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ST 04: Status of *Rhagoletis* (Diptera: Tephritidae) Pests in the NAPPO Countries

Prepared by the members of the
NAPPO Technical Advisory Group on *Rhagoletis*

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Introduction

Fruit flies (Tephritidae) in the genus *Rhagoletis* Loew include some of the main pests of fruit crops in North America (Lathrop and Nickels 1931, Glasgow 1933, Boyce 1934, Frick et al. 1954, Dean and Chapman 1973, Foote et al. 1993). Because of their economic importance, the biology of these flies has been well researched, with much information available on their ecology, behaviour, host use, distribution, and genetics, as well as control methods. However, because of the globalization of commerce and movement of fruit commodities between countries, the status and distributions of these pests are dynamic, and their threat and economic importance to fruit trade in different countries can change over time. In the North American Plant Protection Organization (NAPPO) countries (Canada, U.S., and Mexico), five *Rhagoletis* species are of major economic importance: apple maggot, *Rhagoletis pomonella* (Walsh), blueberry maggot, *Rhagoletis mendax* Curran, eastern cherry fruit fly, *Rhagoletis cingulata* (Loew), western cherry fruit fly, *Rhagoletis indifferens* Curran, and walnut husk fly, *Rhagoletis completa* Cresson. The black cherry fruit fly, *Rhagoletis fausta* (Osten Sacken), is of lesser economic importance. Each of these species is native to North America (Bush 1966) and occurs in two or three of the NAPPO countries. As might be expected given the large areas of these countries, distributions of the different fly species vary, with some regions being suitable and others being unsuitable for the flies.

The general biology and life cycles of *Rhagoletis* species have been described and information has been drawn from diverse sources, as summarized in the present document (Porter 1928, Frick et al. 1954, Neilson 1962, Bush 1966, Dean and Chapman 1973, AliNiazee 1974, Prokopy and Bush 1973, Prokopy et al. 1976, Boller and Prokopy 1976, Hendrichs et al. 1993, Yee 2008a). A caveat is that of the approximately 62-68 species of *Rhagoletis* worldwide (Smith and Bush 2000, Norrbom 2004), only those of economic importance have been very well studied, and that subtle to large differences exist among species. *Rhagoletis* species are generally found in temperate mesic environments with substantial rainfall, and are univoltine, although there is a small second generation in some species and a few are multivoltine (for e.g., *Rhagoletis solanophaga* Hernández-Ortiz). Most species emerge from puparia in May through August after 8–10 months spent in diapause in the ground beneath host trees. Females emerge before males and within one to two weeks mate on or near the fruit of their host plants. Both sexes appear to be opportunistic feeders. Foods include plant leachates (sugars, amino acids, and minerals), possibly yeasts and bacteria, fruit juice, exudates from extra-floral nectaries, bird excreta, and homopteran honeydew. Males wait on fruit, which are territories that they defend against other males, for arriving females with which to mate. There is no true courtship, in the sense that there are no elaborate or predictable, stereotyped, and sequenced behaviours that lead to mounting and mating, as males in general simply attempt to jump on the backs of females for coupling. Males often try to mate with females that are ovipositing. Eggs are usually deposited singly just below the fruit surface. Marking pheromones deposited by females on fruit after egg laying deter further oviposition. After eggs hatch, the larvae feed on the pulp of the fruit, causing the fruit to rot. There are three larval instars and the larvae usually exit fruit as third instars, drop onto the ground and burrow into soil to pupate. Depending on ambient temperature, the egg to puparium stage

may take 10 days to 4 weeks. In general, it is believed adults survive about one month in nature.

Because much information on *Rhagoletis* host range and distribution is dated and scattered, there is a need to update our knowledge of the status of *Rhagoletis* species as pests in the NAPPO countries, especially practical knowledge that affects fruit trade issues within and among these countries, in one document. The purpose of this paper is to briefly review and update information on the taxonomic status, host ranges, and distribution of pest species of *Rhagoletis* in the NAPPO region, the potential establishment of these flies in countries or states within this region where the flies do not currently exist, the regulated commodities for these flies, and the requirements for domestic and foreign trade of affected fruit commodities within this region.

Apple Maggot, *Rhagoletis pomonella* (Walsh)

Related species, host races, and genetics. *Rhagoletis pomonella* belongs to the *pomonella* species group. Other members of the group are *R. mendax* Curran, *R. zephyria* Snow, and *R. cornivora* Bush (Bush 1966). In eastern North America, there are well known hawthorn and apple races of *R. pomonella* (Feder et al. 1988). Hawthorn and apple races differ in behaviour in that they prefer olfactory cues from their natal hosts (Linn et al. 2003), although both hawthorn and apple races can colonize apples (Reissig and Smith 1978). It is unknown if different races exist in the western U.S. or western Canada, where the fly is apparently not native, except possibly in hawthorns in Utah and Colorado. The Mexican populations of *R. pomonella*, because of genetic (Feder et al. 2003) and morphological differences (Foote al. 1993), could represent not only host races or subspecies but undescribed species of fly (Rull et al. 2006). In fact, Mexican populations from the central Altiplano exhibit some degree of reproductive isolation from U.S. populations (Rull et al. 2010).

Host range. For a *Rhagoletis* species, *R. pomonella* has a relatively wide host range within the family Rosaceae (Smith and Bush 2000). The host use literature is somewhat confusing because of plant names that have undergone revision and because of uncertainties of the accuracy of published records (e.g., some are based on larval presence only and descriptions of stages reared for others are unclear), and because of the presence of host races of the fly. Despite this, it can be generalized that *R. pomonella* most commonly infests *Crataegus* (the fly's native hosts) and *Malus* spp. Smith and Bush (2000) compiled the most recent list of host plants of *R. pomonella*, encompassing all NAPPO countries. To this list can be added more host plants identified in the U.S. in the state of Washington (Yee and Goughnour 2005, 2008) and in Mexico (Rull et al. 2006) in more recent years (Appendix 1; questionable host records have been left out of the table).

Infestation of apples. *Rhagoletis pomonella* moved from *Crataegus* onto apples in the eastern U.S. about 150 years ago (Walsh 1867). In this region, *R. pomonella* infests commercial orchards (Reissig 1988), but no commercial apples from central Washington have been found to be infested by *R. pomonella* (WSDA 2010), despite the fly having been present in Washington since at least 1980 (Brunner 1987) and in central Washington since at least 1995 (Klaus 1996).

Distribution. *Rhagoletis pomonella* is found in all three countries in the NAPPO region.

Canada. According to the Canadian Inspection Food Inspection Agency (CFIA) (CFIA 2006a), *R. pomonella* is widespread throughout eastern Canada (Prince Edward Island, New Brunswick, Nova Scotia, Quebec, Ontario), with the exception of Newfoundland. In western Canada, *R. pomonella* occurs in Manitoba, Saskatchewan, and was detected in Edmonton, Alberta in October 2005. It was also detected in the Lower Mainland and Vancouver Island of British Columbia in August 2006 (CFIA 2011) and most recently in Prince George in the eastern part of the province (BCMA 2013).

U.S. According to CABI (1989) and CFIA (2006a),*R. pomonella* is found in 38 of the 50 states in the U.S.: Arizona, Arkansas (uncertain), California, Colorado, Connecticut, Delaware, Florida, Georgia, Idaho, Illinois, Indiana, Iowa, Kansas, Maine, Maryland, Massachusetts, Michigan, Minnesota, Mississippi, Nebraska, New Hampshire, New Jersey, New York, North Carolina, North Dakota, Ohio, Oregon, Pennsylvania, Rhode Island, South Carolina, South Dakota, Texas, Utah, Vermont, Virginia, Washington, West Virginia, and Wisconsin. In Washington, where the major commercial apple-growing region in the U.S. is located, a *R. pomonella* quarantine is established in 22 counties, including two under partial quarantine, Kittitas and Yakima Counties. Counties fully quarantined are Clallam, Clark, Cowlitz, Grays Harbor, Jefferson, Island, King, Klickitat, Kitsap, Lewis, Mason, Pacific, Pierce, Skamania, Skagit, Snohomish, Spokane, Thurston, Whatcom, and Wahkiakum (Klaus 2008, 2012). *Rhagoletis pomonella* is widespread and abundant in Washington west of the Cascade Mountain range, but is much less abundant in central and eastern Washington except in Spokane County. It occurs in very low numbers in the major apple-growing regions in central Washington in native hawthorns (*Crataegus douglasii* Lindey.) (Yee 2008b) and in even lower numbers in unmanaged roadside and backyard apples (Yee 2008b, Yee et al. 2012). In neighboring Oregon, 22 counties are under quarantine for *R. pomonella*: Benton, Clackamas, Clatsop, Columbia, Coos, Curry, Douglas, Gilliam, Hood River, Jackson, Josephine, Lane, Lincoln, Linn, Marion, Multnomah, Polk, Sherman, Tillamook, Yamhill, Wasco, and Washington. In addition, the city of Pendleton in Umatilla County is quarantined (ODA 2013a). In Idaho, six counties are quarantined: Ada, Boise, Caribou, Franklin, Gooding, and Oneida. Portions of Gem and Washington Counties are also quarantined (IDA 2013).

Mexico. There are three distinct Mexican populations of *R. pomonella*, the first ranging from Veracruz to Coahuila on the Sierra Madre Oriental, the second from Veracruz to Jalisco on the Eje Volcanico Trans Mexicano, and a third isolated population in the Sierra de los Altos de Chiapas (Hernández-Ortiz 1999, Rull et al. 2006, Michel et al. 2007). None of these populations has been found to exhibit strong association with apples. CFIA (2006a) states that *R. pomonella* is found in northern and central México, Hidalgo (Zaqualtipan, central highlands), Nuevo Leon (Mt El Potosi), and Veracruz (Xalapa and Perote areas). Recent surveys (Hernández-Ortiz 1999, Hernández-Ortiz et al. 2004, Rull et al. 2006) have revealed the existence of *R. pomonella* populations in Chiapas, Coahuila, México City, Guerrero, Hildalgo, Jalisco, Michoacan, Morelos, Nuevo Leon, Puebla, San Luis Potosi, Tlaxcala, and Veracruz. This species has not been found south of the Balsas depression in the states of Oaxaca and Guerrero, nor to the northwest in the Sierra Madre Occidental north of the Eje Volcanico trans Mexicano in Chihuahua, Durango, Guanajuato and Sinaloa.

Potential for establishment and suitability of climate and other factors. Because different populations of *R. pomonella* exhibit differences in the length of diapause regulation (Rull et al. 2006), introductions from different areas may not result in establishment due to difficulties in timing adult emergence with fruit maturation in environments with different environmental cues. However, *R. pomonella* possesses the necessary genetic variation for selection to act on diapause regulation, eventually resulting in successful adaptation (Feder et al. 2003). Genetic differences exist among flies across countries (Michel et al. 2007, Xie et al. 2007). Climate differences affecting host plant presence may dictate whether a fly population can establish in an area. Populations of *R. pomonella* in Mexico are restricted to *Crataegus* species that occur in associations with pine-oak forests distributed at altitudes from 1000 to 2800 m where rainfall levels are estimated to be 500 and 1500 mm annually (Hernández-Ortiz et al. 2004).

Management. In the eastern U.S., *R. pomonella* is still managed primarily using insecticides (Reissig 2003). In the major apple-producing regions of the Pacific Northwest of the U.S., control does not occur at the orchard level but rather outside orchards. There is a zero tolerance for infested apples (WSDA 2001). The probability of *R. pomonella* being moved in apples from Washington to Canada or Mexico is minimized by an extensive annual fly detection and insecticide spray response program conducted by the Washington State Department of Agriculture and cooperating county pest control boards. The program's objectives in brief are (1) to determine areas of the state that meet ISPM 4:1995, (2) to conduct monitoring in and around orchards to determine which growers meet regulations for shipping fresh apples out of fly quarantine areas of Washington, and (3) to implement the apple maggot detection response plan intended to prevent the establishment of apple maggot (in areas of the state where it is not yet found). Apple maggot survey programs such as that in Washington also exist in California, Idaho, and Oregon.

Export of apples from U.S. to Canada and Mexico. Apples from the Pacific Northwest of the U.S. can be moved to Canada without restriction, except to British Columbia, for which a phytosanitary certificate is required stating fruit is free of *R. pomonella*. One of four additional declarations (ADs) is also required: two ADs state that fruit must be cold treated to kill larvae (two cold treatment regimes described); one AD states that apples originate in a U.S. state free of *R. pomonella*; a fourth AD states that fruit originate in counties that are free of the fly (even though the fly is in the states: California, Oregon, Idaho, and Washington), as indicated by official annual trapping surveys, or that the apples are cold treated using one of the two cold treatments. Trade of apples from the U.S. to Mexico is achieved by complying with the requirements and specifications established in the *Work plan for exportation of apples from the central and northeastern U. S. to Mexico*, the *Work plan for exportation of apples from the northwestern U.S. to Mexico*, and in the *Work plan for export of apples from California to Mexico with methyl bromide as a quarantine treatment*. Apples exported to Mexico must be cold treated against oriental fruit moth, *Grapholita molesta* (Busck), which also provides control of *R. pomonella*.

Export of apples from Canada to Mexico. Apples originating in the provinces of Ontario, Quebec, Nova Scotia and New Brunswick can be exported to Mexico as long as the conveyances are submitted to cold treatment and are certified according to the *Work plan for importing fresh apples originating from Ontario, Quebec, Nova Scotia and New Brunswick*.

Regulated commodities for *R. pomonella*

Canada. CFIA (2011) states that commodities regulated for *R. pomonella* in Canada are: (1) rooted plants of *Malus* spp., *Crataegus* spp., *Prunus avium*, and *P. cerasus* spp., and (2) fresh fruit of *Malus* spp., *Crataegus* spp., *P. avium*, and *P. cerasus*.

U.S. The United States Department of Agriculture's (USDA) Animal and Plant Health Inspection Service's (APHIS) National Identification Services (NIS) reports that there are no national U.S. quarantines for any host fruit for *R. pomonella*. However, Washington, Idaho, Oregon, Florida, and California have domestic quarantines for *R. pomonella* as follows.

Washington. The Washington State Department of Agriculture has a quarantine for *R. pomonella.* All fresh fruit of apple (including crab apple), cherry (except cherries that are commercial fruit), hawthorn (haw), pear (except pears that are commercial fruit from California, Idaho, Oregon, Utah, and Washington), plum, prune, and quince are regulated under quarantine for apple maggot (WSL 2013a, WSR 2006).

A quarantine for apple maggot is declared for all states or foreign countries where apple maggot is established. The area under quarantine includes, but is not limited to, the states of Idaho, Oregon, Utah, and California, and, in the eastern United States, all states and districts east of and including North Dakota, South Dakota, Nebraska, Kansas, Oklahoma, and Texas, and any other areas where apple maggot is established (WSL 2013b).

Idaho. The Idaho State Department of Agriculture (ISDA) has a quarantine for *R. pomonella*. Regulated hosts for the fly are: fresh fruit of apple (including crabapple), cherry (except cherries that are commercial fruit), hawthorn (haw), pears (except pears that are commercial fruit from California, Idaho, Oregon, Utah and Washington), plum, prune, quince, and rose hips (ISDA 2001, 2010; IDA 2013).

Oregon. The Oregon Department of Agriculture (ODA) has a quarantine for *R. pomonella*. Regulated hosts include: all fresh fruit of hawthorn (haw); all non-commercial fresh fruit of pear; and all fresh fruit of apple (including crabapple) (ODA 2013a).

Florida. The Florida Department of Agriculture and Consumer Services Department of Plant Industry (FDACS) has a quarantine for all *Rhagoletis* species. Regulated hosts are listed as "All host fruit which is known to be or found to be a host or articles that may be infested of any fruit flies listed above" (FDACS 2013)

California. Per California Department of Food and Agriculture (CDFA) regulations (CDFA 2013a), apples, or apple trees, are prohibited entry into Contra Costa, El Dorado, Fresno, Kern, Kings, Madera, Merced, Monterey, San Benito, San Joaquin, San Luis Obispo, Santa Barbara, Stanislaus, Tulare and Ventura Counties except under the following provisions:

1. Commercially packed apples produced using conventional pest control practices are not restricted. "Conventional pest control practices" shall mean treatment with pesticides at label dosages and on a schedule effective against apple maggot.

2. Commercially packed organic apples (apples produced by growers in compliance with and registered under the California Organic Foods Act of 1990) may enter the county if the producing orchard was trapped and found negative for apple maggot.
3. Commercially produced apples may enter the county in bulk for packing, juicing, and processing under a compliance agreement between the importing company and the county agricultural commissioner.
4. Apple trees which are free of fruit and bareroot or free of fruit and certified by origin agricultural officials as being treated with a soil drench effective against apple maggot may enter the county, subject to inspection.

Mexico. SAGAR (1998) states that in domestic trade the commodities regulated for *R. pomonella* in Mexico are: fresh fruit of *Crataegus* spp. James Bird Phipps and *Malus* spp. In addition, the cherry *Prunus serotina* Ehrhart is regulated for *R. pomonella* (SAGAR 1998), although there have never been any records of it infesting fruit of this species.

Blueberry Maggot, *Rhagoletis mendax* Curran

Related species, host races, and genetics. *Rhagoletis mendax* belongs to the *pomonella* species group (Bush 1966). *Rhagoletis mendax* is a sibling species of *R. pomonella*, differing on the basis of crossbreeding experiments, host plant range, slight morphological differences and geographical distribution (Geddes et al. 1987, Feder et al. 1989). *Rhagoletis* fruit flies in Alabama, Georgia, Missouri, and South Carolina (U.S.) that infest sparkleberry (farkleberry), *Vaccinium arboreum* Marshall, were identified as *R. mendax*, but they probably represent a separate, undescribed species of *Rhagoletis* (Payne and Berlocher 1995a). Flies reared from *V. arboreum* apparently were mistakenly identified as *R. zephyria* by Benjamin (1934). Emergence of flies can occur earlier in wild sites than in commercial blueberry fields (Teixeira and Polavarapu 2001), suggesting there could be genetic differences governing emergence patterns among *R. mendax* populations.

Host range. Various species of *Vaccinium* (blueberry) and *Gaylussacia* (huckleberry) are hosts for *R. mendax*. Similar to hosts of *R. pomonella*, the literature on hosts of *R. mendax* is confusing due to nomenclatural inconsistencies by entomologists and botanists alike and some host records possibly being unreliable (i.e., only larvae were identified). According to the host lists of Bush (1966) and Wasbauer (1972) compiled from diverse sources, *R. mendax* infests the following 12 plants (*V. arboreum* eliminated from this list, see above): highbush blueberry, *Vaccinium corymbosum* L., lowbush blueberry, *Vaccinium angustifolium* Aiton (including var. *laevifolium*), southern blueberry, *Vaccinium formosum* Andrews (questionable), cranberry, *Vaccinium macrocarpon* Aiton (questionable, not considered a host by Canada, see "Regulated commodities for R. mendax" section), sourtop blueberry, *Vaccinium myrtilloides* Michaux (= *V. canadense* Achille Richard), California huckleberry, *Vaccinium ovatum* Pursh (questionable), hillside blueberry, *Vaccinium pallidum* Aiton, lingonberry, *Vaccinium vitis-idaea* L. (var. *minus*), black huckleberry, *Gaylussacia baccata* (Wangenheim) Karl Koch, dwarf huckleberry, *Gaylussacia dumosa* (Andrzejowski) Torrey & Gray, and dangleberry, *Gaylussacia frondosa* (L.) Torrey & Gray [the last three plants were listed as varieties of *Gaylussacia decamerium* by Wasbauer (1972)]. Payne and Berlocher (1995b) definitively recorded deerberry, *V. stamineum* L., as a host. Wintergreen, *Gaultheria procumbens* L., also was

stated to be a host in Maine, U.S., but this was based only on larvae (Lathrop and Nickels 1932). Smith and Bush (2000) list only six plants as definitive hosts for *R. mendax* (*V. corymbosum*, *V. stamineum*, *V. angustifolium*, *G. baccata*, *G. frondosa*, and *G. dumosa*).

Infestation of blueberries. Infestations of blueberries, presumably by *R. mendax*, were recorded in eastern Canada as early as 1930 (Brittain and Pickett 1933). In the U.S., *R. mendax* was first reported infesting blueberries in 1914 in New Hampshire (O'Kane 1914), although it was referred to then as *R. pomonella*.

Distribution. *Rhagoletis mendax* is native to eastern Canada and U.S. (Bush 1966). It is unclear if there are populations within these countries that occur outside the original range, as the fly's range along eastern North America is extensive. A distribution map was developed to indicate its range in the U.S. corresponding to the range of a host plant, *V. stamineum* (Payne and Berlocher 1995b).

Canada. In Canada, *R. mendax* is known from New Brunswick, Nova Scotia, Ontario, and Prince Edward Island (Foote et al. 1993). CFIA (2006b) states that *R. mendax* is widespread in eastern Canada (Prince Edward Island, New Brunswick, and Nova Scotia) (Vincent and Lareau 1989), with small isolated populations occurring in southwestern Ontario and southwestern Quebec. *Rhagoletis mendax* was not found in Newfoundland (Berlocher and Dixon 2004).

U.S. Based on information combined from diverse sources (Foote et al. 1993, CABI 7a, Liburd et al. 1998, Payne and Berlocher 1995b, Smith et al. 2001) and references therein, *R. mendax* is found in 25 U.S. states, all in the east: Alabama, Connecticut, Delaware, Florida, Georgia, Illinois, Kentucky, Maine, Maryland, Massachusetts, Michigan, Minnesota, Missouri, New Hampshire, New Jersey, New York, North Carolina, Ohio, Pennsylvania, Rhode Island, South Carolina, Tennessee, Virginia, West Virginia, and Wisconsin.

Mexico. *Rhagoletis mendax* has not been found in Mexico after limited blueberry sampling in central Mexico (Zacatlan Puebla) (J. Rull, unpublished).

Potential for establishment and suitability of climate and other factors. The commercial blueberry industry expanded in eastern Canada in the 1980s, but the distribution of *R. mendax* remained relatively localized, suggesting slow dispersal of the species (Geddes et al. 1987). There have been no reports of *R. mendax* in British Columbia, where the highbush blueberry industry in Canada is concentrated. Blueberries are also commercially grown in the Pacific Northwest of the U.S., but there have been no captures of *R. mendax* in trap surveys conducted by the Oregon Department of Agriculture. Possibly the drier climate in the inland areas in this region is unsuitable for the fly. However, blueberries are also grown west of the Cascade Mountains, where it is wetter and where *R. pomonella* has established large populations. There may not be major climatic barriers preventing establishment of *R. mendax* in blueberries in western Washington and Oregon. Although at present there are only some localized areas of commercial blueberry production in Mexico, a number of native plants could host introduced populations of *R. mendax*.

Management. *Rhagoletis mendax* control is achieved mostly through insecticide sprays (Gaul et al. 2002). CFIA regulations detail the quarantine requirements for management of

blueberries (CFIA 2006b). Briefly, a certification system has been established to minimize expansion of distribution of *R. mendax*. A brown sugar flotation technique was found more effective than direct recovery trays and fruit dissection for detecting *R. mendax* larvae (Dixon and Knowlton 1994).

Regulated commodities for *R. mendax*

Canada. Canada has a quarantine for *R. mendax* (CFIA 2011, 2012). The regulated host species are:

- Lowbush blueberry [*Vaccinium angustifolium* (= *V. pennsylvanicum*)]
- Sourtop blueberry [*V. myrtilloides* (= *V. canadense*)]
- Highbush blueberry [*V. corymbosum* (= *V. ashei*) and *V. atrococcum* (Asa Gray) Amos Arthur Heller)
- Small cranberry (*V. oxycoccus* L.)
- Deerberry (*V. stamineum*)
- Lingonberry (*V. vitis-idaea*)
- Black huckleberry (*Gaylussacia baccata*)
- Dangleberry (*G. frondosa*)
- Dwarf huckleberry (*G. dumosa*)
- Hillside blueberry [*V. pallidum* (= *V. vacillans*)]

NOTE: Cranberry, *V. macrocarpon*, commonly used for commerce, is not considered a host of *R. mendax* and is not included in this list. The following six commodities are regulated.

1. Fresh fruit: Unprocessed fruit (not frozen, canned or dried) of cultivated and wild plants of the listed host species.
2. Rooted plants: Plants of the listed host species, with roots.
3. Used containers: Any receptacle, package, box, tray or wrapper previously used for containing, transporting, packaging or wrapping the fresh fruit or plants of the listed host species, irrespective of size or material.
4. Used farm machinery and equipment: All tractors, burners, harvesters, blowers, rakes, sprayers or cultivators used in the cultivation or management of the crop of the listed host species.
5. Transportation vehicles: Any conveyance used to move fruit, used containers or plants of the listed host species.
6. Soil: Soil alone or attached to plants of the listed host species or as a contaminant of fruit, used containers, farm machinery and equipment, or transportation vehicles.

Exempt commodities in Canada are: frozen and cleaned, dehydrated or canned blueberries, unrooted cuttings, seeds, new containers and plants in tissue culture.

U.S. There is no national U.S. quarantine for any host fruit for *R. mendax*. However, Oregon has a quarantine against *R. mendax* for domestic trade (ODA 2013b), as follows: “Commodities covered comprise all fresh fruit of blueberry and blueberry plants (except when free from soil and growing media; clumps of soil or growing media larger than 1/2 inch diameter will be cause for rejection). Areas under quarantine include all states, districts, and territories of the United States east of and including the States of North Dakota, South Dakota, Nebraska, Kansas, Oklahoma, and Texas. All states of the United States west of North Dakota, South Dakota, Nebraska, Kansas, Oklahoma, and Texas are

not included therein.

All commodities covered are prohibited entry into Oregon from the area under quarantine with the exception of items listed in below:

1. No restrictions are placed by this quarantine upon the entry into the State of Oregon of fruits which upon arrival are frozen solid and which are held under refrigeration to assure their solid frozen state.
2. Fruits affected by this quarantine, which have been held in cold storage for a continuous period of at least 40 days during which period the temperature in said cold storage area has been maintained at 32° F or less, may be admitted into the State of Oregon providing that the lot or shipment of the same is accompanied by an official certificate, issued by an agency of the state of origin authorized to do so, evidencing compliance with the requirements of this subsection."

FDACS has a quarantine for all *Rhagoletis* species (see under *R. pomonella*). CDFA regulates blueberry and huckleberry for *R. mendax* (CDFA 2013b). In addition, the Mississippi Department of Agriculture and Commerce lists *R. mendax* as a type B quarantine pest with the regulated host being blueberry (MDAC 2010).

Mexico. For domestic trade the hosts of *R. mendax* are not regulated in Mexico by SAGAR (1998). However, the Mexican Official Norm (NOM-008-FITO-1995), by which the phytosanitary requirements and specifications are established for the import of fresh fruits and vegetables, specifies that for blueberries originating from the U.S. the following must be specified as part of the certification: "The product of this shipment comes from areas that are not regulated (quarantined) for fruit flies of quarantine importance".

Eastern Cherry Fruit Fly, *Rhagoletis cingulata* (Loew)

Related species, host races, and genetics. *Rhagoletis cingulata* belongs to the *cingulata* species group. Other members of the group are *R. indifferens* Curran, *R. osmanthi* Bush, *R. chionanthi* Bush (Bush 1966), and *R. turpiniae* Hernández-Ortiz, an endemic species from eastern Mexico (Hernández-Ortiz 1993). No host races of *R. cingulata* have been identified, although it is possible that populations on native and domesticated hosts may differ. Also, specimens from widely different geographic locations appear to differ phenotypically with respect to apical wing spot frequency (Bush 1966). Populations in Mexico and the U.S. may yet prove to be genetically distinct.

Host range. The native hosts of *R. cingulata* are black cherry, *Prunus serotina* Ehrhart, pin cherry, *Prunus pennsylvanica*, Carolus Linnaeus the Younger, and (rarely) choke cherry, *P. virginiana* L. Domestic hosts are sweet cherry, *Prunus avium* (L.) L., and sour cherry, *Prunus cerasus* L. (Bush 1966, and references therein). In Mexico, hosts are *Prunus serotina* Ehrhart var. *capuli* (Cavanilles) McVaugh and *Prunus serotina* Ehrhart var. *virens* (Wooton & Standley) McVaugh (Rull et al. 2011).

Infestation of cultivated cherries. *Rhagoletis cingulata* was first reported to be a pest of domesticated cherries in the U.S. (assumed) around 1900 (Bush 1966). Limited sampling in el Carmen, Puebla (Rull et al. 2011) failed to yield *R. cingulata*. Flies from Mexico, however, can be bred in commercial sweet cherries from California and Chile in the laboratory.

Distribution. *Rhagoletis cingulata* is found in all three countries in the NAPPO region. The native range of *R. cingulata* is the eastern U.S. and southeastern Canada (Bush 1966); the population in México (below) may also be native. This species has recently been found in several European countries (e.g., Lampe et al. 2005, Baugnée 2006), indicating the potential for *Rhagoletis* to be introduced into new regions through world trade and human movement.

Canada. According to the EPPO fact sheet (*Rhagoletis cingulata* and *Rhagoletis indifferens), R. cingulata* is found in Manitoba, New Brunswick, Newfoundland, Nova Scotia, Ontario, Prince Edward Island, Quebec, and Saskatchewan (CABI and EPPO 2006).

U.S. According to C.A.B.I. (1990), Foote et al. (1993), and references therein, *R. cingulata* is found in 30 U.S. states: Alabama, Arizona, Arkansas, Connecticut, Delaware, Florida, Georgia, Illinois, Indiana, Iowa, Louisiana, Maine, Maryland, Massachusetts, Michigan, Mississippi, Nebraska, New Hampshire, New Jersey, North Carolina [specimens housed at the Canadian National Collection (CNC), det. by B. J. Sinclair]., New York, Ohio, Pennsylvania, South Carolina, Tennessee, Texas, Vermont, Virginia, West Virginia, and Wisconsin.

Mexico. *Rhagoletis cingulata* is found in Texcoco in central Mexico (Foote 1981). A form of *R. cingulata* has been found in an area of the central high plateau encompassing the state of Tlaxcala, Mexico, Mexico City, Puebla, and Hidalgo (Padilla 1964, Hernández-Ortiz 1999, Rull et al. 2011). A second disjunct population can be found from San Luis Potosi to Coahuila in high elevation areas of the Sierra Madre Oriental (Rull et al. 2011).

Potential for establishment and suitability of climate and other factors. *Rhagoletis cingulata* has not been reported from the western states of the U.S. outside of Arizona and Texas, but there appears to be no climatic factors that would prevent its establishment there. Although commercial production of cherries in Mexico is limited, this species could expand its range to several species of wild *Prunus* and become established in many areas where these hosts are present.

Management. Historically, to meet the stringent zero tolerance levels mandated by federal and state regulations (Michigan 1929), growers generally have applied two to three applications of broad-spectrum insecticides, primarily organophosphates, for reducing *R. cingulata* populations. More recently, organic spinosad bait has been used for fly control. Integrated control using spinosad bait, traps, and nematodes have been studied (Kostarides 2002).

Regulated commodities for *R. cingulata*

Canada: Hosts of *R. cingulata* are not regulated by CFIA.

U.S. There is no national U.S. quarantine for any host fruit for *R. cingulata*. However, ISDA has a quarantine for the "*Rhagoletis cingulata* complex*"*. The regulated host is cherry (except cherries that are commercial fruit) (ISDA 2013). FDACS has a quarantine for all *Rhagoletis* species (see under *R. pomonella*).

Mexico. *Rhagoletis cingulata* is not regulated in Mexico.

Western Cherry Fruit Fly, *Rhagoletis indifferens* Curran

Related species, host races, and genetics. *Rhagoletis indifferens* belongs to the *cingulata* species group. Other members are *R. cingulata*, *R. osmanthi*, *R. chionanthi* (Bush 1966), and *R. turpiniae* (Bush 1966, Hernández-Ortiz 1993). No host races of *R. indifferens* have been identified (Maxwell et al. 2013), but this may be because no work has been done in this area, as *R. indifferens* found in cultivated sweet and sour cherries (*Prunus avium* [L.] L. and *Prunus cerasus* L.) could be genetically distinct from flies found in native *Prunus emarginata* (bitter cherry). Adult abundance of flies associated with cultivated cherries (*Prunus avium*) peaks earlier in the season (usually June) than abundance of flies associated with bitter cherry (usually August), as emergence is tied closely to the phenologies of the host plants. Because of this, there is a likelihood the genetics underlying diapause characteristics of the puparia from cultivated and native cherries differ, similar to those of *R. pomonella* from hawthorns and apples. Microsatellite loci of *R. indifferens* have been characterized that could help assess genetic structure and movement patterns of the fly (Maxwell et al. 2009).

Host Range. *Rhagoletis indifferens* has been confirmed to infest 15 host plants in nature: sweet cherry, *Prunus avium*, sour cherry, *Prunus cerasus*, mahaleb cherry, *Prunus mahaleb* L. (Wilson and Lovett 1913, Frick et al. 1954), bitter cherry, *Prunus emarginata* (Douglas ex Hooker) David Dietrich (*emarginata* and *mollis* varieties) [ancestral host (Curran 1932)], choke cherry, *Prunus virginiana* (Frick et al. 1954), European bird cherry,

Prunus padus L. (Yee and Goughnour 2008), cherry laurel, *Prunus laurocerasus* L. (Yee and Goughnour 2005), Japanese plum, *Prunus salicina* Lindley, Pacific plum, *Prunus subcordata* Bentham (Ellertson 1961), cherry plum, *Prunus cerasifera* Ehrhart (Yee and Goughnour 2008), apricot, *Prunus armeniaca* L. (Yee et al. 2010), black hawthorn, *Crataegus douglasii*, and cascara, *Rhamnus purshiana* de Candolle (Yee and Goughnour 2005). Pin cherry, *Prunus pensylvanica*, is also infested by *R. indifferens* in British Columbia (H. M. A. Thistlewood, personal communication). In addition, the fly can infest Chinese crabapple, *Malus spectabilis* (Aiton) Borkhausen (Yee and Klaus 2013).

Infestation of cultivated cherries. Introduced cherries of various varieties were first brought into the Pacific Northwest of the U.S. (in Oregon) in 1847 (McClintock 1967), but it was not until the early 1900s that *R. indifferens* was first reported attacking introduced cherries in this region (Wilson and Lovett 1913). The fly was first reported from bitter cherry in 1932 in Oregon (Curran 1932). The first reports of introduced cherries being attacked in two major cherry-producing areas in Washington, the Yakima Valley and Wenatchee, were in 1942 (Eide et al. 1949) and 1950 (Frick et al. 1954), respectively. *Rhagoletis indifferens* has been a pest of introduced cherries in Montana since at least the early 1960s (USDA 1964). It was found in Utah in 1980 (Davis and Jones 1986). This species was first reported on cultivated cherries in British Columbia in 1968 (Maxwell et al. 2013).

Distribution. The native range of *R. indifferens* is the western U.S. and southwestern Canada (Bush 1966). Some populations in commercial cherry-growing areas in Washington apparently are introduced from other areas within the state. Reports of *R. indifferens* in Europe (Merz 1991) were based on misidentifications of *R. cingulata* (Merz and Niehuis 2001).

Canada. British Columbia is the only province where this species has been recorded (Madsen 1970, Banham and Arrand 1978) where it is present in the main fruit-growing regions and continues to slowly disperse into smaller and more remote areas (Maxwell et al. 2013).

U.S. The fly is found in California, Colorado, Idaho, Montana, New Mexico, Oregon, Utah, and Washington (Foote et al. 1993). In Washington and Oregon, it is found in all commercial cherry-growing areas and apparently wherever its native host, bitter cherry, *P. emarginata*, exists. In commercial areas of central Washington, the fly is found almost exclusively on unmanaged sweet and sour cherry trees in yards and roadsides, and not in commercial orchards, which if properly managed are usually free of the fly. In higher elevations of central Washington and in western Washington, where rainfall is greater than in lower elevations in central Washington, *R. indifferens* is common in seedling sweet cherry trees in woodlots and roadsides. In California, this species is found in the northern counties at high altitudes (Mackie 1940, Frick et al. 1954, Blanc and Kiefer 1955) and not in the lower elevation commercial cherry growing areas farther south. *Rhagoletis indifferens* is found in northern and southwestern Idaho (ISDA 2001) and in western Montana (USDA 1964), with populations in the Flathead Lake area where there is a commercial cherry industry, and in southwestern Colorado in La Plata County (Kroening et al. 1989). In New Mexico, *R. indifferens* has been found in the Albuquerque area (Ward 1990).

Mexico. Absent

Potential for establishment and suitability of climate and other factors. *Rhagoletis indifferens* has not been recorded in Mexico, where *R. cingulata* occurs (above). Wild cherries, *P. serotina*, occur in Mexico, and could serve as a host for *R. indifferens*. This species requires chilling to break diapause, so it needs areas that have cold winters to establish. Once diapause is initiated and expressed, it is maintained by elevated temperatures; at ~23 ºC and a 17:7 LD photoperiod, 90–95% of pupae entered diapause (AliNiazee 1988). In another study, only 1.1% of a *R. indifferens* population in Oregon emerged without undergoing a chilling period under 19L:5D photoperiod (Brown and AliNiazee 1977), consistent with findings from earlier studies (Frick et al. 1954). Optimal adult emergence occurs after pupae have undergone chilling at 0–5 °C for 3–5 months (Frick et al. 1954). *R. indifferens* is found in California at higher altitudes where chilling requirements are met and not near commercial cherry orchards where they apparently are not; this could reflect a potentially similar situation in Mexico. However, quantitative data from modeling are much needed to predict where *R. indifferens* could establish in Mexico if it did enter the country and suitable hosts were available. *Rhagoletis indifferens* is abundant in areas with hot, dry summers (e.g., in Benton County in interior Washington), so it appears these conditions are not a barrier for its establishment and population growth.

Management. As mentioned, *R. indifferens* is rarely found in commercial sweet cherry orchards in the Pacific Northwest of the U.S. and in sour cherry in Utah, and is apparently not found in cherry orchards in California. In the Pacific Northwest of the U.S., sprays are still applied because of zero tolerance for larval infestations (Anonymous 1968). Spray schedules and use of sprays vary among growers, but weekly sprays of spinosad bait (GF-120) are applied by many growers, for four or five total sprays in a season. Neonicotinoids and other insecticides are also available for use. How and if the presence of spotted wing drosophila, *Drosophila suzukii* Matsumura (Drosophilidae) (Walsh et al. 2010), in cherries will affect *R. indifferens* control is unclear. Producers now need to choose treatment protocols that offer control for both species, which leads to a reduction in spinosad bait and therefore does not always offer adequate control of the spotted winged *Drosophila* (Warner 2012). After pre-harvest insecticide sprays, a spray of the organophosphate dimethoate is used by some growers as a post-harvest spray to kill possible immature stages inside unpicked fruit (Zwick et al. 1975). Methyl bromide is effective at killing larvae inside cherries (Moffit et al. 1977) and is required by some export markets. At the packing house, cherries may be inspected for larvae using a brown sugar flotation method or a hot water method (Yee 2012). One of these two is required by California for Northwest cherries (CDFA 2010), but not by Canada and Mexico.

Export of cherries from U.S. to Canada and Mexico. As of 2012, there were no restrictions for movement of cherries from the northwestern U.S. to Canada. However, movement of cherries from California, Idaho, Oregon, and Washington to Mexico requires a phytosanitary certificate issued by Animal and Plant Health Inspection Service (APHIS) stating that the fruit in a shipment are free of *R. indifferens*, as well as an import permit (Phytosanitary Agreement between USDA/APHIS and SAGARPA/SENASICA/ DGSV for the Export of US Cherries to Mexico, last updated May 18, 2010). Within the agreement between the U.S. and Mexico, section III states that measures need to be taken to mitigate risk, including implementation of a trapping and monitoring program for *R. indifferens* and

inspection of a minimum of 2% of the boxes in each shipment of cherries at the packing house. Cherry inspection involves cutting fruit and examining for internal damage.

Regulated commodities for *R. indifferens*

Canada: Hosts of *R. indifferens* are not regulated by CFIA.

U.S. There is no national U.S. quarantine for any host fruit for *R. indifferens*, and it is not listed in the APHIS NIS. However, Idaho, and California have listed quarantines for *R. indifferens*.

Idaho. ISDA has an external quarantine for *R. indifferens*. The regulated host is cherry (except cherries that are commercial fruit) (ISDA 2010, 2013).

Florida. FDACS has a quarantine for all *Rhagoletis* species (see under *R. pomonella*).

California. The California Department of Food and Agriculture (CDFA) has interior and exterior quarantines for *R. indifferens* in their plant quarantine manual. Cherry fruits of all domesticated and wild cherries are regulated hosts plants (CDFA 2010, 2013a). CDFA lists the following *Prunus* species as regulated for *R. indifferens*: *P. avium*, *P. cerasus*, *P. emarginata*, *P. laurocerasus* (a popular ornamental fruiting plant), *P. salicina*, *P. serotina*, *P. subcordata*, and *P. virginiana* (CDFA 2008). Not regulated are Portugal laurel, *Prunus lusitanica* L., and various flowering cherries. Soil or planting media "from or under the dripline of any fruiting host or host which has previously produced fruit is considered a regulated article" (CDFA 2013a).

Mexico. For domestic trade, the hosts of *R. indifferens* are not regulated by SAGAR (1998). In addition to the phytosanitary agreement for the export of cherries from the U.S. to Mexico mentioned earlier, the document *Work plan for the exportation of apricots from the U.S. (Idaho, Oregon and Washington) to Mexico* establishes the phytosanitary measures to certify the absence of *R. pomonella* and "fruit flies (Tephritidae)" in general but not specifically for *R. indifferens*: "The procedures being followed are to ensure that apricots are free of Oriental fruit moth (*Cydia molesta*), apple maggot (*Rhagoletis pomonella*), plum curculio (*Conotrachelus nenuphar*) and fruit flies (Tephritidae)" (SAGARPA 2009).

Walnut Husk Fly, *Rhagoletis completa* Cresson

Related species, host races, and genetics. *Rhagoletis completa* is a member of the *Rhagoletis suavis* species group that includes *R. suavis* (Loew), *R. juglandis* Cresson, *R. boycei* Cresson, *R. zoqui* Bush (Bush 1966), and *R. ramosae* Hernández-Ortiz (Hernández-Ortiz 1985). Host races of *R. completa* have not been reported.

Host range. Hosts are *Juglans nigra* L., *J. microcarpa* Berlandier*, J. hirsuta* Manning, *J. major* (Torrey) Heller*, J. regia* L., *J. californica* Sereno Watson, *J. hindii* Rehder (Bush 1966, Smith and Bush 2000) and *J. mollis* Engelm (Rull et al. in press). Peach, *Prunus persica* (L.) Batsch, is infrequently attacked (Boyce 1934).

Infestation of cultivated walnuts. Infestations of commercial walnuts in the U.S. by *R. completa* were first reported in the mid to late 1920s in California (1934).

Distribution. *Rhagoletis completa* is found in all three countries in the NAPPO region.

Canada. *Rhagoletis completa* is found in southern British Columbia (observations, H. M. A. Thistlewood and B. J. Sinclair, but no citations found in the literature).

U.S. According to CABI (1997b), Foote et al. (1993), and references therein, *R. completa* is found in 17 U.S. states: Arizona, California, Colorado, Idaho, Iowa, Kansas, Minnesota, Mississippi, Missouri, Nebraska, Nevada, New Mexico, Oklahoma, Oregon, Texas, Utah, and Washington. In California, the only state where *R. completa* is a major pest due to the walnut industry there, the fly is found wherever walnuts are grown (UC IPM Online 2013), including San Joaquin, Butte, Tulare, Sutter, Stanislaus, Tehama, Glenn, Yolo, Yuba, and Kings Counties, the counties with highest walnut acreage (NASS 2012).

Mexico. *Rhagoletis completa* is found in Monterrey, Nuevo Leon (Foote 1981, Foote et al. 1993). It is restricted to *J. hirsuta* in higher elevation areas within the canyons of the Sierra Madre Oriental in the state of Nuevo Leon. It is also present in Coahuila and Tamaulipas in northeastern Mexico, infesting *J. mollis* in Tamaulipas (J. Rull et al. in press), but absent south of the Tamaulipas-San Luis Potosi border.

Potential for establishment suitability of climate and other factors. No apparent barrier exists for the establishment of *R. completa* if suitable *Juglans* hosts are available. In the major commercial fruit-growing areas of the Pacific Northwest of the U.S., *R. completa* is common in backyard walnut trees, with nearly 100% of trees infested (Yee 2008b). Because walnuts are not grown commercially (on a large scale) there, the fly is of relatively little economic importance in that region. The fly, however, continues to be a problem in commercial walnut-growing areas of California (Strand 2003).

Management. *Rhagoletis completa* is controlled in California using reduced-risk insecticides, including spinosad bait (GF-120) or spinosad plus bait and kaolin. Recent results indicate malathion 75% and the bait Nu-Lure applied in low volumes are effective (Van Steenwyk et al. 2006, Coates and Van Steenwyk 2005, Van Steenwyk et al. 2013). All recent work on *R. completa* control within NAPPO countries has been conducted in California; detailed yearly reports of the work are found in the Walnut Research

Proceedings (UC 2012). In addition to the work conducted in California (Coates 2005, 2006, Van Steenwyk et al. 2013), there has been a recent effort in Switzerland, where this species has recently been introduced (Aluja et al. 2011), to develop or identify varieties of walnuts that are resistant to *R. completa* attack (Guillen et al. 2011). Methyl bromide fumigation is an effective quarantine treatment against larvae in peaches (Yokoyama et al. 1992).

Regulated commodities for *R. completa*

Canada: Fruit for *R. completa* are not regulated by CFIA.

U.S. There is no national U.S. quarantine for any host fruit for *R. completa.* FDACS has a quarantine for all *Rhagoletis* species (see under *R. pomonella*).

Mexico. Fruit for *R. completa* are not regulated by SAGAR (1998).

Black Cherry Fruit Fly, *Rhagoletis fausta* (Osten Sacken)

Related species, host races, and genetics. *Rhagoletis fausta* attacks cherries but is not closely related to *R. cingulata* and *R. indifferens* and is not yet placed in a species group (Smith and Bush 2000). It may be most related to members of the *suavis* species group (Berlocher and Bush 1982). Host races of *R. fausta* have not been reported, although the allopatric western and eastern U.S. populations (Bush 1966) may have time to differentiate genetically.

Host range. Hosts are *Prunus cerasus*, *P. avium*, *P. mahaleb, Prunus emarginata, P. pensylvanica, P. serotina*, and *P. virginiana* L. var. *demissa (*Nuttal)(Torrey) (Farleman 1932, Mackie 1940, Proverbs 1953, Raine and Andison 1958, Banham and Arrand 1978).

Infestation of cultivated cherries. The first specimen from Canada was recorded in 1904 from sour cherry near Victoria (Fletcher 1907). *Rhagoletis fausta* has been reported to attack both sour and sweet cherries in the Okanagan Valley of British Columbia (Proverbs 1953), although in Vancouver Island in British Columbia the fly was only reared from sour cherries (Raine and Andison 1958).

Distribution. *Rhagoletis fausta* is found in Canada and the U.S. There are two allopatric populations, one in western and one in eastern North America (Bush 1966). No reports of introduced populations could be found in the literature.

Canada. *Rhagoletis fausta* is found in southern British Columbia and Vancouver Island (Raine and Andison 1958). It is also found in southern Manitoba, southern Ontario, southern Quebec and New Brunswick (Foote et al. 1993), Nova Scotia (specimens housed in CNC, det. B. J. Sinclair), and more recently in Newfoundland (Berlocher and Dixon 2004).

U.S. According to CABI (1963), Bush (1966), Foote et al. (1993), and references therein, *R. fausta* is found in 14 U.S. states: in the west, California, Idaho, Oregon, Montana, and Washington; in the east, Ohio, Michigan, Minnesota, Maine, Massachusetts, New Hampshire, New York, Pennsylvania, and Wisconsin.

Mexico. Absent.

Potential for establishment suitability of climate and other factors. Thorough studies of the environmental requirements for *R. fausta* could not be found. However, it is much rarer than *R. indifferens* in the western states in cultivated as well as native bitter cherry (Raine and Andison 1958, Frick et al. 1954), suggesting it does not establish as readily in new habitats (Banham and Arrand 1978).

Management. As stated, *R. fausta* is rare compared with *R. indifferens* and thus of less economic importance. Methods for controlling it should be similar to those for *R. indifferens*. One caveat is that *R. fausta* emerges 1–3 weeks earlier than *R. indifferens* (Frick et al. 1954, Madsen 1970, Liburd et al. 2001, Dowell and Penrose 2012), except for the Vancouver Island population (Raine and Andison 1958), suggesting timing of control methods may vary.

Regulated commodities for *R. fausta*

Canada: Fruit for *R. fausta* are not regulated by CFIA.

U.S. The same regulations enforced by Idaho, California, and Florida for *R. indifferens* (above) are enforced for *R. fausta*.

Mexico. Fruit for *R. fausta* are not regulated by SAGAR (1998).

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Appendix 1: Natural host range of *Rhagoletis pomonella* based on available literature

Plant Species[a]	Common Name[a]	Host Records, Country or U.S. States[b]	All Reference (s) Found, Up to a Maximum of Five [c]	Importance as Fly Host[d]
Apples, *Malus*				
M. domestica Borkh., *M. pumila* Mill.	Apple	Canada, U.S. (many eastern and western states), México	Walsh (1867), Porter (1928), Bush (1966), Dean and Chapman (1973), Feder et. (1988), many others	High
M. baccata (L.) Borkh. and hybrid crab apples	Siberian and other crabapples	U.S.: NH, MI, UT; Canada	Riley (1872), Fletcher (1905), Ross (1912), O'Kane (1914), Allred and Jorgensen (1993)	Low
Hawthorns, *Crataegus*				
C. aestivalis (Walter) Torr. & A. Gray	Eastern mayhaw	U.S.: GA	Lyons-Sobaski and Berlocher (2009), Powell (2012)	High?
C. brainerdii Sarg.	Brainerd's hawthorn	U.S.: NY	Wellhouse (1922)	Medium?
C. brachyacantha Sarg. & Engelm.	Blueberry hawthorn	U.S.: AK, TX	Berlocher and Enquist (1993), Berlocher and McPheron (1996), Powell (2012)	High?
C. crus-galli L.	Cockspur hawthorn	U.S.: NY, TX	Reissig and Smith (1978), Berlocher and Enquist (1993)	High?
C. cuprina J. B. Phipps	None	México	Rull et al. (2006)	Medium?
C. douglasii Lindl.	Black hawthorn	U.S.: CA, CO, ID, OR, UT, WA	Joos et al. (1984), Tracewski et al. (1987), Yee (2008b), Yee and Goughnour (2008), Yee et al. (2012)	High
C. erythropoda Ashe	Cerro hawthorn	U.S.: CO	Hood et al. (2013)	Medium?
C. flabellata (Bosc ex	Fan-leaf hawthorn	U.S.: SC, TN	Berlocher and McPheron	High?

Spach) K. Koch			(1996)	
C. flava Ait.	Yellowleaf hawthorn	U.S.: AL, GA, SC	Berlocher and Enquist (1993), Berlocher and McPheron (1996), Lyons-Sobaski and Berlocher (2009)	High?
C. gracilior J. B. Phipps	None	México	Rull et al. (2006)	High?
C. greggiana Eggl.	Gregg's hawthorn	U.S.: TX; México	Berlocher and McPheron (1996), Rull et al. (2006)	High
C. holmesiana Ashe	Holmes' hawthorn	U.S.: NY	Reissig and Smith (1978)	High
C. laevigata (Poir.) DC.	Smooth hawthorn	U.S.: WA	Yee and Goughnour (2008)	Medium
C. invisa Sarg. (unresolved name) = *C. mollis* Scheele?	Unresolved name	U.S.: TX	Berlocher and Enquist (1993), Berlocher and McPheron (1996)	Medium?
C. macracantha Lodd. ex Loudon	Long-thorned hawthorn	U.S.: CO, ID	Hood et al. (2013)	Medium?
C. macrosperma Ashe	Bigfruit hawthorn	U.S.: NY	Wellhouse (1922), Reissig and Smith (1978)	High?
C. marshallii Eggl.	Parsley hawthorn	U.S.: TX	Berlocher and Enquist (1993)	Medium?
C. mexicana Moc. & Sessé ex DC.	Manzanita tejocotera	México	Berlocher and McPheron (1996), Rull et al. (2006)	High
C. mollis Scheele	Downy, red hawthorn	U.S.: CO, IL, KY, MD, MI, NY, TX	McPheron et al. (1988a), Berlocher and Enquist (1993), Berlocher and McPheron (1996), Powell (2012), Hood et al. (2013)	High
C. monogyna Jacq.	Oneseed hawthorn	U.S.: NY, OR, UT, WA	Reissig and Smith (1978), Tracewski et al. (1987), McPheron (1990), Allred and Jorgensen (1993), Yee and Goughnour (2008)	High
C. opaca Hook. & Arn.	Riverflat hawthorn	U.S.: TX	Berlocher and Enquist (1993), Powell (2012)	High?
C. pedicellata Sarg.	Scarlet hawthorn	U.S.: NY	Wellhouse (1922)	

				Medium?
C. pruinosa (Wendl.f.) K. Koch	Waxyfruit hawthorn	U.S.: NY, MD, PA, VA	Wellhouse (1922), Berlocher and McPheron (1996)	High?
C. punctata Jacq.	Dotted hawthorn	U.S.: NY	Wellhouse (1922), Reissig and Smith (1978)	High?
C. rivularis Nutt. ex Torr. & A. Gray[e]	River hawthorn	U.S: CO, UT	Kroening et al. (1989), Allred and Jorgenson (1993)	High
C. rosei Eggl.	None	México	Rull et al. (2006)	High
C. suksdorfii (Sarg.) Kruschke	Suksdorf's hawthorn	U.S.: WA	Yee and Goughnour (2008), Yee et al. (2012)	Medium
C. viridis L.	Green hawthorn	U.S.: GA, LA, MS, TX	Berlocher and Enquist (1993), Berlocher and McPheron (1996), Powell (2012)	High
Serviceberries, *Amelanchier*				
A. bartramiana (Tausch) M. Roem.	Oblongfruit serviceberry	U.S.: ME	Lathrop and Nickels (1932)	Low
Chokeberries, *Aronia*				
Photinia pyrifolia (Lam.) K. R. Robertson & Phipps (*A. arbutifolia*)	Red chokeberry	U.S.: FL	Benjamin (1934)	Low
Photinia melanocarpa (Michx.) K. R. Robertson & Phipps (*A. melanocarpa*)	Black chokeberry	U.S.: ME	Lathrop and Nickels (1932)	Low
Firethorns, *Pyracantha*				
P. angustifolia (Franch.) C. K. Schneid.	Narrowleaf firethorn	U.S.: TX	Bush (1966)	Low
P. coccinea M. Roem.	Scarlet firethorn	U.S.: UT	Allred and Jorgensen (1993)	Low
Cotoneasters, *Cotoneaster*				
C. apiculatus Rehd. & E. H. Wilson	Cranberry cotoneaster	U.S.: WA	Yee and Goughnour (2006)	Low

C. integerrimus Medik.	European cotoneaster	U.S.: WA	Yee and Goughnour (2008)	Low
C. lacteus W. W. Smith	Milkflower cotoneaster	U.S.: WA	Yee and Goughnour (2008)	Low
Mountain Ashes, *Sorbus*				
S. aucuparia L.	European mountain ash	U.S.: WA	Yee and Goughnour (2008)	Low
S. scopulina Greene	Greene's mountain ash	U.S.: WA	Yee and Goughnour (2008)	Low
Cherries and Plums, *Prunus* spp.				
P. angustifolia Marsh.	Chickasaw plum	U.S.: FL	Benjamin (1934)	Low
P. armeniaca L.	Apricot	U.S.: NY, UT, WA	Lienk (1970), Allred and Jorgensen (1993), Yee and Goughnour (2008)	Low
P. avium (L.) L.	Sweet cherry	U.S.: UT	Allred and Jorgensen (1993)	Low
P. cerasus L.	Sour cherry	U.S.: UT, WI	Shervis et al. (1970), Jorgensen et al. (1986), Davis and Jones (1986), McPheron et al. (1988b)	Low
P. cerasifera Ehrh.	Cherry plum	U. S.: UT, WA	Allred and Jorgensen (1993), Yee and Goughnour (2008)	Low
P. domestica L.	European plum	U.S.: NY, WA	Herrick (1920), Yee and Goughnour (2006)	Low
P. emarginata (Douglas ex Hook.) D. Dietr.	Bitter cherry	U.S.: WA	Yee and Goughnour (2006)	Low
P. mahaleb L.	Mahaleb cherry	U.S.: UT	Allred and Jorgensen (1993)	Low
P. salicina Lindl.	Japanese plum	U.S.: WA	Yee and Goughnour (2008)	Low
P. umbellata Elliot	Hog plum	U.S.: FL	Benjamin (1934)	Low
P. virginiana L.	Chokecherry	U.S.: UT	Allred and Jorgensen (1993)	Low
Pears, *Pyrus*				
P. communis L.	Common pear	U.S.: WA, WI	Prokopy and Bush (1972),	Low

			Yee and Goughnour (2006)	
P. pyrifolia (Burm. f.) Nakai (*P. serotina* Rehder)	Asian pear	U.S.: WA	Yee and Goughnour (2006, 2008)	Medium
Roses, *Rosa*				
Rosa rugosa Thunb.	Rugosa rose	U.S: MA, RI	Prokopy and Berlocher (1980)	Low
Rosa virginiana Mill.	Virginia rose	U.S.: MA	Prokopy and Berlocher (1980)	Low

[a]Authors of species and common names based mostly on: USDA Natural Resources Conservation Service Plants Database (USDA 2013a, 2013b) and the The Plant List (The Plant List 2010). [b]May not include all U.S. states. [c]Most records based on rearing to adult stage; for crab apples and *Photinia melanacarpa*, larval stage: questionable, but within the *R. pomonella* species group, *R. pomonella* is the most likely species; excludes trap records. [d]Insufficient information to gauge importance of most hawthorns; based on numbers of references and infestation levels when available. [e]Treated as valid species; sometimes referred to as a subspecies of *C. douglasii* (USDA 2013b).

Plant Species	Published records from: country or U.S. states	Reared stage of fly	Key or representative reference (s) documenting use of plant by *R. pomonella*
Apples, *Malus*			
M. domestica (Borkh.) Borkh., *M. pumila* Mill.	Canada, U.S. (many states), Mexico	Adult	Walsh (1867), Bush (1966), Dean and Chapman (1973)
M. baccata (L.) Borkh. and hybrid crab apples	U.S.: NH, MI, UT; Canada	Adult	O'Kane (1914), Allred and Jorgensen (1993)
Hawthorns, *Crataegus*			
C. brainerdii Sarg.	U.S.: NY	Adult	Wellhouse (1922)
C. brachyacantha Sarg. & Engelm.	U.S.: TX, AK	Adult	Berlocher and Enquist (1993), Berlocher and McPheron (1996)
C. crus-galli L.	U.S.: NY, TX	Adult	Reissig and Smith (1978)
C. cuprina J. B. Phipps	Mexico	Adult	Rull et al. (2006)
C. douglasii Lindl.	U.S., WA, OR	Adult	Tracewski et al. (1987), Yee (2008b)
C. flabellata (Bosc ex Spach) K. Koch.	U.S.: SC	Adult	Berlocher and McPheron (1996)
C. flava Ait.	U.S.: AL, GA, SC	Adult	Berlocher and McPheron (1996)
C. gracilior J. B. Phipps	Mexico	Adult	Rull et al. (2006)
C. greggiana Eggl.	U.S.: TX, Mexico	Adult	Berlocher and McPheron (1996), Rull et al. (2006)
C. holmesiana Ashe	U.S.: NY	Adult	Reissig and Smith (1978)
C. laevigata (Poir.) DC.	U.S.: WA	Adult	Yee and Goughnour (2008)
C. invisa Sarg. (unresolved name)	U.S.:TX	Adult	Berlocher and Enquist (1993), Berlocher and McPheron (1996)
C. macrosperma Ashe	U.S.:NY	Adult	Wellhouse (1922), Reissig and Smith (1978)
C. marshallii Eggl.	U.S.:TX	Adult	Berlocher and Enquist (1993)
C. mexicana DC.	Mexico	Adult	Berlocher and McPheron (1996), Rull et al. (2006)
C. mollis Scheele	U.S.: TX	Adult	Wellhouse (1922), Berlocher and Enquist (1993), Berlocher and McPheron (1996)
C. monogyna Jacq.	U.S.: NY, UT, WA	Adult	Reissig and Smith (1978), Allred and Jorgensen (1993), Yee and Goughour (2008b)
C. opaca Hook. & Arn.	U.S.:TX	Adult	Berlocher and Enquist (1993)

C. pedicellata Sarg.	U.S.: NY	Adult	Wellhouse (1922)
C. pruinosa (Wendl.f.) K. Koch.	U.S.: NY, MD, PA, VA	Adult	Wellhouse (1922), Berlocher and McPheron (1996)
C. punctata Jacq.	U.S.: NY	Adult	Wellhouse (1922), Reissig and Smith (1978)
C. rivularis Nutt.	U.S: CO, UT	Adult	Kroening et al. (1989), Allred and Jorgenson (1993)
C. rosei Eggl.	Mexico	Adult	Rull et al. 2006
C. suksdorfii (Sarg.) Kruschke	U.S.: WA	Adult	Yee and Goughnour (2008b)
C. viridis L.	U.S.: TX, GA	Adult	Berlocher and Enquist (1993), Berlocher and McPheron (1996)
Serviceberries, *Amelanchier*			
A. bartramiana (Tausch) M. Roem.[a]	U.S.:ME	Larval	Lathrop and Nickels (1932)
Chokecherries, *Aronia*			
Photinia pyrifolia (Lam.) K. R. Robertson & Phipps (*A. arbutifolia*)	U.S.: FL	Adult	Benjamin (1934)
Photinia melanocarpa (Michx.) K. R. Robertson & Phipps (*A. melanocarpa*)[a]	U.S.: ME	Larval	Lathrop and Nickels (1932)
Firethorns, *Pyracantha*			
P. angustifolia (Franch.) C. K. Schneid.	U.S.: TX	Adult	Bush (1966)
P. coccinea M. Roem.	U.S.: UT	Adult	Allred and Jorgensen (1993)
Cotoneasters, *Cotoneaster*			
C. apiculatus Rehd. & E. H. Wilson	U.S.: WA	Adult	Yee and Goughour (2005)
C. integerrimus Medik.	U.S.: WA	Adult	Yee and Goughnour (2008)
C. lacteus W. W. Smith	U.S.:WA	Adult	Yee and Goughnour (2008)
Mountain Ash, *Sorbus*			
S. aucuparia L.	U.S.: WA	Adult	Yee and Goughnour (2008)
S. scopulina Greene	U.S.: WA	Adult	Yee and Goughnour (2008)
Cherries, Plums, *Prunus*			
P. angustifolia Marsh.	U.S.: FL	Adult	Benjamin (1934)
P. armeniaca L.	U.S.: NY, UT, WA	Adult	Lienk (1970), Allred and Jorgensen (1993), Yee and Goughnour (2008)

P. avium (L.) L.	U.S.: UT	Adult	Allred and Jorgensen (1993)
P. cerasus L.	U.S.: WI, UT	Adult	Shervis et al. (1970), Davis and Jones (1986)
P. cerasifera Ehrh.	U.S.: UT, WA	Adult	Allred and Jorgensen (1993), Yee and Goughnour (2008)
P. domestica L.	U.S.: NY, WA	Adult	Herrick (1920), Yee and Goughnour (2005)
P. emarginata (Douglas ex Hook.) D. Dietr.	U.S.: WA	Adult	Yee and Goughnour (2005)
P. mahaleb L.	U.S.: UT	Adult	Allred and Jorgensen (1993)
P. salicina Lindl.	U.S.:WA	Adult	Yee and Goughnour (2008)
P. umbellata Elliot	U.S.:FL	Adult	Benjamin (1934)
P. virginiana L.	U.S.:UT	Adult	Allred and Jorgensen (1993)
Pears, *Pyrus*			
P. communis L.	U.S.:WI, WA	Adult	Prokopy and Bush (1972), Yee and Goughnour (2005)
P. serotina L.	U.S.:WA	Adult	Yee and Goughnour (2005)
Roses			
Rosa rugosa Thunb.	U.S: MA, RI	Adult	Prokopy and Berlocher (1980)
Rosa virginiana Mill.	U.S.: MA	Adult	Prokopy and Berlocher (1980)

Authors of plant species based on: USDA Natural Resources Conservation Service Plants Database (http://plants.usda.gov/java/profile?symbol=CRBR); Germplasm Resources Information Network Taxonomy for Plants (http://www.ars-grin.gov/cgi-bin/npgs/html/taxon.pl?414964); The Plant List (http://www.theplantlist.org/tpl/record/tro-50249452). [a]Somewhat questionable records, but within the *R. pomonella* species group, *R. pomonella* appears to be the most likely species; also listed as hosts by Bush (1966).