations of greenheaded leafrollers not only in orchards but also on their many host plants in the surrounding environment. This could minimise immigration of moths into orchards and reduce the need for chemical control.

Insect pathogens, such as bacteria and viruses, offer an alternative method of biological control. The bacterium *Bacillus thuringiensis* is widely used for control of leafrollers.

Another biological method of controlling greenheaded leafrollers is mating disruption, which uses high concentrations of the insect pheromone to prevent mating.

The same insecticidal chemicals are used to control the whole complex of five leafroller species on apples. There are three main approaches to chemical control. Since the 1960s, chemical control has been based on the use of broad-spectrum insecticides, such as organophosphates, carbamates, and to a limited extent, synthetic pyrethroids. These highly toxic products have provided very effective control of leafrollers and other pests but they have had the disadvantage of wider toxicity to many natural enemies. More recently, the chemical industry has developed effective insect growth regulator compounds which combine high toxicity to leafrollers with safety to many important beneficial species, such as predators and parasitoids. These selective qualities are also present in a new group of natural insecticidal products, the first of which is Success Naturolyte™.

IFP aims to eliminate the use of organophosphate and carbamate chemicals in apple orchards and replace these with selective chemicals. At present, all three groups of chemicals are permitted in IFP but with a strong preference for the use of insect growth regulators and the other selective materials. Organophosphates or carbamates may still be required for the control of some pests (for example, woolly apple aphid) and these uses must be efficiently integrated with the control of leafrollers. Several leafroller species in New Zealand have developed resistance to insecticides.

Pheromone trapping can be used to monitor leafroller populations and trap catches provide action thresholds for guiding spray decisions.

All the pest leafroller species have many host plants. A valuable measure which can greatly assist with control is the destruction, mowing or grazing of host plants of leafrollers outside or within the orchard. Annual weeds and ground covers (dock, plantains, clovers) in the orchard are especially important for overwintering by the leafroller caterpillars. Mowing in summer and grazing in winter and early spring can substantially reduce leafroller populations on the ground cover plants. Similar benefits can be obtained by topping shelter trees which host leafrollers (for example, willow, poplar, alder) to a manageable height; caterpillars may descend from these shelter trees onto the crop prior to harvest.

The short-stemmed (for example, Cox's Orange Pippin, Sturmer Pippin) and late season apple varieties have the greatest risk of infestation by leafrollers. Short stems and large fruit bunches create well-protected feeding niches for leafroller caterpillars. Careful pruning and thinning can help to achieve good spray penetration of the trees and the fruit clusters, as well as reducing the number of feeding niches, particularly on the short-stemmed varieties. Mummified fruits are used by leafrollers for overwintering and their removal can help to reduce overwintering populations.

Insect growth regulators (IGRs) are chemicals that interfere with the development of insects. Many are of low human toxicity and are selective because they are specifically targeted at processes occurring in particular stages of insects for example, moulting of caterpillars. Many

IGRs have increased selectivity because the target insect must eat them. There are IGRs currently registered (below) which provide control of both leafrollers and codling moth, and their selectivity makes them among the preferred chemicals for use in IFP. The registered chemicals are:

Lufenuron (Match®). This IGR interferes with formation of the caterpillar's exoskeleton (= a CSI or chitin synthesis inhibitor). Match® must be eaten by the caterpillars, and this rapidly leads to mortality, particularly during moulting. It also affects egg hatch and is highly selective, being non-toxic or of low toxicity to many beneficial species.

Tebufenozide (Mimic®). This IGR induces early moulting of caterpillars before they are ready (= a MAC or moulting accelerator compound). Mimic® must be eaten, and it then causes immediate cessation of feeding and a lethal moult. Sublethal effects at the caterpillar stage may also prevent later pupation and reduce the egg production of female moths. It is highly selective, being non-toxic or of low toxicity to many beneficial species. Greenheaded leafroller, *Planotortrix octo*, is resistant to Mimic® in some parts of New Zealand.

Triflumuron (Alsystin®) is another CSI which interferes with insect moulting. Like other chemicals in this group, it is mainly taken up by ingestion and also reduces the hatching of eggs that have been sprayed or are laid on treated surfaces. It is most effective against young caterpillars, and is highly selective, being non-toxic or of low toxicity to many beneficial species.

Appendix 3 – Data sheets – Grey-brown cutworm

Graphania mutans Walker, 1857 [Lepidoptera: Noctuidae]

Adapted from Landcare Research (1999) and HortResearch (1999b).

Synonyms or changes in combination:

G. mutans (Walker) was originally described in the genus *Hadena*.

Hadena debilis Butler, 1877; *Hadena lignifusca* Walker, 1857; *Hadena mutans* Walker, 1857; *Mamestra acceptrix* Felder & Rogenhofer, 1875; *Mamestra passa* Morrison, 1874; *Maoria mutans* ab. *pallescens* Warren, 1912; *Melanchra mutans* (Walker); *Morrisonia mutans* (Walker); *Xylina spurcata* Walker, 1857; *Xylina vexata* Walker, 1865.

Common name(s):

Grey-brown cutworm, common garden noctuid.

Host(s):

Graphania mutans is polyphagous on a wide range of dicotyledonous herbaceous plants and occasionally trees or shrubs; rarely on grasses. Hosts include *Brassica rapa* (cabbage), *Malus domestica* (apple), *Pisum sativum* (garden pea), *Plantago* sp. (plantain), *Triticum aestivum* (bread wheat).

Plant part(s) affected:

Leaves, occasionally also buds and young fruit.

Distribution:

New Zealand.

Biology:

The grey-brown cutworm (GBC) has four life stages: adult, egg, larva (or caterpillar) and pupa.

Eggs are laid in batches on leaves or sometimes under the calyces of apple fruit. Each is in the shape of a flattened sphere, and cream to yellow in colour, with irregular brown markings in the upper half. Egg batches are also sometimes laid on the fruit close to harvest (HortResearch, 1999b).

Newly hatched larvae are pale yellow in colour with distinct black spots and covered in stiff, erect hairs. The young larva first consumes the egg-shell before commencing to feed on the foliage of the host-plant: occasionally when eggs are laid on young fruit they will damage the surface of the fruit. Larvae continue to feed on foliage of host trees until fully grown

(Landcare Research, 1999). HortResearch (1999b) states that most of the young caterpillars of *G. mutans* descend from the trees to the ground cover of the orchard after a short time, where they feed on a variety of pasture plants. *Graphania mutans* caterpillars, which were artificially prevented from their normal behaviour of descending to the orchard understorey, cause considerable damage to the surface of apple fruit (HortResearch, 1999b). Mature larvae are approximately 25 mm long, light to dark brown in colour with a broken, white longitudinal stripe down each side (Landcare Research, 1999). In coloration the final instar larva is very variable, but the more distinctive and diagnostic features include a characteristic 3-pronged dark pattern which is usually present on the dorsum of abdominal segment 8, and segments 7-9 lacking dark patterning sublaterally and ventrally.

Appendix 3 – Data sheets – Citrophilus mealybug

Pseudococcus calceolariae Maskell [Hemiptera: Pseudococcidae]

Adapted from Poole et al. (2001).

Synonyms and changes in combination:

Dactylopius calceolariae Maskell, 1879; *Erium calceolariae* (Maskell) Lindinger, 1935; *Pseudococcus citrophilus* Clausen, 1915; *Pseudococcus fragilis* Brain, 1912; *Pseudococcus gahani* Green, 1915.

Common name(s):

Citrophilus mealybug, Currant mealybug, Scarlet mealybug.

Host(s):

Abutilon spp. (maple), *Aeonium balsamiferum* (cactus), *Aguilegia* spp. (columbine), *Arachis hypogaea* (peanut), *Brachychiton* spp. (flame tree), *Brassica* spp. (cabbage), *Buddleja madagascariensis* (smoke bush), *Ceanothus* spp. (lilac), *Chenopodium* spp. (goosefoot), *Choisya ternala* (Mexican orange blossum), *Citris paradisi* (grapefruit), *Citrus cedra* (cedrat lemon), *Coprosma australis* (raurekau), *Crataegus* spp. (hawthorn), *Cydonia oblonga* (quince), *Daucus carota* (carrot), *Digitalis* spp. (foxglove), *Dodonaea viscose* (varnish leaf), *Eugenia* spp., *Exocarpos* spp., *Ficus* spp. (fig), *Fragaria* spp. (strawberry), *Geranium* spp. (geranium), *Grevillea banksii* (grevillea), *Hedera helix* spp. (common ivy), *Helianthus* spp. (sunflower), *Heliotropium arborescens* (fragrant heliotrope), *Hibiscus* spp. (hibiscus), *Juglans regia* (walnut), *Kalanchoe beharensis* (kalanchoe), *Laburnum* spp. (laburnum), *Lavandula stoechas* (French lavender), *Ligustrum* spp. (privet), *Lolium* spp., *Malus pumila* (apple), *Malva* spp. (mallows), *Melilotus* spp. (melilot), *Nerium oleander* (oleander), *Pelargonium* spp. (geranium), *Pinus radiata* (pine), *Pisum sativum* (garden pea), *Pittosporum tobira* (mock orange), *Polyscias* spp. (ming aralia), *Prunus* spp. (stone fruit), *Pyrus communis* (pear), *Rheum rhaponticum* (rhubarb), *Rhododendron* spp. (rhododendron), *Ribes sanguineum* spp. (red-flowering currant), *Rosa* spp. (rose), *Rubus* spp. (berry), *Schinus molle* (California pepper tree), *Sechium edule* (chayote), *Solanum tuberosum* (potato), *Sophora microphylla* (weeping kowhai), *Theobroma cacao* (cacao), *Vitis vinifera* (grape vine), *Welwitschia mirabilis* (tree tumbo) (Ben-Dov, 1994).

Plant part(s) affected:

Foliage, fruit and twigs.

Distribution:

Africa, Asia, Australia, Europe, New Zealand, North and South America (Ben-Dov and German, 2002a). In Australia this species occurs in New South Wales (Smith et al., 1997), Queensland (Williams, 1985), South Australia (Smith et al., 1997), Tasmania (Williams, 1985) and Victoria (Smith et al., 1997).

Biology:

Citrophilus mealybug, *Pseudococcus calceolariae*, is a slow moving oval shaped insect approximately 3-4 mm in length, native to eastern Australia. Developmental stages include egg, 3-4 nymphal stages, pupae (male only) and adults. Eggs are laid in groups of up to 500 in egg sacs and 3-4 generations can occur throughout the year (Smith et al., 1997). The economically important stage of this pest is the female adult and nymphs. During feeding, citrophilus mealybug produce honeydew, an exudate high sugar that encourages the development of sooty mould (Hely et al., 1982). The presence of honeydew and sooty mould on the fruit downgrades its quality. Citrophilus mealybug is considered a pest of citrus in South Australia (Smith et al., 1997) and has been recorded from 40 host families (CABI, 2005). Dispersal mechanisms for citrophilus mealybug include wind, animals and orchard workers. Dispersal between orchards can be attributed to infested fruit, animals and workers (Hely et al., 1982).

Appendix 3 – Data sheets – Native leafroller

Pyrgotis plagiatana (Walker, 1863) [Lepidoptera: Tortricidae]

Synonyms or changes in combination:

Conchylis plagiatana Walker, 1863; *Conchylis recusana* Walker, 1863; *Paedisca luciplagana* Walker, 1863; *Grapholitha punana* Felder and Rogenhofer, 1875; *Grapholitha xylinana* Felder and Rogenhofer, 1875; *Catamacta trichroa* Meyrick, 1901; *Pyrgotis tornota* Meyrick, 1907; *Epagoge parallela* Salmon and Bradley, 1956.

Common name(s):

Native leafroller.

Host(s):

Cassinia sp.; *Coprosma foetidissima* and *Coprosma* spp.; *Dacrydium* sp.; *Hebe elliptica, Pittosporum tenifolium; Pleurophyllum* spp. and *Podocarpus* spp. (Hudson, 1928; Dugdale, 1971; Patrick, 1994); apple and pear (HortResearch, 1999b).

Plant part(s) affected:

Occasionally attacking apples and pears (HortResearch, 1999b; MAFNZ, 2000b) with no parts specified.

Distribution:

The species appears to be widespread in New Zealand and has been recorded from North and South Islands and some offshore islands (Dugdale, 1971; Dugdale, 1988).

Biology:

The Native leafroller has the following life stages: adult, egg, larva (or caterpillar) and pupa.

There is no published study on the biology of this species.

This native leafroller species is occasionally found attacking apples and pears, particularly in Otago (HortResearch, 1999b).

From the illustration provided in (Dugdale, 1971) the larva of *P. plagiatana* is about 10 – 11 mm in length.

Appendix 3 – Data sheets – Oriental fruit moth

Grapholita molesta (Busck) [Lepidoptera: Tortricidae]

Adapted from Poole et al. (2001).

Synonyms and changes in combination:

Carpocapsa molesta Busck; *Cydia molesta* Busck; *Laspeyresia molesta* Busck.

Common name(s):

Oriental Fruit Moth, Oriental peach moth, Peach tip moth.

Host(s):

Cotoneaster spp. (cotoneaster), *Crataegus laevigata* (hawthorn), *Cydonia oblonga* (quince), *Eriobotrya japonica* (loquat), *Malus domestica* (apple) (Zhao et al., 1989); (Reis et al., 1988), *Prunus amygdalus* (almond), *Prunus armeniaca* (apricot), *Prunus avium* (cherry) (Bailey, 1985), *Prunus domestica* (plums) (Yokoyama and Miller, 1988b), *Prunus persica* (peaches) (Jones et al., 1984), *Prunus persica* var. *nucipersica* (nectarines) (Weakley et al., 1987), *Pyrus communis* (pear), *Vitis vinifera* (grape vine) (Hely et al., 1982).

Plant part(s) affected:

Fruit and vegetative shoots.

Distribution:

Africa, Asia, Australia, Europe, New Zealand, North and South America (CABI, 2005). In Australia this species occurs in New South Wales (Jones et al., 1984), Queensland (Swaine et al., 1991), South Australia (Bailey, 1979), Tasmania (Terauds et al., 1989) and Victoria (McLaren and Rye, 1981).

Biology:

Oriental fruit moth has four life stages: adult, egg, larva, and pupa.

Oriental fruit moth is a small dark-grey moth with a wing span of 10-16 mm. When resting, the moth's wings are held in a roof-like position over the body with the antennae bent backward over the wings. However, a definitive identification of Oriental fruit moth involves investigation of the genitalia. Eggs are white to yellow, round to slightly oval, measuring about 0.7 mm across. The final instar larvae are approximately 12 mm long and are pink to red in colour. The head, pronotum and anal plate are brown and a black anal fork, above the anal opening, is also present (Rothschild and Vickers, 1991).

Egg deposition usually begins 2-5 days after the females emerge and continues for 7-10 days. Some 50-200 eggs are laid on the underside of leaves near the growing tips. Larval development lasts 6-22 days, varying with temperature, humidity and feeding conditions. Life cycle development is temperature dependant and ranges from 11-40 days.

Oriental fruit moth overwinters as cocooned larvae. The cocoon is the protective covering for the full-grown larva and pupa. It is made of silken threads and particles of the objects on which it rests. The pupa itself is reddish-brown. Cocoons can be found on the host within fissures, under bark, on the ground beneath the leaf litter, under mummified fruit and within the soil. Overwintering larvae usually emerge from August to October. The adults of the first generation survive 30-40 days, compared to 11-17 days in later generations (Rothschild and Vickers, 1991). Dispersal of Oriental fruit moth within an orchard is by flight, however as the moths are not strong fliers, dispersal between orchards can be attributed to infested nursery stock, fruit and equipment such as picking boxes (Hely et al., 1982).

A feature of the life cycle of OFM is that there is an extended period during each season (late autumn/winter) during which the available rosaceous host plants are without shoots or fruit. Prevailing temperatures during this period are also low. OFM overcomes these problems by entering diapause during the final larval instar. The main determinant of diapause is photoperiod modulated by temperature (Dickson, 1949). The factors governing the breakage of diapause are not fully understood, although temperature and photoperiod are both involved (Rothschild and Vickers, 1991). Russell (1986) has demonstrated that diapause breakage is not linked to any requirement for exposure to a particular cold period, and he concludes that the termination of diapause is, in part, related to an as yet undefined interaction between photoperiod and temperature.

Oriental fruit moth adults disperse locally by flight. International movement is likely to occur on fruit, possibly in packing material (CABI and EPPO, 1997).

Oriental fruit moth is native to northwest China and is thought to have established in Australia at the beginning of the twentieth century. Oriental fruit moth is considered a major pest of stone fruit throughout the world and has a host range including peach, nectarine, cherry, apricot, plum, almond, pear, quince, apple, and loquat. In spring, larvae infest the young shoots of fruit trees and fruits in summer. An infestation results in tip dieback and damaged fruit. Tip dieback results from larvae burrowing into the growing tips, this type of injury interferes with the structural development of young trees (Hely et al., 1982). Fruit can be attacked at any stage resulting in a downgrading of fruit quality and an increase in fruit drop. Injuries from Oriental fruit moth often predispose fruit to brown rot infections.

Oriental fruit moth has been previously detected in Western Australia at Bickley in 1952 (DAWA, 1952). A delimiting survey of the Bickley valley east of Perth found extensive tunnelling of peach tips typically caused by this species. Eradication measures were initiated in the area and established the valley as an Oriental fruit moth quarantine area. Eradication began in 1953 (DAWA, 1953) with applications of DDT or DDT and Parathion on a weekly rotation basis. A winter survey of twig growth in adjoining areas showed no evidence that the outbreak had spread. Eradication procedures continued in 1954 and 1955 (DAWA, 1954); (DAWA, 1955) with no infestations recorded. In 1955, with no infestations recorded, the pest was considered eradicated. The latest survey for Oriental fruit moth (using pheromone traps) was conducted in 1994 to 1996 in the Darling Scarp horticultural area, including the Bickley Valley (Poole et al., 1998). This survey did not detect the presence of the pest.

Appendix 3 – Data sheets – Oystershell scale

Diaspidiotus ostreaeformis (Curtis) [Hemiptera: Diaspididae]

Adapted from Poole et al. (2001).

Synonyms and changes in combination:

Aspidiotus almaatensis Borchsenius, 1935; *Aspidiotus betulae* Baerensprung, 1849; *Aspidiotus hippocastani* Signoret, 1869; *Aspidiotus ostreaeformis* Curtis, 1843; *Aspidiotus ostreaeformis* var. *oblongus* Goethe, 1899; *Aspidiotus oxyacanthae* Signoret, 1869; *Diaspidiotus ostreaeformis* (Curtis) Borchsenius; *Mytilococcus ellipticus* (Amerling, 1858); *Quadraspidiotus williamsi* (Takagi, 1958) Danzig, 1993.

Common name(s):

Oystershell scale, European fruit scale, yellow plum scale.

Host(s):

Acer spp. (maples), *Aesculus* spp. (chestnut), *Alnus* spp. (alder), (Zahradník, 1990).*Betula* spp. (birch), *Carpinus betulus* (European hornbeam), *Fagus sylvatica* (beech), *Fraxinus* spp. (ash), *Malus domestica* (apple), *Populus spp*. (poplar), *Prunus amygdalus* (almond), *Prunus avium* (cherry), *Prunus domestica* (European plums), *Prunus persica* (peaches), *Prunus persica* var. *nucipersica* (nectarines), *Prunus salicina* (Japanese plums), *Pyrus communis* (pear), *Quercus* spp. (oak), *Salix* spp. (willow), *Sorbus* spp. (ash), *Tilia* spp. (linden), *Ulmus* spp. (elm).

Plant part(s) affected:

Fruit, branches (Davidson and Miller, 1990)

Distribution:

Africa, Asia, Australia, Europe, New Zealand, North and South America (CABI, 2005). In Australia this species occurs in South Australia (Brookes and Hudson, 1969), Tasmania (Brookes and Hudson, 1969) and Victoria (Brookes and Hudson, 1969).

Biology:

The female life stages of oystershell scale include adult, egg and nymph while the male has adult, egg, nymph, pre-pupa and pupa stages.

The mature adult female oystershell scale is grey coloured, conically shaped and approximately 1.3 mm in diameter. Oystershell scale has a similar appearance and is often confused with the more important San Jose scale (*Quadraspidiotus perniciosus*) (McLaren, 1989), which is established in Western Australia (Woods et al., 1996) and other regions of Australia (Brookes and Hudson, 1969). Developmental stages for Oystershell scale include adult, eggs and nymphs. The mature male is typical of diaspid scales, being seldom seen and approximately 1 mm in length (Giliomee, 1990). The male develops through the pupal stages and emerges as a mobile winged insect devoid of mouthparts and lives from 1-3 days. The male is attracted to the female by pheromones and dies after mating. Oystershell scale reproduces sexually with one annual generation. Oviposition occurs in the early summer with eggs being laid under the female covering. Mobile crawlers emerge from late summer to early autumn and as such are unlikely to settle on host fruit. Overwintering occurs as a diapausing second instar larvae.

Oystershell scale does not cause serious damage to its host plants but its similarity to San Jose scale makes oystershell scale a pest of quarantine concern in areas where San Jose scale is not established or in low numbers (McLaren, 1989). Mobile crawlers are the dispersal mechanism for diaspid scales, including oystershell scale, with most crawlers settling within the host plant. However, wind assisted dispersal can also occur (McClure, 1990). Long distance dispersal is facilitated by the distribution of infested nursery stock (Beardsley and Gonzalez, 1975). The nymphs and adult female are the destructive stage of this pest where they settle on fruit and branches of the host plant.

Appendix 3 – Data sheets – Planococcus mali

Planococcus mali Ezzat and McConnell, 1956 [Hemiptera: Pseudococcidae]

Synonyms and changes in combination:

None.

Common name(s):

None.

Host(s):

Acacia longifolia (Sydney golden wattle), *Acacia verticillata* (prickly moses), *Callitris tasmanica* (pine), *Cotoneaster* spp. (cotoneaster), *Cyathodes juniperina* (prickly heath), *Nothofagus fusca* (red beech), *Olearia chathamica* (Chatham Island tree daisy), *Phlomis* spp. (sage) *Pittosporum* spp. (pittosporum), *Primula* spp. (primrose), *Psoralea pinnata* (fountain bush), *Malus pumila* (apple), *Ribes nigrum* (black current), *Ulex* spp. (gorse) (Ezzat and McConnell, 1956; Williams, 1985; Cox, 1987; Cox, 1989).

Plant part(s) affected:

Foliage, fruit and twigs.

Distribution:

Australia and New Zealand. In Australia the species occurs in New South Wales (Williams, 1985; Ben-Dov, 1994) and Tasmania (Williams, 1985; Ben-Dov, 1994).

Biology:

Adult female mealybugs of *Planococcus mali* are dark red, 2.3-3.3 mm long, and covered with a powdery white wax that extends into 12-18 short lateral filaments (Cox, 1987).

Specific details on the biology/life history of *Planococcus mali* are not available. The published literature mainly deals with the systematic aspects of the species (Ezzat and McConnell, 1956; Williams, 1985; Cox, 1987; Cox, 1989).

Planococcus mali is recorded from Australia and New Zealand on apple, blackcurrant and a variety of other woody host plants (Cox, 1989). This species was intercepted in the USA: on *Olearia chathamica* from New Zealand in Honolulu in 1937, and on apple (*Pyrus malus*) from Tasmania in New York and Massachusetts in 1946 (Ezzat and McConnell, 1956). Williams (1985) indicates that *Planococcus mali* is probably fairly common in Tasmania. This species is reasonably common and widespread in New Zealand and is mainly found on introduced plants (Cox, 1987).

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