Importation of Fresh Citrus Fruit (Sweet Orange, *Citrus sinensis*, Lemon, *C. limon*, and Grapefruit, *C. paradisi*) From Argentina Into the Continental United States

Supplemental Plant Pest Risk Assessment

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I. Introduction

This pest risk assessment was prepared by the Animal and Plant Health Inspection Service (APHIS) of the United States Department of Agriculture (USDA) to examine plant pest risks associated with the importation into the United States of fresh citrus fruit grown in certain areas of Argentina. Agricultural officials in Argentina have requested authorization for growers in Argentina to export *Citrus sinensis* (sweet orange), *C. limon* (lemon) and *C. paradisi* (grapefruit) to the United States.

Under the Federal Plant Pest Act, as amended 1957 (7 United States Code 150aa *et seq.*) and the Plant Quarantine Act of 1908, as amended 1967 (7 United States Code 150aa *et seq.*), USDA has broad authority to regulate the importation and interstate movement of organisms that may directly or indirectly injure, damage, or cause disease in plants. APHIS' authority to regulate these organisms is granted by Title 7 of the Code of Federal Regulations (CFR), Part 330 (*i.e.*, 7 CFR §330). Quarantine 56 (7 CFR §319.56) provides APHIS with specific regulatory authority for importation of fruits and vegetables. Subpart §319.19 of 7 CFR (*Citrus Canker and Other Citrus Diseases*) prohibits importation into the United States of citrus plants or plant parts except fruit. Subpart §319.28 (*Citrus Fruit*) prohibits importation of citrus fruit from Argentina because of the presence of sweet orange scab (*Elsinoe australis*) in Argentina. Subpart §319.28 also promulgates a general prohibition against importation of citrus fruit from countries where citrus canker disease occurs. However, subsequent sections of §319.56 allow importation of citrus fruit from certain countries (*e.g.*, Japan) where citrus canker occurs under strict risk mitigation measures.

The methods we used to initiate, conduct, and report this plant pest risk assessment are consistent with guidelines provided by United States law (*e.g.*, Federal Plant Pest Act) and international organizations such as the North American Plant Protection Organization (NAPPO), the United Nations Food and Agricultural Organization (FAO), and the International Plant Protection Convention (IPPC). Our use of biological and phytosanitary terms (*e.g.*, introduction, quarantine pest) conforms with the *NAPPO Compendium of Phytosanitary Terms* (NAPPO 1996) and the *Definitions and Abbreviations* (Introduction Section) in *International Standards for Phytosanitary Measures, Section 1—Import Regulations: Guidelines for Pest Risk Analysis* (FAO, 1996). The FAO (1996) guideline describes three stages in pest risk analysis: initiation of the pest risk analysis, pest risk assessment, and pest risk management. This document satisfies the requirements of FAO Stages 1 (initiation) and 2 (pest risk assessment). FAO (1996) defines "pest risk assessment" as "Determination of whether a pest is a quarantine pest and evaluation of its introduction potential." "Quarantine pest" is defined as "A pest of potential economic importance to the area endangered thereby and not yet present there, or present but not widely distributed and being officially controlled" (FAO, 1996; NAPPO, 1996). Thus, a pest risk assessment should consider both the likelihood and consequences of introduction of quarantine pests.

This assessment follows ***RISK ASSESSMENT: CITRUS FRUIT FROM ARGENTINA*** (USDA, 1995). Since completion of the 1995 assessment, several factors affecting our assessment of the risks posed by commercial shipments of citrus from Argentina have changed. Additionally, since 1995 PPQ has expanded its risk assessment format. We produced the current document to update our assessment of the plant pest risks associated with these importations. Our primary reasons for producing a new document are:

1. The 1995 assessment identified several significant quarantine pests associated with importation of citrus fruit from Argentina. Three citrus diseases and several arthropods were of special concern. Following completion of the assessment, USDA decided not to consider

importations until further studies had been completed and detailed risk management programs had been designed and tested by Argentina.

2. During the past two years, agricultural officials, statisticians and researchers in Argentina have designed and conducted a variety of studies to clarify the plant pest risk associated with export of citrus fruit from Argentina. Results from those studies were submitted to USDA during October 1996. We have incorporated those results into our current assessment of the plant pest risk.

3. During the past two years, USDA and agricultural officials in Argentina have worked together to design risk mitigation programs for the variety of the pests identified in the 1995 risk assessment.

4. The methods and formats we used for risk assessments in 1995 are different from our current methods and formats.

To prepare the present assessment, we reformatted those portions of the 1995 assessment that comply with current standards and we added certain sections that were not part of our process in March 1995. Although this document supersedes APHIS' 1995 assessment, our estimates of the unmitigated risks (*i.e.*, risk without implementation of the risk mitigation programs proposed during 1996) have not changed significantly; some additional data were obtained that slightly modified our estimate of the unmitigated risk. This assessment also includes estimates of risk based on the newly proposed export/import program as well as a completely new section that provides estimates for the likelihood that plant pests will be introduced with citrus fruit imported from Argentina.

Our assessment of the "Consequences of Introduction" (Section II.7) is qualitative; estimates are expressed in qualitative terms such as high or low (*e.g.*, expected to have a high economic impact). The "Likelihood of Introduction" portion (Section II.8) is quantitative. The quantitative method we use is referred to as "Probabilistic Risk Assessment". In a quantitative assessment, estimates are expressed in quantitative terms such as "a probability of 0.001 that a pest will be introduced in any given year" or "one introduction every 1,000 years." However, because this is a probabilistic assessment we do not express our estimates as single numbers. Our estimates for the likelihood of introduction are expressed as probability density functions. That is, each estimate is reported as a distribution (*i.e.*, range) of values, and we report various components of the distribution: minimum calculated value, maximum, mean, mode, median, and 95th percentile (see Section II.8).

II. Risk Assessment

1. Initiating Event: Proposed Action

This pest risk assessment is commodity-based, and therefore "pathway-initiated"; we initiated the assessment in response to the request for USDA authorization to allow imports of a particular commodity presenting a potential plant pest risk. In this case, the importation into the United States of fresh citrus fruit grown in Argentina is a potential pathway for introduction of plant pests. Quarantine 56 (7 CFR §319.56) provides a general regulatory authority for importation of fruits and vegetables. Species of *Citrus* are the most economically important plants in the Family Rutaceae and are among the most economically important fruits worldwide. Although citrus is grown commercially in the tropics, it is primarily a subtropical group and citrus production is most successful in subtropical regions (Janick, 1972). Citrus production is an important industry in both Argentina and the United States.

2. Assessment of Weediness Potential of *Citrus* species

The initial step, after receiving a request for importation of a commodity, is to analyze the weediness potential of the species. Table 1 shows how the weediness potential was assessed and presents the findings for the three species of *Citrus* covered in this assessment. Because citrus is already grown widely in the United States and because the scientific literature offers no indication that *Citrus* species have significant potential as weeds, we proceeded with this assessment.

3. Previous Risk Assessments, Current Status and Pest Interceptions

During the past 75 years USDA has conducted numerous risk assessments for commercial shipments of citrus fruit from countries in South America (Table 2). In all cases where shipments of citrus fruit were authorized from countries in South America, some form of pest mitigation treatment was required for fruit flies or other pests. In some cases, authorization was subsequently revoked when pesticides became unavailable for phytosanitary treatments (*e.g.*, ethylene dibromide, EDB). None of these earlier assessments covered Argentina and there is no previous decision record for Argentina. In 1995, USDA completed a preliminary risk assessment for commercial shipments of citrus fruit from Argentina (USDA, 1995). The 1995 assessment identified several hazards. We decided to produce the present risk assessment to update the information used by USDA to make a decision regarding import of Argentine citrus.

Table 1: Process for determining weediness potential of imported plant species

Plant Species: ***Citrus sinensis*** **(L.) Osbeck (Rutaceae) = Sweet orange**
Citrus x paradisi **Macfad. (Rutaceae) = Grapefruit**
Citrus limon **(L.) Burm. f. (Rutaceae) = Lemon**

Phase 1: Consider whether the genus is new to or not widely prevalent in the United States (exclude plants grown under USDA permit in approved containment facilities)?

Citrus sinensis **(L.) Osbeck (sweet orange)** probably is native to China and Cochin-China. Widely grown in California and Florida, sweet orange is also grown in Arizona, Louisiana, Hawaii and Texas.

Citrus x paradisi **Macfad. (grapefruit)** is of uncertain origin. Once considered the same species as *Citrus maxima* (shaddock), it is now thought to be a hybrid between C. *maxima* and *C. sinensis* (sweet orange). Grapefruit may have arisen as a seedling sport in the West Indies, is now widely grown in California, Texas, Arizona and Florida.

Citrus limon **(L.) Burm. f. (lemon)** is native to subtropical Asia, widely grown in California and Florida.

Phase 2: Weediness Potential

Is *Citrus* listed in:

- NO *Geographical Atlas of World Weeds* (Holm *et al*., 1979)
- NO *World's Worst Weeds* (Holm *et al*., 1977)
- NO *Report of the Technical Committee to Evaluate Noxious Weeds; Exotic Weeds for Federal Noxious Weed Act* (Gunn and Ritchie, 1982)
- NO *Economically Important Foreign Weeds* (Reed, 1977)
- NO Weed Science Society of America list (Weed Science Society of America, 1989)

NO Is there any literature reference indicating weediness (*e.g.*, *AGRICOLA*, *CAB*, *Biological Abstracts*, *AGRIS*; search on "species name" combined with "weed").

Phase 3: Conclusion

Because various species of *Citrus*, including *C. sinensis*, *C. x paradisi* and *C. limon*, are grown commercially (and for a variety of other purposes) throughout the United States and because the scientific literature provides no indication of weediness potential, we find that there is no reason to consider these species as potential weeds and we proceed with the pest risk assessment.

Table 2: Decision history for importation of citrus fruit from South America.		
Year	**Country**	**Decision**
1924	Brazil	Deny entry of *C. paradisi* and *C. sinensis* due to fruit flies
1926	Ecuador	Deny entry of *C. sinensis* due to fruit flies
1928	Peru	Deny entry of *C. paradisi* and *C. sinensis* due to fruit flies
1962	Chile	Deny entry of *C. limon* and *C. sinensis* due to lack of treatment for *Brevipalpus chilensis*
1963	Venezuela	Permit entry of *C. sinensis* subject to cold treatment for *Anastrepha* spp. (other than *A. ludens*)
1963	Colombia	Permit entry of *C. paradisi* and *C. sinensis* subject to cold treatment for *Anastrepha* spp. (other than *A. ludens*)
1963	British Guiana (Guyana)	Permit entry of *C. sinensis* subject to cold treatment for *Anastrepha* spp.
1963	Bolivia	Permit entry of *C. paradisi* and *C. sinensis* subject to cold treatment for *Anastrepha* spp. (other than *A. ludens*) and *Ceratitis capitata*
1964	Ecuador	Permit entry of *C. sinensis* subject to cold treatment
1964	Venezuela	Permit entry of *C. paradisi* subject to cold treatment for *Anastrepha* spp. (other than *A. ludens*)
1970	Ecuador	Permit entry of *C. paradisi* from subject to cold treatment
1971	Chile	Deny entry of *C. limon* due to lack of treatment for *B. chilensis*
1974	Venezuela	Permit entry of *C. paradisi* and *C. sinensis* subject to cold treatment
1979	Chile	Deny entry of *Citrus* spp. due to lack of treatment for *B. chilensis*
1982	Chile	Permit entry of *C. limon* subject to treatment for *B. chilensis*
1984	Chile	Deny entry of *Citrus* spp., except *C. limon* from due to lack of tolerance of commodities to treatment for *B. chilensis*
1993	Chile	Deny entry of *Citrus sinensis* due to lack of treatment for *B. chilensis*

4. Pest List: Pests Associated with *Citrus* species in Argentina

Table 3 shows the list of plant pests reported to be associated with citrus in Argentina. These pests are all **potential** quarantine pests for *Citrus* grown in Argentina.

Table 3: Pest List - *Citrus* spp. From Argentina			
Pest	**Distrbution** [1]	**Comment** [2]	**References**
Arthropods			

Table 3: Pest List - *Citrus* spp. From Argentina			
Pest	**Distrbution** [1]	**Comment** [2]	**References**
Aceria sheldoni (Ewing) (Acarina: Eriophyidae)	AR, US	a, o	Costilla, et. al., 1987; Jeppson et al., 1975; Pelekassis, 1962
Acromyrmex sp. (Hymenoptera: Formicidae)	AR (some spp. in US)	e	Argentina, 1994
Acutaspis scutiformis Cockerell (Homoptera: Diaspididae)	AR, US (TX)	g, j, n	Molinari, 1948; Nakahara, 1982
Aleurothrixus floccosus (Maskell) (Homoptera: Aleyrodidae)	AR, US (FL, CA)	a, c, o	Argentina, 1994; Mound and Halsey, 1978
Aleurothrixus howardi Quaintance (Homoptera: Aleyrodidae)	AR	a	Molinari, 1948; Rizzo, 1977
Anastrepha alveatoides Blanchard (Diptera: Tephritidae)	AR	1	Norrbom and Kim, 1988
Anastrepha chiclayae Greene (Diptera: Tephritidae)	AR	1	Jiron, *et al.*, 1988; Norrbom and Kim, 1988
Anastrepha daciformis Bezzi (Diptera: Tephritidae)	AR	1	Norrbom and Kim, 1988
Anastrepha fraterculus (Wiedemann) (Diptera: Tephritidae)	AR [3]	g, h, z_i	Argentina, 1994; Berg, 1979; Jiron, *et al.*, 1988; Rosillo and Portillo, 1971
Anastrepha grandis (Macquart) (Diptera: Tephritidae)	AR	1	Norrbom and Kim,1988; Stone, 1942; PNKTO, 1987
Anastrepha obliqua (Macquart) (Diptera: Tephritidae)	AR	z_i	CIE, 1988; Enkerlin *et al.* 1989
Anastrepha punctata Hendel (Diptera: Tephritidae)	AR	1	Norrbom and Kim, 1988
Anastrepha rosilloi Blanchard (Diptera: Tephritidae)	AR	1	Norrbom and Kim, 1988
Anastrepha schultzi Blanchard (Diptera: Tephritidae)	AR	1	Norrbom and Kim, 1988
Anastrepha serpentina (Wiedemann) (Diptera: Tephritidae)	AR [4]	g, n, z_i	Berg, 1979; Jiron, *et al.*, 1988; Shaw and Starr, 1946; White and Elson-Harris, 1992
Ancyclodera cardinalis (Dalman) (Coleoptera: Cerambycidae)	AR	a, k	Duffy, 1960

Table 3: Pest List - *Citrus* spp. From Argentina			
Pest	**Distrbution** [1]	**Comment** [2]	**References**
Antias lucidus Berg (Heteroptera: Miridae)	AR	e	Molinari, 1948
Anychus verganii Blanchard =*Eutetranychus banksi* (Mcgregor) (Acarina: Tetranychidae)	AR, US	a, c, o	Jeppson, *et al.*, 1975; Molinari, 1948
Aonidiella auranti (Maskell) (Homoptera: Diaspididae)	AR, US	c	Argentina, 1994
Aphis gossypii Glover (Homoptera: Aphididae)	AR, US	c	Argentina, 1994; Palmer, 1952; Rizzo, 1977
Aspidiotus nerii (Bouché) (Homoptera: Diaspididae)	AR, US	c, o, z_e	Molinari, 1948; Nakahara, 1982; Rizzo, 1977
Astylus quadrilineatus Germar (Coleoptera: Melyridae)	AR	a	Blackwelder, 1945; Molinari, 1948
Athaumastus haematicus Stal. (Heteroptera: Coreidae)	AR	e	Molinari, 1948
Atta cephalotes (Ewing) (Hymenoptera: Formicidae)	AR	e, n	Cherrett *et al.* 1982; Squire, 1972
Atta sexdens (L.) (Hymenoptera: Formicidae)	AR	e, n	INKTO No. 28; Robinson and Cherret, 1978; Squire, 1972
Battus polydamas L (Lepidoptera: Papilionidae)	AR	a	Molinari, 1948
Brachystylodes pilosus Hastache (Coleoptera: Curculionidae)	AR	a, n	Costilla, 1994; Wibmer and O'Brien, 1986
Caliothrips fasciatus Pergande (Thysanoptera: Thripidae)	AR	c, e	Molinari, 1948
Carpophilus hemipterus (L.) (Coleoptera: Nitidulidae)	AR, US	b, c, o	EIS, 1996; Molinari, 1948
Ceratitis capitata (Wiedemann) (Diptera: Tephritidae)	AR, US[6]	h, n, x, z_i	Argentina, 1994; Berg, 1979; EPPO, 1997; Rosillo and Portillo, 1971; Sabatino, 1974
Ceroplastes grandis Hemp. (Homoptera: Coccidae)	AR	a	Molinari, 1948; Rizzo, 1977

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Pest	**Distrbution**[1]	**Comment**[2]	**References**
Ceroplastes rusci (L.) (Homoptera: Coccidae)	AR	a	Avidov and Harpaz, 1969; CIE, 1993
Ceroplastes sinensis Del Guercio (Homoptera: Coccidae)	AR, US (CA)	a, g	CIE, Map No. 412, 1980; Ebeling, 1959; Hamon and Williams, 1984
Chlorida costata Serville (Coleoptera: Cerambycidae)	AR	a	Duffy, 1960
Chlorida festiva (L.) (Coleoptera: Cerambycidae)	AR	a, n	Duffy, 1960; EIS, 1996
Chrysomphalus aonidum (L.) (Homoptera: Diaspididae)	AR, US	a, c, o	Argentina, 1994; Nakahara, 1982
Chrysomphalus dictyospermi (Morgan) (Homoptera: Diaspididae)	AR, US	a, c, o	Argentina, 1994; Nakahara, 1982
Coccus hesperidium (L.) (Homoptera: Coccidae)	AR, US	a, c, o	Argentina, 1994; Ebeling, 1959; Hamon and Williams, 1984
Diabrotica marginata Harold (Coleoptera: Chrysomelidae)	AR	e	Molinari, 1948
Diabrotica significata Jacoby (Coleoptera: Chrysomelidae)	AR	e, n	Molinari, 1948
Diabrotica speciosa Germar (Coleoptera: Chrysomelidae)	AR	e, n	INKTO No. 36; Molinari, 1948;Lin, *et al.*, 1984
Ecdytolopha punctidiscana Dyar (Lepidoptera: Tortricidae)	AR, US	o	Hodges, 1983; Molinari, 1948; Zhang, 1994
Edessa meditabunda F. (Heteroptera: Pentatomidae)	AR	e, n	Molinari, 1948
Edessa pictiventris (Heteroptera: Pentatomidae)	AR	e	Molinari, 1948
Edessa polita (Heteroptera: Pentatomidae)	AR	e	Molinari, 1948
Edessa quadridens (Heteroptera: Pentatomidae)	AR	e	Molinari, 1948
Epilachna paenulata Germar (Coleoptera: Coccinellidae)	AR	a	INKTO No. 62

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Pest	**Distrbution [1]**	**Comment [2]**	**References**
Eulecanium perinflatum Cockerell (Homoptera: Coccidae)	AR	a	Molinari, 1948
Frankliniella rodeos Moulton (Thysanoptera: Thripidae)	AR	a, n	Rizzo, 1977
Frankliniella tritici (Fitch) (Thysanoptera: Thripidae)	AR, US	e, o	Argentina, 1994
Hemiberlesia rapax Comstock (Homoptera: Diaspididae)	AR, US	a, c	Molinari, 1948; Nakahara, 1982
Horcias nobilellus (Berg) (Heteroptera: Miridae)	AR	e	INKTO No. 26
Hypselonotus interruptus Hahn (Heteroptera: Coreidae)	AR	e, n	Molinari, 1948
Icerya purchasi (Maskell) (Homoptera: Margarodidae)	AR, US (CA, AZ)	c, e	Gill, 1993; Molinari, 1948; Rizzo, 1977
Lecanodiaspis dendrobii Douglas (Homoptera: Diaspididae)	AR	a	Molinari, 1948
Lepidosaphes beckii (Newman) (Homoptera: Diaspididae)	AR, US	c, o	Argentina, 1994; Nakahara, 1982
Linepithema humile (Mayr) (Hymenoptera: Formicidae)	AR, US	a, o	Rizzo, 1977
Liriomyza huidobrensis (Blanchard) (Diptera: Agromyzidae)	AR, US (CA, TX)	a, h	EPPO, 1997; Spencer, 1973
Loxa flavicornis Drury (Heteroptera: Pentatomidae)	AR, US	e, o	Henry and Froeschner, 1988; Molinari, 1948
Macrodactylus pumilio Burmeister (Coleoptera: Scarabaeidae)	AR	a	Blackwelder, 1957
Macropophora accentifer Oliv. (Coleoptera: Cerambycidae)	AR	a	Duffy, 1960; Molinari, 1948
Macrosiphum euphorbiae (Thomas) (Homoptera: Aphididae)	AR, US	c, o	Palmer, 1952; Rizzo, 1977
Macrosiphum gei Koch (Homoptera: Aphididae)	AR, US	a, c, o	Molinari, 1948; Palmer, 1952

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Pest	**Distrbution [1]**	**Comment [2]**	**References**
Melanaspis paulista Hempel (Homoptera: Diaspididae)	AR	a, n	Molinari,1948
Mesolecanium deltae (Liz.) (Homoptera: Coccidae)	AR, US	a, c, o	Molinari, 1948; Rizzo, 1977
Myzus persicae Sulzer (Homoptera: Aphididae)	AR, US	c, o	Molinari, 1948; Palmer, 1952
Naupactus xanthographus (Germar) (Coleoptera: Curculionidae)	AR	a, n	Bosq, 1934
Nezara viridula L. (Heteroptera: Pentatomidae)	AR, US	c, e, o	Henry and Froeschner, 1988; Molinari, 1948
Oiketicus platensis Berg (Lepidoptera: Psychidae)	AR	a	Rizzo, 1977; Zhang, 1994
Oncopeltus stali (Heteroptera: Lygaeidae)	AR	e	Molinari, 1948
Orasema spp. (Hymenoptera: Eucharitidae)	AR[5]	a	Molinari, 1948
Orthezia insignis Browne (Homoptera: Ortheziidae)	AR	e, n	Molinari, 1948; Morrison, 1952
Orthezia praelonga Douglas (Homoptera: Ortheziidae)	AR, US	e, o	Molinari, 1948; Morrison, 1952
Pantomorus cervinus Boheman (Coleoptera: Curculionidae)	AR, US	a, c, o	Molinari, 1948; Wibmer and O'brien, 1982
Papilio anchisiades capys Hubner (Lepidoptera: Papilionidae)	AR	a	Molinari, 1948
Papilio thoas brasiliensis R.& J. (Lepidoptera: Papilionidae)	AR	a	Molinari, 1948
Papilio thoas thoantiades Burmeister (Lepidoptera: Papilionidae)	AR	a	Molinari, 1948
Paratetranychus pilosus Can et Fanz. (Acarina: Tetranychidae)	AR	a	Molinari, 1948
Parlatoria cinerea Hadden (Homoptera: Diaspididae)	AR	j	Avidov and Harpaz, 1969; Morrison, 1939

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Pest	**Distrbution** [1]	**Comment** [2]	**References**
Parlatoria pergandii (Comstock) (Homoptera: Diaspididae)	AR, US	c, o	Argentina, 1994; Nakahara, 1982
Parlatoria ziziphi (Lucas) (Homoptera: Diaspididae)	AR, US (FL)	j, o	PNKTO, 1984
Phenacoccus tucumanus Granara de Willink (Homoptera: Pseudococcidae)	AR	a, n	Granara de Willink, 1983; Odermatt, 1997 (Pers. comm.); Williams and Granara de Willink, 1992
Phyllocoptruta oleivora (Ashmead) (Acarina: Eriophyidae)	AR, US	a, c, o	Ebeling, 1959; Jeppson, *et al.*, 1975; Molinari, 1948
Piesma cinereum (Say) (Heteroptera: Piesmatidae)	AR, US	c, e, o	Henry and Froeschner, 1988; Molinari, 1948
Pinnaspis aspidistrae (Signoret) (Homoptera: Diaspididae)	AR, US	a, c, o	Argentina, 1994; Molinari, 1948; Nakahara, 1982; Rizzo, 1977
Planococcus citri (Risso) (Homoptera: Pseudococcidae)	AR US	c, o	Argentina, 1994; McKenzie, 1967
Platypus sulcatus Dejean (Coleoptera: Platypodidae)	AR	a	Molinari, 1948
Platypus wesmaeli Chapuis (Coleoptera: Platypodidae)	AR, US	a, o	EIS, 1996; Molinari, 1948
Pseudococcus comstocki (Kuwana) (Homoptera: Pseudococcidae)	AR, US	c, o	Kosztarab, 1996; Molinari, 1948
Pseudococcus longispinus Targioni-Tozzetti) (Homoptera: Pseudococcidae)	AR, US	c, o	Kosztarab, 1996; Molinari, 1948
Pulvinaria flavescens Brethes (Homoptera: Coccidae)	AR	a	Molinari, 1948; Rizzo, 1977
Quadraspidiotus perniciosus (Comstock) (Homoptera: Diaspididae)	AR, US	c, o	Molinari, 1948; Nakahara, 1982
Rhopalophora collaris (Germar) (Coleoptera: Cerambycidae)	AR	a	Duffy, 1960; Molinari, 1948

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Pest	**Distrbution** [1]	**Comment** [2]	**References**
Rothschildia hespera L. (Lepidoptera: Saturniidae)	AR	a	Molinari, 1948
Saissetia coffeae (Walker) (Homoptera: Coccidae)	AR, US	a, c, o	Hamon and Williams, 1984; Molinari, 1948; Rizzo, 1977
Saissetia oleae (Bernard) (Homoptera: Coccidae)	AR, US	a, c, o	Hamon and Williams, 1984; Molinari, 1948; Rizzo, 1977
Sibine trimaculata Sepp (Lepidoptera: Limacodidae)	AR	a	Molinari, 1948
Sphictyrtus fasciatus (Heteroptera: Coreidae)	AR	e	Molinari, 1948
Spodoptera ornithogalli (Guenee) (Lepidoptera: Noctuidae)	AR, US	a, c, o	Hodges, 1983; Molinari, 1948; Zhang, 1994
Stenodontes spinibarbis L. (Coleoptera: Cerambycidae)	AR	a	Molinari, 1948; Duffy, 1960
Tenuipalpus pseudocuneatus Blanchard (Acarina: Tenuipalpidae)	AR	a	Molinari, 1948
Tetranychus urticae Koch Syn.:*Tetranychus telarius* L. (Acarina: Tetraynchidae)	AR, US	a, c, o	Jeppson, *et al.*, 1975 Molinari, 1948
Tomoplagia costalimai (Wiedemann) (Diptera: Tephritidae)	AR	1	Aczel, 1955; personal communication, A. L. Norrbom to USDA (R. Stewart) 12-XI-1990
Tomoplagia phaedra (Wiedemann) (Diptera: Tephritidae)	AR	1	Aczel, 1955; personal communication, A. L. Norrbom to USDA (R. Stewart) 12-XI-1990
Toxoptera aurantii (Fonscolombe) (Homoptera: Aphididae)	AR, US	c, o, z_e	Argentina, 1994; Palmer, 1952
Toxoptera citricidus (Kirkaldy) (Homoptera: Aphididae)	AR, US (FL)	a, g, n, z_e	Blackman and Eastop, 1984; Brown. *et al.*, 1988; Carver, 1978; EPPO, 1997; INKTO No. 22; , PPQ, 1995

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Pest	**Distrbution** [1]	**Comment** [2]	**References**
Trachyderes striatus (F.) (Coleoptera: Cerambycidae)	AR	a, e	Duffy, 1960
Trachyderes succinctus (L.) (Coleoptera: Cerambycidae)	AR	a, e	Duffy, 1960
Trachyderes thoracicus (Olivier) (Coleoptera: Cerambycidae)	AR	a, e	Duffy, 1960
Unaspis citri (Comstock) (Homoptera: Diaspididae)	AR, US (CA, FL LA)	c, o	Argentina, 1994; CIE, 1962
Xyleborus perforans (Wollaston) (Coleoptera: Scolytidae)	AR	a, g, n	CIE, 1973
Algae			
Cephaleuros virescens Kunze [Trentepohliacae]	AR, US	c,o	Wellman, 1977
Fungi			
Alternaria citri Ellis & Pierce [Fungi Imperfecti, Hyphomycetes]	AR, US	c,o,z_{ei}	Argentina, 1994; Farr *et al.*, 1989; Whiteside *et al.* 1988
Botrytis cinerea Pers.: Fr. [Fungi Imperfecti, Hyphomycetes]	AR, US	c,o,z_{ei}	Argentina, 1994; Farr, *et al.* 1989; Whiteside, *et al.*, 1988
Capnodium citri Mont. [Loculoascomycetes, Dothideales]	AR, US	a,o	Argentina 1994; Farr *et al.* 1989
Colletotrichum gloeosporioides (Penz.) Penz. & Sacc. in Penz. [Fungi Imperfecti, Coelomycetes]	AR, US	a,c,o,z_{ei}	Argentina, 1994; Farr *et al.*, 1989
Diaporthe citri F. A. Wolf [Pyrenomycetes, Diaporthales] Anamorph: *Phomopsis citri* H. Fawc.	AR, US	o	Argentina, 1994; Farr, *et al.*, 1989
Elsinoe australis Bitancourt & Jenk. [Loculoascomycetes, Dothideales]	AR	z_{ei}	Argentina, 1994; CMI, 1976
Elsinoe fawcettii Bitancourt & Jenk. [Loculoascomycetes, Dothideales]	AR, US	c,o,z_{ei}	Argentina, 1994; CMI 1974, Farr, *et al.* 1989

Table 3: Pest List - *Citrus* spp. From Argentina			
Pest	**Distrbution [1]**	**Comment [2]**	**References**
Geotrichum candidum Link Fungi Imperfecti, Hyphomycetes]	AR, US	c, o, z_{ei}	Argentina, 1994; Farr *et al*, 1989
Guignardia citricarpa Kiely Anamorph: *Phoma citricarpa* McAlpine [Loculoascomycetes, Dothideales]	AR	n, z_{ei}	Argentina, 1994; CMI, 1966a; Whiteside, *et al*., 1988
Lasiodiplodia theobromae (Pat.) Griffon & Maubl. [Fungi Imperfecti, Coelomycetes] Syn.: *Diplodia natalensis* Pole-Evans	AR, US	c, o, z_{ei}	Argentina, 1994; Farr *et al*., 1989
Mycosphaerella citri Whiteside [Loculoascomycetes, Dothideales]	AR, US	a,c,o	Argentina, 1994; Farr *et al*., 1989
Mycosphaerella lageniformis Rehm [Loculoascomycetes, Dothideales]	AR, US	a,o	Farr *et al*., 1989; Wellman, 1977
Mycosphaerella loefgreni Noack [Loculoascomycetes, Dothideales]	AR	a	Watson, 1971; Whiteside, *et al*., 1988
Nectria episphaeria (Tode:Fr.) Fr. [Pyrenomycetes, Hypocreales]	AR, US	a,c,o	Farr *et al*., 1989; Wellman, 1977
Nectria ochroleuca (Schwein.) Berk. [Pyrenomycetes, Hypocreales]	AR, US	a,c,o	Farr *et al*., 1989; Wellman, 1977
Oidium tingitanium C. N. Carter [Pyrenomycetes, Erysiphales]	AR, US	o	Farr *et al*., 1989; Wellman, 1977
Pellicularia koleroga Cooke [Basidiomycetes, Aphyllophorales]	AR, US	o	Farr *et al*., 1989; Wellman, 1977
Penicillium digitatum (Pers.:Fr.) Sacc. [Fungi Imperfecti, Hyphomycetes]	AR, US	c,o,z_{ei}	Argentina, 1994; Farr *et al*., 1989
Penicillium italicum Wehmer [Fungi Imperfecti, Hyphomycetes]	AR, US	c,o,z_{ei}	Argentina, 1994; Farr *et al*., 1989
Penicillium ulaiense Hseih, Su & Tzean [Fungi Imperfecti, Hyphomycetes]	AR, US	c,o,z_{ei}	Carrillo, 1995; Holmes *et al*., 1993; Skaria *et al*., 1993

Table 3: Pest List - *Citrus* spp. From Argentina			
Pest	**Distrbution [1]**	**Comment [2]**	**References**
Phyllostica aurantiicola (Berk. & Cooke) Sacc. [Fungi Imperfecti, Coelomycetes]	AR, US	o	Farr, *et al.* 1989; Wellman, 1977
Phyllostica citricola S. Hora ex K. Hara [Fungi Imperfecti, Coelomycetes]	AR, US	o	Wellman, 1977; Farr, *et al.*, 1989
Phyllosticta hesperidearum (Cattaneo) Penz. [Fungi Imperfecti, Coelomycetes]	AR, US	o	Farr *et al.* 1989; Wellman, 1977
Phyllosticta longispora McAlpine [Fungi Imperfecti, Coelomycetes]	AR, US	o	Farr *et al.* 1989; Wellman, 1977
Phytophthora boehmeriae Sawada [Oomycetes, Peronosporales]	AR, US (CA)	o,z_{ei}	CMI, 1978b; Oudemans and Coffey, 1991 ; Watson, 1971
Phytophthora cactorum (Lebert & Cohn) Schrot. [Oomycetes, Peronosporales]	AR, US	c,o,z_{ei}	CMI, 1984b; Whiteside *et al.*, 1988
Phytophthora citricola Sawada [Oomycetes, Peronosporales]	AR, US	c,o,z_{ei}	CMI, 1966b; Whiteside *et al.*, 1988
Phytophthora citrophthora (R. E. Sm. & E. H. Sm.) Leonian [Oomycetes, Peronosporales]	AR, US	c,o,z_{ei}	Argentina, 1994; Farr *et al.*, 1989; Whiteside *et al.*, 1988
Phytophthora nicotianae Breda de Haan var. *parasitica* (Dastur) G. M. Waterhouse [Oomycetes, Peronosporales]	AR, US	c,o,z_{ei}	Argentina, 1994; CMI, 1989
Pythium ultimum Trow [Oomycetes, Peronosporales]	AR, US	c,o	Argentina 1994; Farr, *et al.*, 1989
Sclerotinia sclerotiorum (Lib.) de Bary [Discomycetes, Helotiales]	AR, US	a,c,z_{ei}	Farr *et al.*, 1989; Whiteside *et al.*, 1988
Septoria arethusa Penz. [Fungi Imperfecti, Coelomycetes]	AR	a, c	Watson, 1971; Wellman, 1977
Septoria citri Pass. [Fungi Imperfecti, Coelomycetes]	AR, US	c,o	Argentina, 1994; Farr, *et al.*, 1989; Wellman, 1977
Septoria limonum Pass. [Fungi Imperfecti, Coelomycetes]	AR, US	c,o	Argentina, 1994; Farr *et al.*, 1989

Table 3: Pest List - *Citrus* spp. From Argentina			
Pest	**Distrbution [1]**	**Comment [2]**	**References**
Spegazzinia tessarthra (Berk. & Curt.) Sacc. Syn.: *Spegazzinia ornata* Sacc. [Fungi Imperfecti, Hyphomycetes]	AR, US	a,o	Ellis, 1971; Wellman, 1977
Thanatephorus cucumeris (A.B. Frank) Donk Basidiomycetes, Tulasnellales) Anamorph: *Rhizoctonia solani* Kuhn	AR, US	a,c,o	Argentina, 1994; Farr *et al.*, 1989; Whiteside *et al.*, 1988
Thielaviopsis basicola (Berk. & Br.) Farraris [Fungi Imperfecti, Hyphomycetes]	AR, US	a,c,o	Farr *et al.*, 1989; Whiteside *et al.*, 1988
Bacteria			
Agrobacterium tumefaciens (Smith & Town.) Conn	AR, US	a,c,f,m,o	Bradbury, 1986; C.M.I., 1980
Pseudomonas syringae pv. *syringae* van Hall	AR, US	c,f,o	Bradbury, 1986; C.M.I., 1988
Xanthomonas axonopodis pv. *citri* Vauterin, *et al.* [Syn. *X. campestris* pv. *citri* (Hasse) Dye] (Citrus canker A)	AR, US	h	Podleckis, 1995; EPPO, 1997; Whiteside, *et al.*, 1988
Xanthomonas axonopodis pv. *aurantifolii* Vauterin, *et al.* [Syn. *X. campestris* pv. *aurantifolii* (Hasse) Dye] (Citrus canker B)	AR	n	Podleckis, 1995; EPPO, 1997; Whiteside, *et al.*, 1988
Xylella fastidiosa Wells, *et al.* Citrus variegated chlorosis strain Syn.: Pecosita, declinamiento, fruta bolita	AR	d	Brlansky, *et al.*, 1991; Hartung, *et al.*, 1994
Phytoplasmas and Spiroplasmas			
Spiroplasma citri Saglio, *et al.*	AR, US	f,m,o	C.M.I., 1970; Ramallo, 1970; Whiteside, *et al.*, 1988
Virus and Viruslike Agents			

Table 3: Pest List - *Citrus* spp. From Argentina			
Pest	**Distrbution**[1]	**Comment**[2]	**References**
Citrus cachexia viroid (Syn.: Xyloporosis)	AR, US	a,d,f,o	C.M.I., 1972; Whiteside, *et al.*, 1988
Citrus exocortis viroid	AR, US	a,d,f,o	C.M.I., 1979; Whiteside, *et al.*, 1988
Citrus leprosis rhabdovirus	AR, US	f,o	Alfieri, *et al.*, 1994; Brunt, *et al.*, 1996
Citrus psorosis associated virus (naturally transmitted strain) Syn.: Psorosis	AR	a,d	Garcia, *et al.*, 1994; Whiteside, *et al.*, 1988
Citrus ringspot virus Syn.: Psorosis B	AR, US	a,f,o	Alfieri, *et al.*, 1994; C.M.I., 1984a; Whiteside, *et al.*, 1988
Citrus tristeza closterovirus	AR, US	a,d,f,o	C.M.I., 1978a; Whiteside, *et al.*, 1988
Eruptive gummosis Syn.: Impietratura	AR	d	Cook, 1975; Whiteside, *et al.*, 1988
Nematodes			
Tylenchus semipenetrans Cobb Tylenchida: Tylenchulidae Citrus nematode	AR, US	a,f,k,o	Anonymous, 1984; Whiteside, *et al.*, 1988
Xiphinema index Thorne & Allen Dorylaimida: Longidoridae Dagger nematode	AR, US	a,f,k,o	Anonymous, 1984; Lau, 1993
Diseases of unknown etiology			
Marchitamiento repentino Syn.: Citrus blight	AR, US	f,o	Whiteside, *et al.*, 1988

Table 3: Pest List - *Citrus* spp. From Argentina			
Pest	**Distrbution** [1]	**Comment** [2]	**References**

Table Footnotes

1 Distribution legend: AR=Argentina; AZ=Arizona; CA=California; FL=Florida; LA=Louisiana; TX=Texas; US=United States

2 Comment legend:
- a - Pest mainly associated with plant part other than commodity
- b - Not likely to be a primary plant pest
- c - Listed in non-reportable dictionary as non-actionable.
- d - Commodity is unlikely to serve as a source of inoculum because the vector is unknown or does not feed on the commodity and/or seed transmission has not been reported in *Citrus* spp.
- e - Although pest attacks commodity, it would not be expected to remain with the commodity during processing
- f- Pest occurs in the U.S. and is not subject to official restrictions and regulations (*i.e.*, not listed as actionable, and no official control program).
- g: Quarantine pest; pest has limited distribution in the U.S. and is under official control as follows: pest listed by name in USDA's pest dictionary, official quarantine action may be taken on this pest when intercepted on this commodity.
- h- Quarantine pest; pest has limited distribution in the United States and is under official control as follows: (1) pest listed by name in USDA's pest dictionary, official quarantine action taken on this pest when intercepted on this commodity and (2) pest is a "program pest" (there is an official Federal or State program for control of this pest beyond its being listed in the pest dictionary as actionable).
- j - Armored scale insect: no quarantine action on fruit for consumption because "...armored scales in general have a low probability of establishment from infested shipments of commercial fruit" (ARS, 1985)
- k - Not specifically listed for host, but reported from other hosts in same plant genus/family.
- l: A single unconfirmed report lists this species (with no supporting evidence)
- m - Pest occurs within the area of origin for the commodity being assessed and has been reported to attack the commodity host species in other geographic regions, but has not been reported to attack the commodity host species in the area of origin being assessed.
- n - Listed in the USDA catalogue of intercepted pests as actionable.
- o - Organism does not meet the geographical and regulatory definition for a quarantine pest.
- x- Interception records exist
- z_i- Internal feeder: Pest is known to attack or infect commodity and it would be reasonable to expect the pest may remain with the commodity during processing and shipping
- z_e- External feeder: Pest is known to commonly attack or infect commodity and it would be reasonable to expect the pest may remain with the commodity during processing and shipping

3 Foote, et al. (1993) and White and Elson-Harris (1992) include south Tesas, USA in the distribution of *A. fraterculus*. However, the flies trapped occasionally in south Texas and identified as *A. fraterculus* are considered to be distinct from the *A. fraterculus* (South American fruit fly) found in Argentina and other South American countries (personal communication A. Norrbohm, R. L. Mangan). The fruit flies identified as *A. fraterculus* in South American do not occur in the United States.

4 At least two sources (Foote, *et al.*, 1993; White and Elson-Harris ,1992) include south Texas, USA in the distribution of *A. serpentina*. However, only adults of *A. serpentina* have been trapped in south Texas, and only as rare detections. Foote *et al.* (1993) describe the situation as "*A. serpentina* seldom has been found in Texas since 1959". *A. serpentina* is known to be established in Mexico and recent (since 1959) rare detections of adult *A. serpentina* in south Texas are considered to have resulted from stray flying adults, not from established populations (personal communication A. Norrbohm, R. L. Mangan).

5 Some species of the genus *Orasema* occur in the United States, but it is not known whether these are the same species as those occurring in Argentina.

6 An outbreak of *Ceratitis capitata* occurred in certain counties of Florida in 1997 where it is currently subject to an official eradication program.

5. List of Quarantine Pests

Our list of quarantine pests for *Citrus* from Argentina is provided in Table 4. Should any of these pests be intercepted on *Citrus* fruits (commercial shipments or other), quarantine action may be taken.

Table 4: Quarantine Pests: Citrus from Argentina

Arthropods

Acutaspis scutiformis
Aleurothrixus howardi
Anastrepha alveatoides
Anastrepha chiclayae
Anastrepha daciformis
Anastrepha fraterculus
Anastrepha grandis
Anastrepha obliqua
Anastrepha punctata
Anastrepha rosilloi
Anastrepha schultzi
Anastrepha serpentina
Ancyclodera cardinalis
Antias lucidus
Astylus quadrilineatus
Athaumastus haematicus
Atta cephalotes
Atta sexdens
Battus polydamus
Brachystylodes pilosus
Ceratitis capitata
Ceroplastes grandis
Ceroplastes rusci
Chlorida costata
Diabrotica marginata
Diabrotica significata
Diabrotica speciosa
Edessa meditabunda
Edessa pictiventris
Edessa polita
Edessa quadridens
Empoasca lybica
Epilachna paenulata
Eulecanium perinflatum
Frankliniella rodeos
Frankliniella tritici
Hercothrips fasciatus
Horcias nobilellus
Hypselonotus interruptus
Lecanium deltae
Lecanodiaspis dendrobii
Macrodactylus pumilio
Macropophora accentifer
Melanaspis paulista
Naupactus xanthographus
Oiketicus platensis
Oncopeltus stali
Papilio anchisiades capys
Papilio thoas brasiliensis
Papilio thoas thoantiades
Paratetranychus pilosus
Parlatoria cinerea
Phenacoccus tucumanus
Platypus sulcatus
Pulvinaria flavescens
Rhopalophora collaris
Rothschildia hespera
Sibine trimaculata
Sphictyrtus fasciatus
Stenodontes spinibarbis
Tenuipalpus pseudocuneatus
Tomoplagia costalimai
Tomoplagia phaedra
Toxoptera citricidus
Trachyderes striatus
Trachyderes succinctus
Trachyderes thoracicus
Xyleborus perforans

Fungi

Elsinöe australis
Guignardia citricarpa
Mycosphaerella loefgreni

Bacteria

Xanthomonas axonopodis pv. *citri*, (Syn. *X. campestris* pv. *citri*)
Xanthomonas axonopodis pv. *aurantifolii* (Syn. *X. campestris* pv. *aurantifolii*)
Xylella fastidiosa, Citrus variegated chlorosis strain

Virus and Viruslike Agents

Citrus psorosis associated virus (naturally transmitted strain)
Eruptive gummosis, Syn.: Impietratura

6. Quarantine Pests Likely to Follow Pathway (Quarantine Pests Selected for Further Analysis)

We analyzed in detail only those quarantine pests that can reasonably be expected to follow the pathway, *i.e.,* be included in commercial shipments of *Citrus* (see USDA, 1995 for selection criteria). Table 5 shows the list of pest selected for further analysis. Only quarantine pests selected for further analysis are subjected to steps 7-9 below.

Table 5: Quarantine Pests Selected for Further Analysis: *Citrus* from Argentina
Arthropods
Anastrepha fraterculus
Anastrepha obliqua
Anastrepha serpentina
Ceratitis capitata
Fungi
Elsinöe australis
Guignardia citricarpa
Bacteria
Xanthomonas axonopodis pv. *citri*, (Syn. *X. campestris* pv. *citri*, citrus canker)
Xanthomonas axonopodis pv. *aurantifolii* (Syn. *X. campestris* pv. *aurantifolii,* cancrosis B)

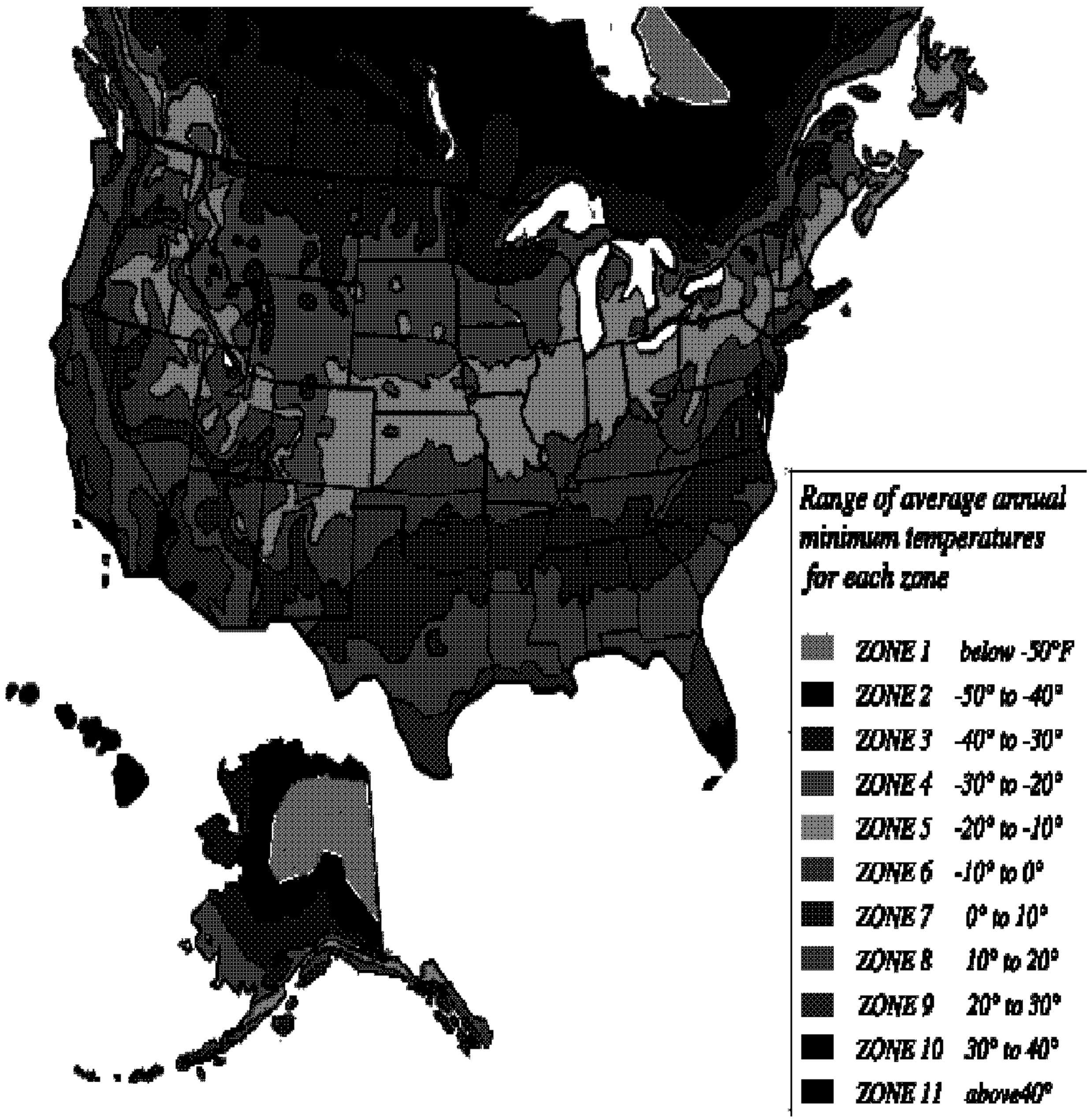
7. Consequences of Introduction: Economic/Environmental Importance

Our assessment of the consequences of introduction refers to an assessment of the severity of negative impacts that might result from the introduction of the quarantine pests listed in Table 5. Our process for assessing the consequences of introduction is qualitative. We rate the consequences of introduction for each quarantine pest according to the five risk elements (RE) described below (RE #1-5). Additional details beyond those provided below are provided in ***Pathway-Initiated Pest Risk Assessment: Guidelines for Qualitative Assessments***, ver. 4.0. RE 1-5 reflect the biology of the pest and its hosts. For each RE, we assign each pest a rating of High, Medium, or Low according the following criteria.

RE #1: Climate—Host Interaction

When introduced to new areas, pests can be expected to behave as they do in their native area if host plants are available and the climate is similar. We consider ecological zonation and the interaction between the geographic distributions of the pest and host. Estimates are

Figure 1: USDA Plant Hardiness Zone Map



based on availability of both host material and suitable climate conditions. To rate this RE, we use the U.S. "plant hardiness zones" as described by the United States Department of Agriculture (Figure 1; USDA, 1990). Assign ratings as follows:

Due to the availability of both suitable host plants and suitable climate, the pest has potential to establish a breeding colony:

High: In four or more plant hardiness zones.
Medium: In two or three plant hardiness zones.
Low: In at most a single plant hardiness zone.

If none of the quarantine pests are capable of becoming established in the PRA area because of the absence of both suitable climate and suitable hosts, the PRA stops at this point.

RE #2: Host range

The risk posed by a plant pest depends on both its ability to establish a viable reproductive population and its potential for causing plant damage. For arthropods, risk is assumed to be correlated positively with host range. For pathogens, risk is more complex and is assumed to depend on host range, aggressiveness, virulence and pathogenicity; for simplicity, we rate risk as a function of host range.

High: Pest attacks multiple species within multiple plant families.
Medium: Pest attacks multiple species within a single plant family.
Low: Pest attacks a single species or multiple species within a single genus.

RE #3: Dispersal Potential

A pest may disperse after introduction to a new area. The following items are considered:

- reproductive patterns of the pest (*e.g.*, voltinism, reproductive output)
- innate dispersal capability of the pest
- whether natural factors (*e.g.,* wind, water, presence of vectors) facilitate dispersal

High: Pest has high reproductive potential (*e.g.*, many generations per year, many offspring per reproduction, high innate capacity for population increase (*i.e.*, "r-selected" species), ***AND*** evidence exists that the pest is capable of rapid movement (*e.g.*, over 10 km per year) either under its own power, human-assisted, or by natural forces such as wind, water or vectors.
Medium: Pest has either high reproductive potential ***OR*** the species is motile.
Low: Neither high reproductive potential nor highly mobile.

RE #4: Economic Impact

Introduced pests are capable of causing a variety of economic impacts. We divide these impacts into three primary categories (other types of impacts may occur):

- Lower yield of the host crop (*e.g.*, by causing plant mortality, or by acting as a disease vector).
- Lower value of the commodity (e.g., by increasing costs of production, lowering market price, or a combination).

- Loss of markets (foreign or domestic) due to presence of new quarantine pest.

High: Pest causes all three of the above impacts.
Medium: Pest causes any two of the above impacts.
Low: Pest causes any one or none of the above impacts.

RE #5: Environmental Impact

Our assessment of the potential of each pest to cause environmental damage (FAO, 1996) proceeds by considering the following factors:

- Introduction of the pest is expected to cause significant, direct environmental impacts (*e.g.*, ecological disruptions, reduced biodiversity). When used within the context of the National Environmental Policy Act (NEPA), "significant" has a special meaning different from its use in a scientific or statistical context (*e.g.*, different from its use in the term "statistically significant"). As used by NEPA, significance is qualitative and encompasses both the likelihood and severity of an environmental impact.
- Pest is expected to have direct impacts on species listed by Federal or State agencies as endangered, threatened, or candidate. An example of a direct impact would be feeding on a listed plant. If feeding trials have not been conducted with the listed organism and the pest, a pest will be expected to feed on the plant if it feeds on other species within the genus or other genera within the family.
- Pest expected to have indirect impacts on species listed by Federal or State agencies as endangered, threatened, or candidate (*e.g.*, by disrupting sensitive, critical habitat).
- Introduction of the pest would stimulate control programs including toxic chemical pesticides.
- Introduction of the pest would stimulate control programs including release of nonindigenous biological control agents.

High: Two or more of the above.
Medium: One of the above.
Low: None of the above. It is assumed that introduction of a nonindigenous pest will have some environmental impact (*e.g.*, by definition, introduction of a nonindigenous species affects biodiversity).

8. Likelihood of Introduction

For the pests listed in Table 6, we estimate the likelihood of introduction using a quantitative method referred to as "probabilistic risk assessment" or "probabilistic scenario analysis." The purpose of a probabilistic risk assessment is to estimate the likelihood of an undesirable outcome (bad event). The bad event is represented by the endpoint of the risk model, *i.e.*, introduction of a quarantine pest. Our method has four basic components: scenario analysis, development of a mathematical model, estimation of input values for the likelihood model, and Monte Carlo simulation (see details below).

Table 6: Risk Rating: Consequences of Introduction

Pest	Climate/ Host	Host Range	Dispersal	Eco-nomic	Environ-mental	Risk Rating
Arthropods						
Anastrepha fraterculus	high	high	high	high	high	high
Anastrepha obliqua	high	high	high	high	high	high
Anastrepha serpentina	high	high	high	high	high	high
Ceratitis capitata	high	high	high	high	high	high
Fungi						
Elsinoe australis	high	medium	medium	high	medium	high
Guignardia citricarpa	high	low	high	high	medium	high
Bacteria						
Xanthomonas axonopodis Citrus canker A and B	high	medium	high	high	medium	high

8.a. Scenario Analysis

First, we use the method of **Scenario Analysis** to conceptualize the events (referred to as nodes) that must occur before the endpoint or "bad event" (*e.g.,* introduction of *Anastrepha fraterculus* or *Elsinöe australis*) can occur. Scenario analysis provides a conceptual framework for assessing and managing risk. Before the quarantine pest can be introduced, all of the events shown in the model must occur. Figure 2 shows a graphical representation of our likelihood (risk) model. We consider two scenarios, both of which are represented by Figure 2. Scenario 1 is the BASELINE scenario. Citrus production in Argentina—as in any area of the world—involves measures to minimize the impact of plant pests. Scenario 1 represents the likelihood introducing plant pests posed by importation of fresh citrus fruit from Argentina produced using typical pest control practices. Scenario 2 is the PROGRAM scenario. Scenario 2 incorporates pest mitigation measures currently proposed for citrus fruit exported from Argentina to the United States in addition to measures used routinely for citrus production in Argentina.

Measures that comprise this "Systems Approach" to risk mitigation include the following:

- A 150 meter buffer area exists around the export groves. The buffer area and the plants within the buffer receive the same treatment, inspections, sanitation, etc., as the export groves;

- Citrus planting stock grown in the canker-free area must originate from within the zone. Citrus propagative material from outside the zone may only enter as tissue culture plantlets and is processed through a quarantine station to insure disease freedom;

- Export groves must be registered with the plant protection service of Argentina;

- Fallen leaves and fruit are removed from the grove floor to remove potential disease inoculum;

- Groves are inspected for disease symptoms prior to fungicide applications. Fruits with possible disease symptoms are sent to a laboratory for analysis;

- Groves receive two, or more, treatments with a copper-oil spray per season. Timing of the spray is determined by an expert system which monitors disease inoculum;

- Groves are surveyed for disease symptoms 20 days before harvest. In this survey, 320 fruit are taken from every 200 hectares using a specific sampling protocol. The sampled fruit are held for the 20 day period and examined for disease symptoms. Fruits with possible disease symptoms are sent to a laboratory for analysis;

- Blemished fruit are culled during harvest;

- Harvested fruit are held at room temperature in the packing house for 4-5 days to allow for symptom expression of citrus black spot, if latent infections exist on the fruit;

- The fruit are chemically treated (dipped) in the packing house to control fungal and bacterial growth;

- After treatment the fruit are inspected again before packing and blemished fruit are culled;

- The identity and origin of the fruit is maintained throughout the process; and

- Packing houses in the program will be used for export to the United States only.

APHIS would require that the plant protection service of Argentina issue a phytosanitary certificate (PC) certifying that the citrus originated in one of the citrus canker-free States (Catamarca, Jujuy, Salta, and/or Tucuman). The PC must bear an additional declaration that the fruit is apparently free of citrus black spot (*Guignardia citricarpa)* and sweet orange scab (*Elsinöe australis*).

Due to the risk of Medfly and other *Anastrepha* fruit flies, APHIS would require that oranges and grapefruits from Argentina undergo cold treatment, T107(c) (PPQ, 1992). Smooth- skinned lemons are not a host of these fruit flies and, therefore, are exempt from the cold treatment. The cold treatment requirement necessitates an amendment to the PPQ Treatment Manual. This, in turn, requires that 7 CFR 300.1 be amended.

Fruit that has been cold treated in transit would be allowed to enter, subject to inspection; fruit that has not been cold treated prior to arrival, may undergo inspection and cold treatment at ports listed in 319.56-2d(b)(1).

Detection of *Guignardia citricarpa* (Citrus black spot) or *Elsinöe australis* (sweet orange scab) during grove, packing house or port of entry inspections will result in removal of the source grove from the export program for the remainder of the shipping season.

8.b. Development of a Mathematical Model

The final estimates for the likelihood of introductions are a function of the nodes, the mathematical relationship among the nodes, and the values estimated for the probabilities at each node. Development of the scenario is the first step in establishing the likelihood (risk) model. Once the scenario is designed, the appropriate mathematical relationship among the nodes can be determined. The nodes in our scenario (risk model) represent independent events that must all take place before an introduction can occur. The mathematical relationship between the major nodes is expressed as a linear, multiplicative model.

8.c. Estimation of the Input Probabilities

We were uncertain about the input values for the likelihood model. This is typical for risk assessments. Uncertainty in the estimated values may arise from (among other things):

- natural variation over time
- natural variation from place to place
- data gaps or unconfirmed data
- relationships among multiple components in a node.

Because the actual values for some of the parameters in the model are unknown, we estimated them using the best available data and expert judgement as our basis. However, it must be emphasized that these are estimates. It is possible to estimate the probability for each node identified in the scenario analysis as a single point estimate. For example, we might estimate that the probability that a box of fruit is infested with fruit flies is 0.01. However, specifying our estimate as a single value does not allow us to account for our uncertainty. Probabilistic methods allow the assessor to account for at least some of this uncertainty by expressing each estimate as a probability distribution —such as a normal distribution—rather than point estimates. The two basic components of the estimates are the shape of the distribution function and the values for the distribution parameters (*i.e.,* mean, mode, median) By expressing the probabilities as distribution functions, a Monte Carlo sampling technique can be employed to account for the uncertainty of estimated probabilities. We estimate values for the input parameters using methods described by Kaplan (1992).

8.d. Monte Carlo Simulations

In a typical Monte Carlo simulation, the endpoint probability value is calculated 1,000 or more times. We ran each simulation with 10,000 iterations. Input values for the calculations are drawn from the specified input probability distributions; for each individual calculation (iteration), a computer program randomly selects a value from each of the input probability distributions. Each random input probability value is selected according to the specific parameters of the given probability distribution. After performing the specified number of iterations, the software generates a probability distribution of estimates for the frequency of endpoint bad events. We also express this output in terms of the annual chance of the bad event occurring. We use the risk analysis computer software package *@Risk* for Excel (Palisade Corp., Newfield, NY, USA) to run our simulations.

8.e. Inputs: Fruit flies

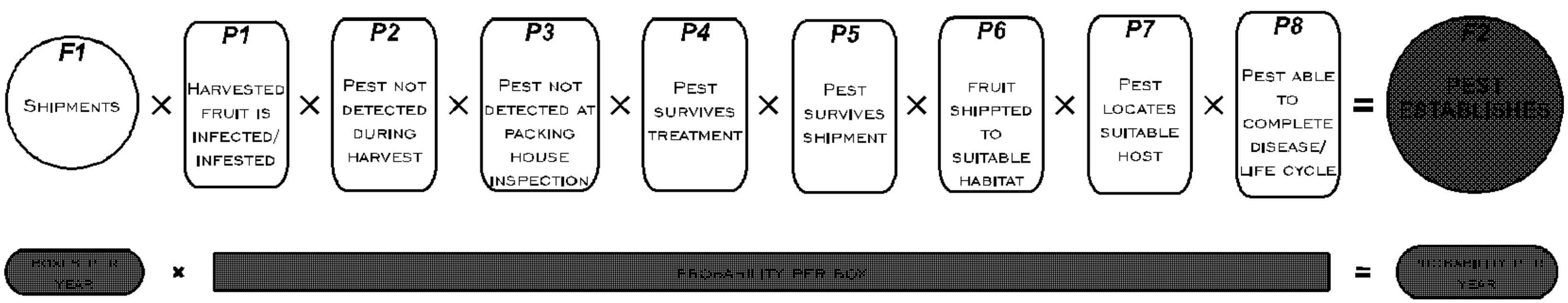
F1: Number of shipments (18 kg boxes) of fruit

APHIS staff from the PPQ Phytosanitary Issues Management Team (PIMT) requested information from agricultural officials in Argentina regarding the size and frequency of shipments of fresh citrus fruit. Officials in Argentina consulted with their industry representatives and provided USDA with an estimate of 1.2 million 18-kg boxes of fruit per year. This figure represents the total for all types of citrus being considered. The number of individual fruit in a box is variable and depends on size differences both within and among varieties (*e.g.,* lemons *vs*. oranges *vs*. grapefruit). We estimate that there will be about 150 fruit in each box of lemons, about 100 fruit in each box of oranges, and about 50 fruit in each box of grapefruit. We represented our estimate for the frequency of shipments as a normal distribution with a mean of 1.2 million boxes and a standard deviation of 200,000 (Tables 7-10). This distribution was constructed to allow for variation in the frequency of shipments that might result from variation in production, frequency of shipments that are cleared for shipment (as opposed to being offered for shipment but rejected by inspectors), and variation in market demands in the United States. This distribution is the same for likelihood estimates for both the baseline and the proposed risk mitigation program, and for all pests considered in this risk assessment.

P1: Harvested fruit is infested with fruit flies

Because we chose an 18 kg box of fruit as our "risk unit" for this assessment, our estimate for the probability of infestation is on a "per box" basis. The corresponding infestation level on a **per fruit** basis would be lower. For example, an infestation level of 0.01 (one in 100) per box corresponds to an infestation level of 0.0001 (one in 10,000) per fruit if there are 100 fruit in a box. Our simulation for fruit flies incorporates the cumulative risk from four species of fruit flies in the Family Tephritidae: *Anastrepha fraterculus* (South American fruit fly), *A. obliqua* (West Indian fruit fly), *A. serpentina* (Serpentine fruit fly) and *Ceratitis capitata*, (Mediterranean fruit fly). There is variation among these species regarding their likelihood of infesting the various varieties of citrus being considered. However, this probability, and others where appropriate, are treated as cumulative probabilities. Specifically, this node represents the probability of one or more individual fruit in a box being infested by any of the

Figure 2. Scenario Analysis: Introduction and establishment of citrus pests through importation of Argentine citrus fruit



four species of fruit flies. We made no effort to assign relative probabilities to the various fruit varieties or fruit fly species. Our estimate for this probability applies to both the baseline scenario and the risk mitigation program because the proposed program does not include any measures intended to limit infestations of fruit flies (beyond those already in place). We have no specific information from Argentina regarding fruit fly infestation rates for citrus in Argentina. We based our estimates on the professional judgement of the team of entomologists working on this assessment. The entomologists used their collective experiences which includes both field and laboratory research on fruit fly infestations in commercial citrus production, research on fruit fly disinfestation methods for commercial citrus, inspections of commercial citrus shipments for fruit fly pests, and collectively over 40 years of experience conducting pest risk analyses for commercial shipments of citrus. We characterized our estimate as a lognormal distribution with a mean and standard deviation of 0.025 (Table 7). The mode (the values used for calculations most frequently) of this distribution is 0.009. This corresponds to an per-fruit infestation level for lemons (150 fruit per box) of 0.00006, or, one fruit in every 16,667 fruit (assuming one infested fruit per box). However, the 95th percentile value of this distribution is 0.07. This means that although 95% of the values chosen for this values were below 7% infestation, 5% of the values used in the calculations were above 7% infestation. The minimum value used in the calculations was 0.0005, the maximum was 0.49. This distribution reflects our belief that the infestation rates will be low. However, the distribution also accounts for our uncertainty and acknowledges that although high infestation rates (preharvest) are unlikely, they are possible. The minimum infestation rate used in the calculations was 0.000535 (*e.g.*, one infested lemon per 280,400 lemons). The maximum infestation rate sampled for calculations was 0.495 (*e.g.*, half of all boxes or one infested grapefruit per every 100 grapefruit). The mean infestation rate used for this value (Table 7) was 0.025 (e.g., 2.5% of boxes, or 25 infested oranges for every 100,000

P2: Pest not detected during harvest

There is little chance that fruit flies infesting citrus fruit will be detected at harvest. Pickers do not inspect for fruit flies, the larvae feed internally, and the oviposition marks and eggs are quite small. However, pickers do cull a portion of damaged fruit, and some of the fruit that are damaged may be infested with fruit flies. We assumed that the likelihood that fruit flies would be detected at harvest would be the same for both the baseline and program scenario, we used a beta distribution with α_1=40 and α_2=1.5 (Table 7).

P3: Pest not detected at packing house inspection

Fruit flies infesting fresh, apparently undamaged fruit are difficult to detect. Fresh fruit destined for export markets are picked early to ensure the fruit are still fresh when they arrive at the point of last sale. Fruit that are not completely ripe are less attractive to fruit flies than ripe fruit. Therefore, most fruit infested with fruit flies at the time of packing would most likely have been infested only recently. As such, we assumed that most fruit flies would be in either the egg or early instar stage; both are difficult to detect, even when the inspection is geared towards finding fruit flies. Gould (1995) examined inspectors' ability to detect *Anastrepha* infesting a variety of fruit, including grapefruit. He found that although there was significant variability among inspectors, the best inspectors failed to detect infested grapefruit in most cases, even though inspectors cut the fruit looking specifically for fruit flies. Under the baseline scenario, we assumed that fruit culling at the pack house would focus on fruit quality and not a quarantine inspection for fruit flies. We assumed that fruit infested with fruit flies would show little evidence of the infestation. However, we also assumed that the quality control in the packing house would be greater than in the field. The proposed program does not include an inspection for fruit flies (the program includes a mandatory treatment for fruit flies). For both scenarios we estimated the probability that fruit flies would avoid detections as a beta distribution with α_1=15 and α_2=3 (Table 7).

P4: Pest survives shipment

Very little will occur during shipment to cause fruit fly mortality (although the cold treatment for fruit flies that is part of the proposed program may occur during shipping, mortality due to the cold treatment is estimated separately in P5). For P4 we estimate the natural survival rate during the time that fruit are being shipped. For both the baseline and program scenarios we estimated survival as a beta distribution with α_1=10 and α_2=2 (Table 7). Specification of this distribution led to a wide range of values being used for calculations in the simulation. The minimum survival rate used was 29.5%, the maximum was 99.96%.

P5: Pest survives postharvest treatment

The baseline scenario does not include a postharvest treatment for fruit flies. However, it is normal practice in citrus production (including Argentina) to wash and wax fruit, and to dip the fruit in a solution containing fungicides and perhaps sodium hypochlorite (although not necessarily at the same rate as planned for the proposed program). These baseline treatments are expected to have only a minor effect on fruit flies because fruit flies are not on the surface of the fruit and these treatments are not designed to penetrate the fruit. The treatments may have a small effect on eggs or larvae close to the surface. For the baseline scenario we used a beta distribution with α_1=30 and α_2=1.2 (Table 7). The situation is quite different for the proposed program. USDA has an approved cold treatment schedule for both *Ceratitis capitata,* Treatment T107(a), and *Anastrepha* fruit flies other than *A. ludens*, Treatment T107(c) (PPQ, 1992). The treatment schedule allows different temperature/time combinations to be used. For example, T107(a) allows 32°F (or below) for 10 days as well as 36°F (or below) for 16 days. Treatment schedules were based on demonstrated efficacy of probit 9 (99.9968%) mortality. This corresponds to a survival rate of 0.00003 (0.003%). We represented survival as a lognormal distribution with a mean of 0.0001 and a standard deviation (sd) of 0.00011. A sd of 0.00011 was chosen because the resulting distribution has a mode (peak of the distribution) at 0.00003.

P6: Fruit shipped to suitable habitat

We estimated the probability that fruit would be shipped to suitable habitat to be roughly equal to the proportion of the conterminous United States (lower 48 states) that have suitable habitat. (Although some fruit will probably be shipped to Alaska, we assumed that the potential market in Alaska to be relatively small, corresponding to its relatively low population density). We estimated the proportion of the conterminous states that has habitat suitable for tephritid fruit flies to be about 10-15%. USDA has analyzed what portion of the United States is at risk from *C. capitata* (USDA, 1993). This is consistent with the Medfly EIS. We used a beta distribution with α_1=4 and α_2=25 (Table 7). The 95th percentile of this distribution is 0.25, that is, our uncertainty allowed for 5% of the values used in the simulation to be above 25% of the lower 48 states.

P7: Pest locates suitable host

This probability pertains to fruit flies that have been transported to a suitable habitat (P1 through P6). Therefore, this is the probability that a suitable host will be found in the extreme southern portions of the continental United States where suitable habitat occurs. This probability incorporates both the likelihood that suitable hosts are in the area and the likelihood that an adult fly emerging from imported fruit will find the host material before dying.

P8: Pest able to complete disease or life cycle

This node (P8) multiplied by preceding eight equals the annual probability of an outbreak per infested "lot" of fruit fly host material, for infested lots delivered to suitable habitats. Miller et al. (1996) estimated this value using data on the known number of *Anastrepha* outbreaks from 1990 through 1996 and estimates of the number of infested lots entering favorable habitats in the United States. Miller et al. (1996) used the same Monte Carlo simulation methods used in this assessment and estimated the probability of an *Anastrepha*-infested lot causing an outbreak as a probability density function: the mean of the estimate was 2.6 X 10^{-5}, the mode was 8.4 X 10^{-6}. For the baseline likelihood scenario we estimated P7 as a lognormal distribution with a mean and sd of 0.01. P8 was estimated as a lognormal distribution with a mean and sd of 0.005. The product of our estimated values for P7 and P8 is similar to the Miller et al (1996) estimate for this event with a mean of 5.0 X 10-5 and a mode of 7.6 X 10-6. Thus, our estimate for the baseline likelihood in this assessment correspond with the known frequency of *Anastrepha* outbreaks in the United States and the estimated amount fruit fly infested host material entering the United States. Our estimate for P8 for the risk mitigation program was a lognormal distribution with a mean a standard deviation of 0.001. We assumed that the likelihood that the fruit flies could complete a life cycle would be slightly lower under the risk mitigation program because the proposed cold treatment for fruit flies would reduce the number of live fruit flies entering the United States and therefor make it more difficult for flies to find mates.

8.f. Inputs: Sweet orange scab, citrus black spot and citrus canker

Two sets of estimates were made for each of the three pathogens analyzed. The first set of probabilities was our baseline estimate assuming that only the minimum in good orchard practices was employed in producing an export citrus crop in Northwestern Argentina. The additional safeguards of the proposed export program were assumed **not** to be in place for the baseline scenarios. The mitigated scenarios were comprised of our probability estimates as adjusted to account for proposed safeguards, including buffer zones, additional field inspections, removal of symptomatic fields from export certification, increased sanitation and additional applications of copper oil fungicides (see section 8.a.)

F1: Number of shipments (18 kg boxes) of fruit

The value for number of shipments that was used in all three disease scenarios was identical to that used in the fruit fly scenario. See the discussion for **F1** above.

P1: Harvested fruit is infected

For sweet orange scab (SOS), we characterized our baseline estimate for the likelihood harvested fruit was infected with a beta (3.5, 3.5) distribution. This distribution has a mean and mode of 0.50 and a standard deviation of 0.18. The 5^{th} and 95^{th} percentile values are 0.21 and 0.79, respectively. According to this distribution, 90 percent of the values sampled for the Monte Carlo simulations fall between 0.21 (21 percent disease incidence) and 0.79 (79 percent disease incidence). Conversely, 10 percent of the sampled values lie above and below this range. The mode, or most frequently sampled value is 0.50 (50 percent disease incidence). As with the fruit fly scenarios, our estimate for the probability of infection is on a "per box" basis. The corresponding infection rate on a per fruit basis would be lower. Our estimates for this scenario node were based on limited field survey data provided by Argentina and expert information provided by scientists familiar with citrus production in Argentina and/or the pathogen. In 1996, field surveys for SOS were conducted in treated and control plots in export region orange groves 20 days prior to harvest. In control plots, 39 percent of the sampled trees bore fruit with SOS symptoms. Our expert information predicted disease incidence, on a per box basis, to range from a minimum of 1 percent to a maximum of 90 percent with a most likely value of 50 percent.

It was assumed that the additional safeguards in the proposed workplan- preharvest field inspections, removal of symptomatic groves from the export program and a minimum of two or three additional applications of fungicide would reduce the likelihood that harvested fruit would be infected with the SOS fungus. In the same 1996 field survey described above, none of the trees sampled in plots receiving the proposed safeguards produced fruit with SOS symptoms. Our expert information also predicted that the mitigation measures would be effective in reducing disease incidence. Taking into account the nature of the SOS fungus and the possibility of human error in fungicide applications, our experts predicted that the disease incidence on a per box basis would range from 0.1 percent to 30 percent with a most likely value of 3 percent. We chose a beta (1.011, 6) distribution to characterize our estimate for the mitigated likelihood that harvested fruit would be infected with the SOS fungus. This distribution has a mean of 0.144 and a mode of 0.002 with a standard deviation of 0.124. The 5^{th} and 95^{th} percentile values are 0.009 and 0.40, respectively. According to this distribution,90 percent of the values sampled for the Monte Carlo simulations fall between 0.009 (0.9 percent disease incidence) and 0.40 (40 percent disease incidence). The mode, or most frequently sampled value is 0.002 (0.2 percent disease incidence).

The baseline likelihood that fruit would be infected by the citrus black spot (CBS) fungus was characterized by a beta (3, 2) distribution. This distribution has a mean of 0.60 and a mode of 0.67 with a standard deviation of 0.20. The 5^{th} and 95^{th} percentile values are 0.25 and 0.90,

Table 7. Input values for Monte Carlo simulation: Fruit flies. Likelihood of establishment in the United States, per year (summed across shipments).				
Frequency (F) (per year), or... Probability (P) (per box of fruit, approx 150 fruit)	distribution	mean	mode	standard deviation
Baseline Risk, no risk mitigations specified by USDA.				
F1: Frequency (number) of boxes per year	normal	1,200,000	1,200,000	200,000
P1: Fruit are infested	lognormal	0.025	0.009	0.025
P2: Pest not detected at harvest (fruit not culled)	beta (40,1.5)	0.96	0.99	0.03
P3: Pest not detected at packing house inspection	beta (15,3)	0.83	0.88	0.09
P4: Pest survives shipment	beta (10,2)	0.83	0.90	0.10
P5: Pest survives postharvest treatment	beta (30,1.2)	0.96	0.99	0.03
P6: Fruit transported to suitable habitat	beta (4,25)	0.14	0.11	0.06
P7: Pest finds suitable host	lognormal	0.01	0.004	0.01
P8: Pest able to complete life cycle	lognormal	0.005	0.002	0.005
Proposed Risk Mitigation Program for Exports to the United States				
F1: Frequency (number) of boxes per year	normal	1,200,000	1,200,000	200,000
P1: Harvested fruit is infested	lognormal	0.025	0.008	0.025
P2: Pest not detected during harvest	beta (40,1.5)	0.96	0.99	0.03
P3: Pest not detected at packing house inspection	beta (15,3)	0.83	0.88	0.09
P4: Pest survives shipment	beta (10,2)	0.83	0.90	0.10
P5: Pest survives postharvest treatment	lognormal	0.0001	0.00003	0.00011
P6: Fruit transported to suitable habitat	beta (4,25)	0.14	0.11	0.06
P7: Pest finds suitable host	lognormal	0.01	0.004	0.01
P8: Pest able to complete life cycle	lognormal	0.001	0.0004	0.001

respectively. According to this distribution, 90 percent of the values sampled for the Monte Carlo simulations fall between 0.25 (25 percent disease incidence) and 0.90 (90 percent disease incidence). In untreated export area orange groves, 1994 and 1995 field surveys for CBS found 14 percent and 82 percent of sampled fruit were infected with the CBS fungus, respectively. In a similar 1996 survey, 56 percent of the sampled trees in an untreated lemon grove bore fruit with CBS symptoms. Our expert information predicted that the incidence of CBS, on a per box basis, in untreated groves would range from a minimum of 10 percent to a maximum of 100 percent with a most likely value of 50 percent.

Many of the safeguards incorporated into the proposed workplan are specifically aimed at reducing the likelihood of introducing the CBS pathogen by reducing its incidence in export groves. In the 1994 survey cited above, CBS incidence was reduced from 14 percent in control groves to 0 percent in treated orange groves. In the replicate 1995 survey, CBS incidence was reduced from 82 percent to

11 percent. Likewise, in the 1996 lemon survey, none of the trees sampled in treated groves bore fruit with CBS symptoms, while 56 percent of untreated lemon trees did bear symptomatic fruit. Our experts acknowledged that the prescribed treatment would have an effect on CBS incidence and predicted that, on a per box basis, the likelihood that CBS would be present at harvest ranged from a minimum of 0.1 percent to 70 percent with a most likely value of 15 percent. We characterized our estimate of the mitigated likelihood that harvested fruit would be infected with the CBS fungus using a beta (2.3, 10.6) distribution. This distribution has a mean of 0.18 and a mode of 0.12 with a standard deviation of 0.10. The 5^{th} and 95^{th} percentile values were 0.04 and 0.37, respectively. According to this distribution, 90 percent of the values sampled for the Monte Carlo simulations fall between 0.04 (4 percent disease incidence) and 0.37 (37 percent disease incidence). Conversely, 10 percent of the sampled values lie above and below this range. The mode, or most frequently sampled value is 0.12 (12 percent disease incidence).

While citrus canker disease, both the Asiatic and cancrosis B forms, occurs in Argentina, Argentine officials maintain that the Northwestern citrus export region is a canker free area. Four years of comprehensive survey data (including 1996) support this claim. Domestic quarantine controls at airports and roads servicing the region have been in place in an effort to maintain freedom from canker. Our baseline estimate for the likelihood that fruit would be infected with the canker bacterium at harvest is characterized by a lognormal distribution with a mean of 0.0005, a mode of 0.0002 and a standard deviation of 0.0005. The 5^{th} and 95^{th} percentile values are 0.00009 and 0.0014, respectively. According to this distribution, 90 percent of the values sampled for the Monte Carlo simulations fall between 0.00009 (9 thousandths of a percent disease incidence) and 0.0014 (0.14 percent disease incidence). The mode, or most frequently sampled value is 0.0002 (0.02 percent disease incidence).

We assumed that while the proposed workplan measures are aimed primarily at controlling the two fungal diseases, they would also impact the incidence of canker. Our mitigated estimate for the likelihood that fruit would be infected with the canker bacterium at harvest is characterized by a lognormal distribution with a mean of 0.000005, a mode of 0.000002 and a standard deviation of 0.000005. The 5^{th} and 95^{th} percentile values are 0.0000009 and 0.000014, respectively. According to this distribution, 90 percent of the values sampled for the Monte Carlo simulations fall between 0.0000009 (9 one hundred thousandths of a percent disease incidence) and 0.000014 (about 1 one thousandth of a percent disease incidence). The mode, or most frequently sampled value is 0.000002 (2 ten thousandths of a percent disease incidence).

P2: Pathogen not detected at harvest

The likelihood that a pathogen will escape detection at harvest is the result of, among other things, the nature of the disease symptoms, the skill of the picker in recognizing diseased fruit and the quality standards employed by a given grove in culling diseased fruit. Infection of very young fruit by the SOS fungus promotes the formation of relatively large conical or warty outgrowths. These outgrowths are particularly large in lemons. On grapefruit and sweet orange, these pustules tend to be less raised. Later infections produce pustules that may be raised no more than the normal contour of the fruit, however if numerous enough these pustules may coalesce to form large lesions. SOS symptoms may sometimes be confused with wind injury. Wind scars and SOS commonly occur together. Our expert information predicted that, on a per box basis, SOS diseased fruit would escape detection by pickers a minimum of 0.1 percent of the time, a maximum of 30 percent of the time with a most likely value of 3 percent.

We characterized our estimate using a beta (3, 25) distribution for both the baseline and the mitigated scenarios. This distribution has a mean of 0.11, a mode of 0.08 and a standard deviation of 0.06. The 5th percentile and 95th percentile values are 0.01 and 0.21, respectively. According to this distribution, 90 percent of the values sampled for the Monte Carlo simulations fall between 0.01 (1 percent escape detection) and 0.21 (21% escape detection). Conversely, 10 percent of the sampled values lie above and below this range. The mode, or most frequently sampled value is 0.08 (8 percent escape detection).

Lemons are particularly susceptible to CBS and symptoms can appear in orchards during later stages of fruit development or not until after picking. The first symptoms do not appear until more than six months after fruit set. The symptoms are extremely variable and can be difficult to identify. Our expert information predicted that, without the proposed mitigation measures and on a per box basis, between 20 and 75 percent of the CBS diseased fruit might escape detection at harvest with a most likely estimate of 50 percent. We characterized our estimate using a beta (5.3, 5.3) distribution for the baseline scenario. This distribution has a mean and mode of 0.50 and a standard deviation of 0.15. The 5th percentile and 95th percentile values are 0.26 and 0.74, respectively. According to this distribution, 90 percent of the values sampled for the Monte Carlo simulations fall between 0.26 (26 percent escape detection) and 0.74 (74 percent escape detection). Conversely, 10 percent of the sampled values lie above and below this range. The mode, or most frequently sampled value is 0.50 (50 percent escape detection).

Our expert information predicted that under the proposed workplan, more rigorous export standards and reduced frequency of latent infection would result in fewer CBS diseased fruit escaping detection. They estimated that, under the conditions of the proposed workplan and on a per box basis, the percentage of CBS diseased fruit escaping detection at harvest would range from 1 percent to 40 percent with a most likely value of 10 percent. We characterized our estimate using a beta (3, 25) distribution for the mitigated scenarios. This distribution has a mean of 0.11, a mode of 0.08 and a standard deviation of 0.06. The 5th percentile and 95th percentile values are 0.01 and 0.21, respectively. According to this distribution, 90 percent of the values sampled for the Monte Carlo simulations fall between 0.01 (1 percent escape detection) and 0.21 (21 escape detection). The mode, or most frequently sampled value is 0.08 (8 percent escape detection).

Canker is mostly a leaf spotting and rind blemishing disease. When the disease is present, our expert information predicted that the disease would be readily detectable by pickers. They estimated that for both baseline and mitigated scenarios and on a per box basis, canker diseased fruit would escape detection at harvest a minimum of 0.1 percent of the time, a maximum of 10 percent of the time and a most likely value of 1 percent of the time. We characterized our estimate using a beta (1.8, 34) distribution for both the baseline and the mitigated scenarios. This distribution has a mean of 0.05, a mode of 0.02 and a standard deviation of 0.04. The 5th percentile and 95th percentile values are 0.008 and 0.12, respectively. According to this distribution, 90 percent of the values sampled for the Monte Carlo simulations fall between 0.008 (0.8 percent escape detection) and 0.12 (12 escape detection). The mode, or most frequently sampled value is 0.02 (2 percent escape detection).

P3: Pathogen not detected at packing house inspection

Once harvested, fruit is transported to packing houses where it generally travels through a line of one or more visual inspections prior to receiving postharvest treatments (if any) and being packed into shipping boxes. Also considered in making our estimates for this node in the mitigated scenario, was the orchard sampling 20 days prior to harvest and the incubation of this sample at room temperature to observe post harvest symptom development. This feature of the proposed export program was designed to improve the detection of CBS which, as noted in the previous node, can manifest itself as symptoms late in the season or after harvest. While not as critical in the cases of SOS or canker, the 20 day incubation does provide an additional opportunity for their symptoms to further develop and/or be detected.

Based on expert information, we characterized our estimate of the likelihood that SOS would escape detection at the packing house using a beta (1.8, 8.2) distribution with a mean of 0.18, a mode of 0.10 and a standard deviation of 0.12 (Table 8). The 5th percentile and 95th percentile values were 0.03 and 0.40, respectively. According to this distribution, 90 percent of the values sampled for the Monte Carlo simulations fell between 0.03 (3 percent escape detection) and 0.40 (40 percent escape detection). The mode, or most frequently sampled value was 0.10 (10 percent escape detection).

Although not specifically aimed at SOS, our expert information predicted that the proposed program safeguards would decrease the likelihood that SOS infected fruit would escape detection at the packing house. Our mitigated estimate, on a per box basis, for the likelihood that SOS infected fruit would escape detection at the packing house is characterized by a lognormal distribution with a mean of 0.05, a mode of 0.02 and a standard deviation of 0.05 (Table 8). The 5th and 95th percentile values were 0.009 and 0.14, respectively. According to this distribution, 90 percent of the values sampled for the Monte Carlo simulations fell between 0.009 (0.9 percent escape detection) and 0.14 (14 percent escape detection). The mode, or most frequently sampled value was 0.02 (2 percent escape detection).

Because of the sometimes latent nature of CBS and the lack of a 20 day holding period in the baseline scenario, our expert information predicted that on a per box basis, a minimum of 10 percent, a maximum of 50 percent and a most likely value of 25 percent of CBS infected fruit would escape detection at the packing house. We characterized our estimate of the likelihood that CBS would escape detection at the packing house using a beta (4.3, 12) distribution with a mean of 0.26, a mode of 0.23 and a standard deviation of 0.11 (Table 9). The 5th percentile and 95th percentile values were 0.11 and 0.45, respectively. According to this distribution, 90 percent of the values sampled for the Monte Carlo simulations fell between 0.11 (11 percent escape detection) and 0.45 (45 percent escape detection). The mode, or most frequently sampled value was 0.23 (23 percent escape detection).

The incorporation of the 20 day preharvest sample and incubation period and the presumed increase in the rigor of inspections carried out under the proposed export program substantially reduces the likelihood that CBS infected fruit will pass through the packing house undetected. Our expert information predicted that the likelihood of CBS diseased fruit escaping detection under the proposed export program was similar to that for SOS. We characterized our estimate for CBS using the same lognormal (mean=0.05, standard deviation=0.05) distribution employed for the SOS mitigated scenario (Table 9; see description of distribution above).

To characterize our estimates for both the baseline and the mitigated likelihood that canker diseased fruit would escape detection at the packing house, we chose a beta (13, 1.5) distribution (Table 10). This distribution has a mean of 0.90, a mode of 0.96 and a standard deviation of 0.08. The 5th percentile and 95th percentile values were 0.75 and 0.99, respectively. According to this distribution, 90 percent of the values sampled for the Monte Carlo simulations fell between 0.75 (75 percent escape detection) and 0.99 (99 percent escape detection). The mode, or most frequently sampled value was 0.96 (96 percent escape detection). We based this high failure rate on the assumption that even under the more stringent inspections of the proposed export program, inspection rates would be designed to detect 1 percent infection levels with a 95 percent confidence level. Since the export area is assumed to be canker free, it is reasonable to expect that fruit arriving at the packing house will be infected at a level considerably lower than the limit of detection. We therefore conclude that there is at least a 95 percent probability that the packing house inspection will fail to detect such low levels of infection.

P4: Pathogens survive post harvest treatment

Argentine officials have indicated that even in the absence of a specific export program for the United States, harvested citrus fruit receives some postharvest treatments. These treatments may include, but are not limited to, washing fruit in a detergent bath, waxing and fungicide dips. The only postharvest treatment for pathogens that is specifically prescribed in the proposed export program is a fruit dip in 200 ppm sodium hypochlorite (bleach) for 2 minutes.

No efficacy data were available for the fungicidal activity of any of the post harvest treatments that might be employed in the SOS baseline scenario. However, our expert information predicted that even these minimal treatments would have a deleterious effect on survival of the SOS fungus. We characterized our baseline estimate for the survival of the pathogen on a per box basis using a beta (1.1, 10.9) distribution (Table 8). This distribution had a mean of 0.09, a mode of 0.01 and a standard deviation of 0.08. The 5^{th} percentile and 95^{th} percentile values were 0.006 and 0.25, respectively. According to this distribution, 90 percent of the values sampled for the Monte Carlo simulations fell between 0.006 (0.6 percent survive treatment) and 0.25 (25 percent survive treatment). The mode, or most frequently sampled value was 0.01 (1 percent survive treatment).

We assumed that the additional treatments included in the proposed export program would further reduce the survival rate of the SOS pathogen. We characterized this survival rate on a per box basis using a lognormal distribution with a mean of 0.0012, a mode of 0.00016 and a standard deviation of 0.002 (Table 8). The 5^{th} percentile and 95^{th} percentile values were 0.00009 and 0.004, respectively. According to this distribution, 90 percent of the values sampled for the Monte Carlo simulations fell between 0.00009 (9 thousandths of 1 percent survive treatment) and 0.004 (0.4 percent survive treatment). The mode, or most frequently sampled value was 0.00016 (16 thousandths of 1 percent survive treatment).

As stated elsewhere in these descriptions, CBS infections may be latent. The germinating ascospores form appressoria from which an infection peg penetrates the cuticle and mycelium grows in between the cuticle and the epidermis where it may remain quiescent and effectively protected from fungicidal treatments. Both our baseline and mitigated estimates for the likelihood that the CBS fungus will survive postharvest treatments reflect this potential for increased resistance to mortality. For our baseline probability, we characterized our estimate using a beta (7,4) distribution (Table 9). This distribution had a mean of 0.64, a mode of 0.67 and a standard deviation of 0.14. The 5^{th} percentile and 95^{th} percentile values were 0.40 and 0.85, respectively. According to this distribution, 90 percent of the values sampled for the Monte Carlo simulations fell between 0.40 (40 percent survive treatment) and 0.85 (85 percent survive treatment). The mode, or most frequently sampled value was 0.67 (67 percent survive treatment).

For our mitigated scenario we assumed that the chlorine dip would have an additional deleterious effect on the survival of the CBS fungus. We chose a beta (3.5, 3.5) distribution to describe our estimate (Table 9). This distribution had a mean of 0.50, a mode of 0.50 and a standard deviation of 0.18. The 5^{th} percentile and 95^{th} percentile values were 0.21 and 0.79, respectively. According to this distribution, 90 percent of the values sampled for the Monte Carlo simulations fell between 0.21 (21 percent survive treatment) and 0.79 (79 percent survive treatment). The mode, or most frequently sampled value was 0.50 (50 percent survive treatment).

While canker bacteria can survive for years in plant refuse that has been kept dry, under normal moisture conditions canker bacteria only survive for a matter of days (Whiteside, *et al.*, 1988). Chlorine dips have routinely been employed as effective measures for mitigating the likelihood of transporting viable citrus canker bacteria on harvested fruit. Based on efficacy studies (Obata, *et al.*, 1969; Brown and Schubert, 1987) we considered it highly improbable that the canker bacteria would survive the postharvest treatment. We estimated the baseline likelihood that canker bacteria would survive postharvest treatments on a per box basis using a lognormal distribution with a mean and standard deviation of 0.0003 and a mode of 0.0001. The 5th percentile and 95th percentile values were 0.00005 and 0.0008, respectively. According to this distribution, 90 percent of the values sampled for the Monte Carlo simulations fell between 0.00005 (5 thousandths of 1 percent survive treatment) and 0.0008 (8 one hundredths of 1 percent survive treatment). The mode, or most frequently sampled value was 0.0001 (I hundredth of 1 percent survive treatment).

We estimated the mitigated likelihood that canker bacteria would survive postharvest treatments on a per box basis using a lognormal distribution with a mean and standard deviation of 0.000003 and a mode of 0.000001. The 5th percentile and 95th percentile values were 0.0000005 and 0.000008, respectively. According to this distribution, 90 percent of the values sampled for the Monte Carlo simulations fell between 0.0000005 (5 one hundred thousandths of 1 percent survive treatment) and 0.000008 (8 ten thousandths of 1 percent survive treatment). The mode, or most frequently sampled value was 0.000001 (1 ten thousandth of 1 percent survive treatment).

P5: Pathogen survives shipment

Our experts agreed that the proposed export program safeguards would have no impact on the survival rate of the SOS and CBS fungi and that, in fact, the shipping conditions were not likely to greatly affect fungal survival. They also agreed that the survival rates for the two fungi would likely be the same. Our expert information predicted that, on a per box basis, for both fungi and both the baseline and mitigated scenarios, there would be a minimum of 50 percent, a maximum of 100 percent and a most likely value of 90 percent survival rate. We characterized this estimate with a beta (10,2) distribution (Tables 8 and 9). This distribution had a mean of 0.83, a mode of 0.90 and a standard deviation of 0.1. The 5th percentile and 95th percentile values were 0.64 and 0.96, respectively. According to this distribution, 90 percent of the values sampled for the Monte Carlo simulations fell between 0.64 (64 percent survive shipment) and 0.96 (96 percent survive shipment). The mode, or most frequently sampled value was 0.90 (90 percent survive treatment).

The canker bacterium is considered to be a relatively labile bacterium (E.L. Civerolo, personal communication). It is generally held that populations of the canker bacterium decline rapidly, even within the lesions of infected fruit after harvest (Civerolo, 1981). We characterized our estimate using a beta (4,2) distribution (Table 10). This distribution had a mean of 0.67, a mode of 0.75 and a standard deviation of 0.18. The 5th percentile and 95th percentile values were 0.34 and 0.92, respectively. According to this distribution, 90 percent of the values sampled for the Monte Carlo simulations fell between 0.34 (34 percent survive shipment) and 0.92 (92 percent survive shipment). The mode, or most frequently sampled value was 0.75 (75 percent survive treatment).

P6: Fruit shipped to suitable habitat

All three pathogens analyzed are essentially restricted to citrus hosts (or closely related species). Suitable habitat for these organisms necessarily corresponds to the range of their citrus hosts. Consequently, we considered the citrus growing regions of the continental United States to be "suitable habitat". We estimated the percentage of the area of the contiguous 48 states that supports the growth of citrus species. We characterized our estimate using a truncated lognormal distribution with a mean of 0.09, a standard deviation of 0.1, a minimum of 0 and a maximum value of 0.1 (Tables 8, 9, 10). The 5th percentile and 95th percentile values were 0.01 and 0.09, respectively. According to this distribution, 90 percent of the values sampled for the Monte Carlo simulations fell between 0.01 (1 percent of the contiguous United States) and 0.09 (9 percent of the contiguous United States). The mode, or most frequently sampled value was 0.03 (3 percent of the contiguous United States).

P7: Pathogen reaches suitable host

All three of these pathogens are spread by wind driven rain, inoculum washed off fruit by falling rain or rain splashed inoculum from fallen fruit. The CBS fungus also produces windborne ascospores, but only on fallen leaf tissue, not on fruit. The SOS pathogen does produce windborne conidia on fruit pustules, but these conidia are not considered an important source of inoculum (Whiteside, *et al.*, 1988). Because the primary inoculum is rain splashed, the inoculum source would have to be placed very close (effectively in the orchard) for successful transfer of infectious propagules to take place. Because of the similarities in their modes of transmission we used the identical lognormal distribution to characterize our estimates for all six scenarios (Tables 8, 9, 10). This distribution had a mean of 0.005, a mode of 0.002 and a standard deviation of 0.005. The 5th percentile and 95th percentile values were 0.00009 and 0.0014, respectively. According to this distribution, 90 percent of the values sampled for the Monte Carlo simulations fell between 0.00009 (one chance in 11,111) and 0.0014 (one chance in 714). The mode, or most frequently sampled value was 0.002 (one chance in 500).

P8: Pathogen able to complete disease cycle

This node described our estimate of the likelihood that these pathogens would, having reached a host plant be able to infect that plant and complete the disease cycle. It took into account the type of infectious propagule produced by each of the three pathogens and the environmental and physiological requirements for host plant susceptibility and successful disease progression. For each organism, we assumed that the presence or absence of the proposed export program had no bearing on our probability estimates. A single distribution was used for the mitigated and baseline scenarios for each pathogen.

SOS inoculum is carried in the form of conidia in pustules on the fruit surface. Water is essential for the production of conidia which survive for only a few days on the pustules. New crops of conidia are produced from pustules that are wetted for 1-2 hours. The conidia are rain splashed into wounds of susceptible tissues. Short periods of precipitation promote infection only if conidia are still surviving in the pustules from the last wetting. Leaves are most susceptible to infection just as they emerge from the bud and become immune before they reach full expansion. Fruit remains susceptible to infection for about 3 months after petal fall.

We characterized our estimate of the likelihood that the SOS fungus would be able to complete its disease cycle on a per box basis using a lognormal distribution (Table 8). This distribution had a mean of 0.0005, a mode of 0.0002 and a standard deviation of 0.0005. The 5th percentile and 95th percentile values were 0.000009 and 0.00014, respectively. According to this distribution, 90 percent of the values sampled for the Monte Carlo simulations fell between 0.000009 (one chance in 111,111) and 0.00014 (one chance in 7140). The mode, or most frequently sampled value was 0.0002 (one chance in 5000).

The epidemiology of CBS is influenced by the availability of inoculum, the environmental requirements for infection, the growth cycle of the host and the age of the fruit in relation to its susceptibility. Ascospores formed on dead leaves on the orchard floor form the main source of inoculum, however pycnidia on out of season or late hanging fruit can also serve as sources of rain splashed inoculum. Spores are released during rainfall and during irrigation. Except for lemons, leaf infections seldom occur. The critical period for infection starts at fruit set and lasts for 4 to 5 months. Symptom development is hastened by rising temperatures, high light intensity, drought and poor vigor.

We characterized our estimate of the likelihood that the CBS fungus would be able to complete its disease cycle on a per box basis using a lognormal distribution (Table 9). This distribution had a mean of 0.000005, a mode of 0.000002 and a standard deviation of 0.000005. The 5th percentile and 95th percentile values were 0.00000009 and 0.0000014, respectively. According to this distribution, 90 percent of the values sampled for the Monte Carlo simulations fell between 0.00000009 (one chance in 11,111,111) and 0.0000014 (one chance in 714,000). The mode, or most frequently sampled value was 0.000002 (one chance in 500,000).

We estimated that the probability that canker bacteria from imported Argentine citrus having reached host would be able to cause an infection and complete its disease cycle would be very low. We arrived at this estimate by considering the population dynamics of the canker bacterium on harvested fruit (Civerolo, 1981), the existence of a threshold value for the number of bacteria necessary to incite infection even under optimal conditions for disease progression (Goto, *et al.*, 1978), the requirement for host tissue to be in a susceptible stage of development (EPPO, 1997; Civerolo, 1981) and that no authenticated outbreak of citrus canker has ever been traced to imported fruit for consumption anywhere in the world (EPPO, 1997; Whiteside, *et al.*, 1988).

We characterized our estimate of the likelihood that the canker bacteria would be able to complete their disease cycle on a per box basis using a the same lognormal distribution (Table 10) for both the baseline and mitigated scenarios. This distribution had a mean of 0.000003, a mode of 0.000001 and a standard deviation of 0.000003. The 5th percentile and 95th percentile values were 0.0000005 and 0.000008, respectively. According to this distribution, 90 percent of the values sampled for the Monte Carlo simulations fell between 0.0000005 (one chance in 2,000,000) and 0.000008 (one chance in 125,000). The mode, or most frequently sampled value was 0.000001 (one chance in 1,000,000).

Table 8. Input values, Monte Carlo simulation. Likelihood of the introduction and establishment of sweet orange scab (*Elsinöe australis)* through the importation of Argentine citrus fruit.

Frequency (F) (per year), or... Probability (P) (per 18kg box)	distribution	mean	mode	standard deviation
Baseline Risk, No Workplan Specific Mitigations				
F1: Frequency of shipments	normal	1,200,000	1,200,000	200,000
P1: Harvested fruit is infected	beta (3.5, 3.5)	0.50	0.50	0.18
P2: Scab not detected during harvest	beta (3, 25)	0.11	0.08	0.06
P3: Scab not detected at packing house inspection	beta (1.8, 8.2)	0.18	0.10	0.12
P4: Fungus survives postharvest treatment	beta (1.1, 10.9)	0.09	0.01	0.08
P5: Fungus survives shipment	beta (10, 2)	0.83	0.9	0.1
P6: Fruit shipped to suitable habitat	truncated lognormal	0.05	0.027	0.1
P7: Fungus finds suitable host	lognormal	0.005	0.0018	0.005
P8: Fungus able to complete disease cycle	lognormal	0.0005	0.00018	0.0005
Proposed Mitigation Program for Exports to the United States				
F1: Frequency of shipments	normal	1,200,000	1,200,000	200,000
P1: Harvested fruit is infected	beta (1.011, 6)	0.144	0.002	0.124
P2: Scab not detected during harvest	beta (3, 25)	0.11	0.08	0.06
P3: Scab not detected at packing house inspection	lognormal	0.050	0.018	0.050
P4: Fungus survives postharvest treatment	lognormal	0.0012	0.000163	0.002
P5: Fungus survives shipment	beta (10, 2)	0.83	0.9	0.1
P6: Fruit shipped to suitable habitat	truncated lognormal	0.05	0.027	0.1
P7: Fungus finds suitable host	lognormal	0.005	0.0018	0.005
P8: Fungus able to complete disease cycle	lognormal	0.0005	0.00018	0.0005

Table 9. Input values, Monte Carlo simulation. Likelihood of the introduction and establishment of citrus black spot (*Guignardia citricarpa)* through the importation of Argentine citrus fruit.				
Frequency (F) (per year), or... Probability (P) (per 18kg box)	**distribution**	**mean**	**mode**	**standard deviation**
Baseline Risk, No Workplan Specific Mitigations				
F1: Frequency of shipments	normal	1,200,000	1,200,000	200,000
P1: Harvested fruit is infected	beta (3, 2)	0.60	0.67	0.20
P2: CBS not detected during harvest	beta (5.3, 5.3)	0.50	0.50	0.15
P3: CBS not detected at packing house inspection	beta (4.3, 12)	0.26	0.23	0.11
P4: Fungus survives postharvest treatment	beta (7, 4)	0.64	0.67	0.14
P5: Fungus survives shipment	beta (10, 2)	0.83	0.9	0.1
P6: Fruit shipped to suitable habitat	truncated lognormal	0.05	0.027	0.1
P7: Fungus finds suitable host	lognormal	0.005	0.0018	0.005
P8: Fungus able to complete disease cycle	lognormal	0.000005	0.000002	0.000005
Proposed Mitigation Program for Exports to the United States				
F1: Frequency of shipments	normal	1,200,000	1,200,000	200,000
P1: Harvested fruit is infected	beta (2.3, 10.6)	0.18	0.12	0.10
P2: CBS not detected during harvest	beta (3, 25)	0.11	0.08	0.06
P3: CBS not detected at packing house inspection	lognormal	0.050	0.018	0.050
P4: Fungus survives postharvest treatment	beta (3.5, 3.5)	0.50	0.50	0.18
P5: Fungus survives shipment	beta (10, 2)	0.83	0.9	0.1
P6: Fruit shipped to suitable habitat	truncated lognormal	0.05	0.027	0.1
P7: Fungus finds suitable host	lognormal	0.005	0.0018	0.005
P8: Fungus able to complete disease cycle	lognormal	0.000005	0.000002	0.000005

Table 10. Input values, Monte Carlo simulation. Likelihood of the introduction and establishment of citrus canker (*Xanthomonas axonopodis)* through the importation of Argentine citrus fruit.

Frequency (F) (per year), or... Probability (P) (per 18kg box)	distribution	mean	mode	standard deviation
Baseline Risk, No Workplan Specific Mitigations				
F1: Frequency of shipments	normal	1,200,000	1,200,000	200,000
P1: Harvested fruit is infected	lognormal	0.0005	0.0002	0.0005
P2: Canker not detected during harvest	beta (1.8, 34)	0.05	0.02	0.04
P3: Canker not detected at packing house inspection	beta (13, 1.5)	0.90	0.96	0.08
P4: Bacteria survive postharvest treatment	lognormal	0.0003	0.0001	0.0003
P5: Bacteria survive shipment	beta (4,2)	0.67	0.75	0.18
P6: Fruit shipped to suitable habitat	truncated lognormal	0.05	0.027	0.1
P7: Bacteria find suitable host	lognormal	0.005	0.0018	0.005
P8: Bacteria able to complete disease cycle	lognormal	0.000003	0.000001	0.000003
Proposed Mitigation Program for Exports to the United States				
F1: Frequency of shipments	normal	1,200,000	1,200,000	200,000
P1: Harvested fruit is infected	lognormal	0.000005	0.000002	0.000005
P2: Canker not detected during harvest	beta (1.8, 34)	0.05	0.02	0.04
P3: Canker not detected at packing house inspection	beta (13, 1.5)	0.90	0.96	0.08
P4: Bacteria survive postharvest treatment	lognormal	0.000003	0.000001	0.000003
P5: Bacteria survive shipment	beta (4,2)	0.67	0.75	0.18
P6: Fruit shipped to suitable habitat	truncated lognormal	0.05	0.027	0.1
P7: Bacteria find suitable host	lognormal	0.005	0.0018	0.005
P8: Bacteria able to complete disease cycle	lognormal	0.000003	0.000001	0.000003

Table 11. Results, estimated likelihood of pest establishment in the United States with importation of citrus fruit from Argentina. Likelihood estimates are per year (summed across shipments within a year).

Pest	Import Program	Likelihood (in scientific notation) and Chance of pest establishment			
		Mode	Median	Mean	95th Percentile
Fruit Flies	**Baseline**	0.0023 1 chance in 430	0.041 1 chance in 24	0.13 1 chance in 7.4	0.53 1 chance in 1.9
	With Pest Mitigation Program	1.09×10^{-7} 1 chance in 9.2 million	5.75×10^{-7} 1 chance in 1.7 million	2.89×10^{-6} 1 chance in 350,000	1.07×10^{-5} 1 chance in 93,000
Sweet Orange Scab	**Baseline**	1.73×10^{-5} 1 chance in 57,800	7.58×10^{-5} 1 chance in 13,200	5.58×10^{-4} 1 chance in 1,790	2.29×10^{-3} 1 chance in 435
	With Pest Mitigation Program	2.45×10^{-8} 1 chance in 41 million	3.87×10^{-8} 1 chance in 26 million	5.55×10^{-7} 1 chance in 1.8 million	2.04×10^{-6} 1 chance in 490,000
Citrus Black Spot	**Baseline**	2.13×10^{-7} 1 chance in 4.7 million	8.75×10^{-6} 1 chance in 114,286	3.49×10^{-5} 1 chance in 28,653	1.34×10^{-4} 1 chance in 7,463
	With Pest Mitigation Program	9.29×10^{-9} 1 chance in 108 million	4.77×10^{-8} 1 chance in 21 million	3.08×10^{-7} 1 chance in 3.2 million	1.19×10^{-6} 1 chance in 840,000
Citrus Canker	**Baseline**	1.58×10^{-13} 1 chance in 6.3 trillion	2.48×10^{-13} 1 chance in 4 trillion	2.07×10^{-12} 1 chance in 483 billion	8.12×10^{-12} 1 chance in 123 billion
	With Pest Mitigation Program	2.29×10^{-17} 1 chance in >100 trillion	2.48×10^{-17} 1 chance in >100 trillion	2.07×10^{-16} 1 chance in >100 trillion	8.12×10^{-16} 1 chance in >100 trillion

9. Conclusion: Pest Risk Potential and Phytosanitary Measures

There are several significant arthropod pests and diseases of citrus in Argentina that do not occur in the United States. Introduction of any of these pests would constitute a significant threat to agriculture in general, and citrus production in particular in the United States. We conclude that if Argentine citrus is allowed entry to the United States, unless specific measures are taken to specifically prevent introduction of specific plant pests there is a high likelihood that fruit flies and the fungus causing sweet orange scab will be introduced and a medium likelihood that the fungus causing citrus black spot will be introduced.

An appropriate level of protection from introduction of plant pests with shipments of commercial citrus from Argentina requires strict adherence to risk mitigation measures such as those analyzed in this assessment.

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V. Appendices

Appendix I: Pest Data Sheet, *Anastrepha fraterculus*

PEST DATA SHEET

ANASTREPHA FRATERCULUS (WIEDEMANN)
SOUTH AMERICAN FRUIT FLY

IDENTITY

Name: *Anastrepha fraterculus* (Wiedemann)

Synonymy: Acrotoxa fraterculus (Wiedemann), *Anastrepha braziliensis* Greene, *A. costarukmanii* Capoor, *A. peruviana* Townsend, *A. pseudofraterculus* Capoor, *A. scholae* Capoor, *A. soluta* Bezzi, *Anthomyia frutalis* Weyenburgh, *Dacus fraterculus* Wiedemann, *Tephritis mellea* Walker, *Trypeta fraterculus* (Wiedemann), *Trypeta unicolor* Loew. The recently described *Anastrepha sororcula* Zucchi is also a member of this species complex.

Classification: Diptera:Tephritidae

Common name: South American Fruit Fly

HOSTS (FIELD)

Anacardium occidentale, Annona cherimola, A. humboldtii, A. muricata, A. squamosa, Averrhoa carambola, Birnea sp., *Campomanesia obscura, C. xanthocarpa, Citrus aurantium, C. grandis, C. limetta, C. maxima, C. medica, C. m. limonium, C. paradisi, C. reticulata, C. sinensis, Coffea arabica, C. liberica, Crataegus* sp., *Cydonia oblonga, Diospyros kaki, Dovyalis hebecarpa, Eriobotrya japonica, Eugenia brasiliensis, E. coloradoensis, E. dombeyi, E. tomentosa, E. uniflora, E. uvalha, Feijoa sellowiana, Ficus carica, Fortunella japonica, Fragaria vesca, Inga edulis, Juglans neotropica, J. regia, Lucuma*

spp., *Malphigia* sp., *Malus domestica, M. sylvestris, Mangifera indica, Manilkara zapota, Mastichodendron capiri* var. *tempisque, Myrcia jaboticaba, M. popayanensis, Passiflora* spp., *Persea americana, Pouteria obovata, Prunus* sp., *P. armeniaca, P. capuli, P. domestica, P.*

insititis, P. persica, P. salicina, Psidium cattleianum, P. guajava, P. guineense, P. littorale, Punica granatum, Pyrus communis, Rubus glaucus, Solanum quitoense, Spondias cytherea, S. mombin, S. nigrescens, S. purpurea, Syzygium jambos, S. malaccense, Terminalia catappa, Theobroma cacao, Turpinia paniculata, Vitis vinifera, Ximenia americana.

HOSTS (LABORATORY)

Annona glabra, Malus pumila, Phyllanthus acidus.

GEOGRAPHIC DISTRIBUTION

North America:	Mexico.
Central America:	Belize, Costa Rica, Guatemala, Honduras, Nicaragua, Panama.
South America:	Argentina, Bolivia, Brazil, British Guiana, Chile, Colombia, Ecuador, Paraguay, Peru, Suriname, Uruguay, Venezuela.
West Indies:	Trinidad and Tobago.

LIFE HISTORY

The bionomics of *A. fraterculus* varies by season and country. In general, mating may occur away from the host plant and has been observed mating at the top of the tallest tree in an area, regardless of its status as a host plant (Malavasi and Morgante, 1981). Oviposition takes place below the skin of the host, with up to 50 eggs being laid in a single fruit, depending on the variety and maturity. Eclosion from the egg occurs in 3-6 days. The duration of the three larval instars is 15-25 days. An inactive forth larval instar occurs in the puparium, and precedes pupal formation. Pupation takes place in the soil, with adult eclosion after 15-19 days (EPPO, 1992; Oakley, 1950; Weems, 1980). Dispersal is by adults, and there is evidence that some Anastrepha species can fly as far as 135 km (Fletcher, 1989). This species is multivoltine, with six to seven generations per annum (Christenson and Foote, 1960; EPPO, 1992; Oakley, 1950).

DETECTION AND IDENTIFICATION

Symptoms

Larva occur in the fruit; infested fruit may exhibit oviposition punctures (these are difficult to detect in the early stages of infestation); considerable damage may occur internally before external symptoms are evident.

Morphology

Adult: Foote, et. al., 1993; Steyskal, 1977; Stone, 1942; Weems, 1980; White and Elston-Harris, 1992.

Larval: Berg, 1979; Greene, 1929; Steck et. al. 1990; Weems, 1980.

MOVEMENT AND DISPERSAL

Natural spread

Adult flight - long distance dispersal has been reported in this genus.

Artificial spread

Larvae in fruit; puparia at the bottoms of containers.

PEST SIGNIFICANCE

Economic impact

This insect has been described as the most injurious species of *Anastrepha* (Oakley, 1950). An important pest of citrus, mangoes and peaches.

Control

Cultural practices, such as destruction of fallen and infested fruit; insecticide applications, including cover sprays and bait sprays; limited success with biological control agents against other *Anastrepha* species.

PHYTOSANITARY MEASURES

Treatment

Cold treatment.

Other safeguards

Inspection at port of entry; destruction of containers.

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Appendix II: Pest Data Sheet, *Anastrepha obliqua*

PEST DATA SHEET

ANASTREPHA OBLIQUA (MACQUART)
WEST INDIAN FRUIT FLY

IDENTITY

Name: *Anastrepha obliqua* (Macquart)

Synonymy: *Acrotoxa acidusa* Loew, *A. obliqua* (Macquart), *Anastrepha acidusa* Loew, *A. fraterculus ligata* Lima, *A. fraterculus mombinpraeoptans* Sein, *Anastrepha mombinpraeoptans* Sein), *A. trinidadensis* Greene, *Tephritis obliqua* Macquart, *Trypeta acidusa* Osten Sacken, *T. obliqua* (Macquart)

Classification: Diptera:Tephritidae

Common name: West Indian Fruit Fly, Antillean Fruit Fly

HOSTS (FIELD)

Alchornea latifolia, Anacardium occidentale, Annona hayesii, Averrhoa carambola, Brosimum alicastrum, Citrus aurantium, C. limetta, C. paradisi, C. sinensis, Coffea arabica, Crataegus sp., *Diospyros digyna, Dovyalis hebecarpa, Eriobotyra japonica, Eugenia nesiotica, Geoffraea superba, Godmania aesculifolia, Jambosia* sp., *Malpighia glabra, Malus. sylvestris, Mangifera indica, Manilkara zapota, Passiflora quadrangularis, P. sapota, P. viridis, Prunus arnoldiana, P. capuli, P. dulcis, P. salicina, Psidium guajava, P.littorale, Pyrus communis,S. cytherea, S. dulcis, S. mombin, S. purpurea, S. venulosa, Syzygium jambos, S. malaccense.*

HOSTS (LABORATORY)

Annona cherimola, A. glabra, A. muricata, A. squamosa, Capsicum annuum, Carica papaya, Carissa macrocarpa, Chrysobalanus icaco, Citrofortunella x *mitis, Diopyros kaki, Eugenia uniflora, Ficus carica, Fortunella japonica, Lycopersicon esculentum, Malus* sp., *Phaseolus* sp., *Pouteria campechiana, Prunus* sp., *P. americana, P. persica, Psidium cattleianum, Punica granatum, Terminalia catappa, Thevetia peruviana, Vitis vinifera, Ximenia americana.*

GEOGRAPHIC DISTRIBUTION

North America:	Mexico.
Central America:	Belize, Costa Rica, Guatemala, Honduras, Nicaragua, Panama.
South America:	Argentina, Brazil, Colombia, Ecuador, Guyana, Peru, Suriname, Venezuela.
West Indies:	Bahamas, Bermuda, Cuba, Dominica, Dominican Republic, Guadeloupe, Haiti, Jamaica, Martinique, Montserrat, Nevis, Puerto Rico, St. Christopher, St. Kitts, St. Lucia, Trinidad and Tobago, Virgin Islands.

LIFE HISTORY

The bionomics of of *Anastrepha obliqua* is seasonal and varies by country. The general life history (McAlister, 1936; Weems, 1970) is as follows: after pupal eclosion, females reach sexual maturity in 7-17 days; preoviposition period ranges from 8-21 days; larval stadia, 10-13 days; pupal stadium, 10-13 days. In field cage tests, adult females had a maximum longevity of 169 days, and males, 188 days (McAlister, 1936). Dispersal is by adults, and there is evidence that some *Anastrepha* species can fly as far as 135 km (Fletcher, 1989). This species is multi-voltine, with six to seven generations possible per year (Weems, 1970).

DETECTION AND IDENTIFICATION

Symptoms

Larva occur in the fruit; infested fruit may exhibit oviposition punctures (these are difficult to detect in the early stages of infestation); considerable damage may occur internally before external symptoms are evident.

Morphology

Adult:	Foote, et. al., 1993; Stone, 1942. Steyskal, 1977; Weems, 1970; White and Elston-Harris, 1992.
Larval:	Berg, 1979; Steck et. al. 1990.

MOVEMENT AND DISPERSAL

Natural spread

Adult flight - long distance dispersal has been reported in this genus.

Man-assisted spread

Larvae in fruit; puparia at the bottoms of containers.

PEST SIGNIFICANCE

Economic impact

This insect has a preference for Anacardiaceae and is a serious pest of *Spondias*, and *Mangifera*. *Citrus* is considered a minor host (Enkerlin, et. al., 1989).

Health impact

In Costa Rica, this insect has been reported as a cause of intestinal pseudomyiasis, especially in children (Jiron and Zeledon, 1979).

Control

Cultural practices, such as destruction of fallen and infested fruit; insecticide applications, including cover sprays and bait sprays; some reported biological control agents.

PHYTOSANITARY MEASURES

Treatment

Cold treatment.

Other safeguards

Inspection at port of entry; destruction of containers.

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November, 1994

Appendix III: Pest Data Sheet, *Anastrepha serpentina*

PEST DATA SHEET

ANASTREPHA SERPENTINA (WIEDEMANN)

SERPENTINE FRUIT FLY

IDENTITY

Name: *Anastrepha serpentina* (Wiedemann)

Synonymy: *Acrotoxa serpentina* (Wiedemann), *Dacus serpentinus* Wiedemann, *Leptoxys serpentina* (Wiedemann), *Trypeta serpentina* (Wiedemann), *Urophora vittithorax* Macquart.

Classification: Diptera:Tephritidae

Common name: Serpentine Fruit Fly, Sapote Fruit Fly, Black Fruit Fly

HOSTS (FIELD)

Alchornea latifolia, Annona glabra, Bumelia laetevirens, Byrsonima crassifolia, Chrysophyllum cainito, C. panamense, Citrofortunella x *mitis, Citrus aurantium, C. maxima, C. paradisi, C. reticulata, C. sinensis, Cydonia oblonga, Diospyros digyna, Dovyalis hebecarpa, Ficus* sp., *Lacmellea panamensis, Malus domestica, Mammea americana, Mangifera indica, Manilkara elata, M. zapota, Mastichodendron capiri* var. *tempisque, Micropholis mexicana, Mimusops coriacea, Persea americana, Pouteria* sp., *P. caimito, P.campechiana, P. hypoglauca, P. obovata, P. sapota, P. stylosa, P. viridis, Prunus persica, Psidium guajava, Pyrus communis, Spondias mombin, S. purpurea.*

HOSTS (LABORATORY)

Capsicum annuum, Carissa macrocarpa, Eugenia uniflora, Fortunella sp., *Lycopersicon esculentum, Prunus* sp., *Syzygium malaccense, Terminalia catappa.*

GEOGRAPHIC DISTRIBUTION

North America:	Mexico.
Central America:	Belize, Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua, Panama.
South America:	Argentina, Brazil, Colombia, Ecuador, Guyana, Peru, Suriname, Venezuela.
West Indies:	Curacao, Dominica, Trinidad, Tobago.

LIFE HISTORY

Oviposition takes place beneath the skin of the host fruit. Females may oviposit up to 600 eggs in a 1 1/2 month period (Baker *et al.*, 1969). The bionomics of this insect is temperature and host dependent. The following life history data is reported from laboratory studies (Baker, 1944; Shaw and Starr, 1946): preoviposition period, 17-64 days; oviposition period, 7-64 days; incubation period, 3-16 days; larval development (3 instars), 17-50 days; pupal stadium, 12-55 days.

The developmental limits lie between 10^0 - 15^0 C (lower), and 32.5^0 - 35^0 C (upper). Adult longevity, in the laboratory, has been reported to be as long as 300 days (Baker, 1944; Shaw and Starr, 1946). Dispersal is by adults, and there is evidence that some *Anastrepha* species can fly as far as 135 km (Fletcher, 1989).

DETECTION AND IDENTIFICATION

Symptoms

Larva occur in the fruit; infested fruit may exhibit oviposition punctures (these are difficult to detect in the early stages of infestation); considerable damage may occur internally before external symptoms are evident.

Morphology

Adult:	Foote, *et al.*, 1993; Steyskal, 1977; Stone, 1942; Weems, 1969; White and Elston-Harris, 1992.
Larval:	Berg, 1979; Greene, 1929; Steck, *et al.* 1990.

MOVEMENT AND DISPERSAL

Natural spread

Adult flight - long distance dispersal has been reported in this genus.

Man-assisted spread

Larvae in fruit; puparia at the bottoms of containers.

PEST SIGNIFICANCE

Economic impact

This insect is a serious pest in those areas where one or more of its hosts are commercially grown.

Health impact

In Costa Rica, this insect has been reported as a cause of intestinal pseudomyiasis, especially in children (Jiron and Zeledon, 1979).

Control

Cultural practices, such as destruction of fallen and infested fruit; insecticide applications, including cover sprays and bait sprays; some reported biological control agents.

PHYTOSANITARY MEASURES

Treatment

Cold treatment.

Other safeguards

Inspection at port of entry; destruction of containers.

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November, 1994

Appendix IV: Pest Data Sheet, *Ceratitis capitata*

PEST DATA SHEET

CERATITIS CAPITATA WIEDMANN
MEDITERRANEAN FRUIT FLY

IDENTITY

Name: *Ceratitis capitata* Wiedmann

Synonymy: *Ceratitis citriperda* MacLeay, *Ceratitis hispanica* De Breme, *Pardalaspis asparagi* Bezzi, *Tephritis capitata* Wiedemann, *Trypeta capitata* Wiedemann

Classification: Diptera:Tephritidae

Common names: Mediterranean Fruit Fly, Mouche Mediterraneene des Fruits, Mouche de l'oranger, Mouche des Fruits, Mittelmeerfruchtfliege, Mosca Mediterranea Moscamed, Mosca de las Frutas, Gusano de las Frutas

HOSTS

This insect infests more than 250 types of fruits, flowers, vegetables and nuts. Weems (1981) lists 42 host species as "heavily or generally infested", 15 species as "occasionally infested", 25 species as "rarely infested", 21 species as "laboratory infestations", and 153 species as "unknown importance". Liquido *et al.* (1991) report 180 genera, worldwide, as hosts for this insect.

GEOGRAPHIC DISTRIBUTION

Indigenous to tropical Africa, this insect has now spread to the Mediterranean Region and portions of Central and South America.

Africa: Algeria, Angola, Benin, Burkina Faso, Burundi, Cameroon, Cape Verde Islands, Congo, Cote d'Ivoire, Egypt, Ethiopia, Gabon, Ghana, Guinea, Kenya, Liberia, Libya, Madagascar, Malawi, Mali, Mauritius, Morocco, Mozambique, Niger, Nigeria, Reunion, Sao Tome, Principe, Senegal, Seychelles, South Africa, St. Helena, Sudan, Tanzania, Togo, Tunisia, Uganda, Zaire, Zimbabwe.

Asia: Cyprus, Israel, Jordan, Lebanon, Saudi Arabia, Syria, Turkey.

Europe: Albania, France (locally distributed in the south), Greece (including Crete), Italy, Malta, Portugal (including Azores and Madeira), Spain (including Canary Islands), Switzerland, Ukraine, Yugoslavia.

North America: Hawaii (USA).

Central America: Costa Rica, El Salvador, Guatemala, Jamaica, Nicaragua, Panama.

South America: Argentina (locally), Bolivia, Brazil, Chile (extreme north), Colombia, Ecuador, Paraguay, Peru, Uruguay, Venezuela.

Oceania: Australia (Western Australia), Northern Mariana Islands.

LIFE HISTORY

Female *Ceratitis capitata* oviposit up to 14 eggs below the skin of the host fruit (McDonald and McInnis, 1985), with the potential of producing up to 1000 eggs throughout its lifetime. Hatching occurs in 2-18 days, depending upon the temperature. The three larval instars require 6-50 days. Pupation occurs in
soil, with adult eclosion in 6-60 days (EPPO, 1979; Weems, 1981). The preoviposition period lasts from 2-163 days. Developmental zero is 10^0C. Approximately 50% of the adults die during the first two months, post eclosion. However, some adults survive for up to one year or more under favorable conditions (PNKTO; Weems, 1981). Adults fly short distances, but may be carried by wind for 2.4 km, or more (PNKTO; Weems, 1981). Steiner, *et al.* (1962) have reported migratory movements of 40-72 km, and sustained overwater flights of 19-64 km. This insect is multivoltine, with 10-15 generations possible in warm climates (EPPO, 1979).

DETECTION AND IDENTIFICATION

Symptoms

Larva occur in the fruit; infested fruit exhibit oviposition punctures.

Morphology

Adult: EPPO, 1992; Foote, *et al.*, 1993; PNKTO; White and Elson-Harris, 1992.

Larval: Berg, 1979; Hardy, 1949; PNKTO; Sabatino, 1974; Weems, 1981.

MOVEMENT AND DISPERSAL

Natural spread

Adult flight - long distance dispersal has been reported in this species.

Man-assisted spread

Larva in fruit; puparia at the bottoms of containers.

PEST SIGNIFICANCE

Economic impact

One of the most destructive fruit pests in the world, this insect not only has a broad host range, but has been able to survive and expand its range wherever establishment has occurred.

Control

Cultural practices, such as destruction of fallen and infested fruit; insecticide applications, including cover sprays and bait sprays; limited success with biological control agents.

PHYTOSANITARY MEASURES

Treatment

Fumigation, fumigation plus refrigeration, cold treatment, high temperature forced air treatment, systems approach.

Other safeguards

Inspection at port of entry; destruction of containers.

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Appendix V: Pest Data Sheet, *Xanthomonas axonopodis*

PEST DATA SHEET

XANTHOMONAS AXONOPODIS PV. *CITRI*
XANTHOMONAS AXONOPODIS PV. *AURANTIFOLII*
CITRUS CANKER

IDENTITY

Name: *Xanthomonas axonopodis* pv. *citri* (Hasse) Vauterin, *et al.* 1995
Xanthomonas axonopodis pv. *aurantifolii* Vauterin, *et al.* 1995

Synonyms: *Xanthomonas campestris* (Pammel) Dowson pv. *citri* (Hasse)
Pseudomonas citri Hasse
Xanthomonas citri (Hasse) Dowson
Xanthomonas citri (Hasse) Dowson f.sp. *aurantifolia* Namekata & Oliveira
Xanthomonas campestris (Pammel) Dowson pv. *aurantifolii* Gabriel, *et al.*

Taxonomic position: Bacteria: Gracilicutes

Common names: Citrus canker, bacterial canker of citrus, citrus bacterial canker, Asiatic canker, canker A, cancrosis A, canker B, cancrosis B, canker C, Mexican lime cancrosis, canker D, citrus bacteriosis

Notes on taxonomy: Several changes in the taxonomic status of *X. campestris* pv. *citri* have been proposed (Gabriel, *et al.*, 1989). These include the reinstatement of some strains of pv. *citri* to species level as *X. citri* and the assignment of others to *X. campestris* pv. *aurantifolii*. To date, these revisions have not been universally adopted and the A, B, C and D strains have remained classified as *X. campestris* pv. *citri*. More recently, Vauterin, *et al.* (1995) have proposed new classifications within the genus *Xanthomonas*. The new name *X. axonopodis* pv. *citri* has been proposed for A strains while *X. axonopodis* pv. *aurantifolii* has been proposed for the B, C and D strains. The name *X. axonopodis* pv.*citrumelo* has been proposed, though not officially adopted, for the pathogen previously known as *X. campestris* pv. *citrumelo* (Gabriel, *et al.*, 1989) or the E strain of citrus canker identified in 1984 in Florida citrus nurseries as the cause of citrus bacterial spot disease. In 1990, all regulations of the citrus bacterial spot or E strain of *X. campestris* pv. *citri* (*X. campestris* pv. *citrumelo*) were removed based on scientific evidence and experience in Florida that indicated that none of the E strain forms causes a disease dangerous to citrus or other plants or fruit (Graham & Gottwald, 1991). This rule change effectively removes the citrus bacterial spot or E strain from consideration as a quarantine pest. This data sheet, therefore, will not address the citrus bacterial spot or E strain.

MAIN DISEASE

X. axonopodis pv. *citri*, the causal agent of citrus canker disease, can attack twigs, leaves and fruit of most commercial citrus tree cultivars, as well as other members of the Rutaceae. Citrus canker is primarily a leaf-spotting and rind- blemishing disease, but under favorable conditions fruit drop, defoliation and general decline of nursery stock and producing trees can also occur (Whiteside, *et al.*, 1988).

HOST RANGE

Known hosts are in the family Rutaceae. Citrus is the main host of economic importance. The majority of commercially important *Citrus* spp. and their hybrids are susceptible. In general, grapefruit (*C. paradisi*) is extremely susceptible. Trifoliate orange (*Poncirus trifoliata*), lime (*C. aurantifolia*), sweet orange (*C. sinensis*), sour orange (*C. aurantium*) and lemon (*C. limon*) are all considered susceptible while pummelo (*C. grandis*) and mandarin (*C. reticulata*) are considered moderately resistant. Calmondin orange (*C. mitis*), citron (*C. medica*) and kumquat (*Fortunella margarita*) are highly resistant (Fawcett, 1936). Other rutaceous hosts include *Aegle marmelos, Atalantia* spp., *Balsamocitrus paniculata, Casimiroa edulis, Chaetospermium glutinosa, Citropsis* *schweinfurthii, Clausena lansium, Eremocitrus glauca, Evodia* spp., *Feronia* spp., *Feroniella* spp., *Hesperethusa crenulata, Limonia* spp., *Melicope triphylla, Microcitrus* spp., *Murraya exotica, Paramigyna longipedunculata, Severina buxifolia, Toddalia asiatica* and *Zanthoxylum* spp. (Swings and Civerolo, 1993). One non-rutaceous host, *Lansium domestica* (Meliaceae), has been reported (Anonymous, 1997). Canker A and B strains have similar host ranges while the C and D strains affect only limes (*C. aurantiifolia*).

GEOGRAPHIC DISTRIBUTION

Citrus canker disease probably originated in Southeast Asia and was subsequently spread throughout Asia then to Africa, Oceania and the Americas. The disease has been reported on islands in the Indian Ocean and in the Middle East. Mild strains with a narrower host range than the Asiatic or A strain were reported in South America (cancrosis B, canker C and D). These have not been isolated from naturally-infected trees since the mid-1980's (Anonymous, 1997). **Asia** (Afghanistan, Andaman Islands, Bangladesh, Cambodia, People's Republic of China, Hong Kong, India, Indonesia, Iran, Japan (including Okinawa), Kampuchea, Korea Democratic People's Republic, Republic of Korea, Laos, Malaysia, Maldives, Myanmar, Nepal, Oman, Pakistan, Philippines, Ryuku Islands, Saudi Arabia, Singapore, Sri Lanka, Taiwan, Thailand, United Arab Emirates, Vietnam, Yemen); **Africa** (Comoro Islands, Peoples Republic of Congo, Côte d'Ivoire, Gabon, Madagascar, Mauritius, Morocco, Mozambique (reportedly eradicated), Réunion Island, Rodrigues Islands, Seychelles Islands, South Africa (eradicated), Zaire); **North America** (Mexico-D strain only (reportedly eradicated), U.S. (Asiatic or A strain introduced into FL in 1912, spread to AL, GA, LA, SC, TX; eradicated from FL by 1933, from U.S. by 1947; reappeared in FL in 1986 and was declared eradicated in 1994. After a period when eradication was successful, the disease appeared again in dooryard plantings in the Miami area in 1995 and an eradication program is currently in effect.); **Central America and Caribbean** (Unconfirmed reports from Belize, Dominica, Guadeloupe, Haiti, Martinique, St. Lucia, Trinidad and Tobago); **South America** (Argentina- A&B strains, Brazil- A&C strains, Paraguay- A,B&C strains, Uruguay- A strain, B strain eradicated); **Oceania** (Caroline Islands, Christmas Island, Cocos Islands, Fiji, Guam, Mariana Islands, Micronesia, Papua New Guinea, Thursday Island(eradicated, 1991);

reportedly eradicated from commercial citrus producing areas of Australia and New Zealand; reappeared in Australia in 1990.) (Anonymous, 1997; Anonymous, 1982).

BIOLOGY

Several strains of *X. axonopodis* pv. *citri* are known(see Taxonomy notes above): the A or Asiatic strain causes typical citrus canker disease; the B or cancrosis B strain from South America has a host range similar to the A strain but produces milder symptoms; the C strain affecting Key lime (*C. aurantifolia*) in Brazil; the D strain which has been reported from Mexico infecting twigs and leaves, but not fruit, of grapefruit (*C. paradisi*) and Key lime; and the E strain causing citrus bacterial spot in Florida. *X. axonopodis* pv. *citri* overwinters in lesions formed on leaves and twigs the previous growing season. Bacteria from these overwintering lesions are the primary inoculum during the spring. During warm (20 - 30°C), wet weather of spring and early summer, the bacteria ooze out of the overwintering lesions and are splashed or wind blown to young, actively growing leaves, shoots and fruits. Infection occurs through natural openings (*eg*., stomata) or wounds. A film of moisture is necessary for infection to occur. Leaf infection can occur within 14 - 21 days after shoots begin to develop. Infection rarely occurs until leaves are about 85 % expanded (Ferguson, *et al.*, 1985). Fruit are generally susceptible to infection during expansion when they are 3-6 cm in diameter and may remain susceptible for 60 - 90 days after petal fall. Resistance of leaves, stems and fruit increases with tissue maturation (Civerolo, 1981). Multiplication occurs in the host tissues a7 14 - 36°C with the optimum temperature being 25 - 30°C. Generally, *X. axonopodis* pv. *citri* populations decline very rapidly in soil, in lesions on defoliated leaves and dropped fruit and in infested host and nonhost tissues (*ie.,* roots) (Civerolo, 1981), but *X. axonopodis* pv. *citri* can be detected for as long as 120 days in decomposing citrus leaf tissues. Burial of the leaves reduces the survival time to 85 days and irrigation to increase soil moisture and hasten leaf decomposition further reduces survival time to 24 days (Graham, *et al.*, 1987). In the presence of living citrus tissue, *X. axonopodis* pv. *citri* can survive as long as 10 months (Goto, *et al.*, 1978). Killing of citrus plants with fumigants provides an alternative to removing plants during eradication. If all host tissue is killed, *X. axonopodis* pv. *citri* would not be expected to survive more than 6 months (Graham, *et al.*, 1987). *X. axonopodis* pv. *citri* has also been reported to survive on grasses that grow near infected citrus. In Brazil, the bacterium was found on sourgrass (*Trichachne insularis*) (Lima, 1977) and in Japan, *X. axonopodis* pv. *citri* has been found on two species of *Zoysia* (Goto, *et al.*, 1975, 1978). It is uncertain whether the low populations found in soil, debris and nonhost tissues plays a role as inoculum for susceptible tissues (Serizawa, 1981).

DETECTION AND IDENTIFICATION

Symptoms

X. axonopodis pv. *citri* infects above ground parts of susceptible hosts including leaves, twigs, stems, trunk, thorns and fruit. Leaf symptoms first appear as small, pinpoint spots that become raised above the leaf surface. The spots initially appear on the lower leaf surface but eventually become visible on the upper surface. Early lesions have a water-soaked, translucent appearance. The leaf epidermis eventually ruptures and the lesions become sunken and crater-like. Lesions may be surrounded by a yellow halo and the central necrotic region becomes surrounded by a water-soaked oily or greasy margin. As lesions age and expand to 9 - 10 mm in diameter, the necrotic centers may drop out producing a shot hole symptom. Lesions on shoots and twigs resemble those on leaves except that they may lack the chlorotic halo and are larger (up to 15 cm). Lesions on fruit may or may not be surrounded by a chlorotic halo and are more sunken than leaf lesions and are larger (3 - 6 cm). The lesions on fruit do not penetrate the rind more than 1 - 3 mm (Anonymous, 1982; Anonymous, 1997).

Morphology

X. axonopodis pv. *citri* is a short, motile rod-shaped bacterium measuring 0.5 - 0.75 µm wide by 1.5 - 2.0 µm long with a single, polar flagellum. The rods are single or in chains, but are more often paired. Colonies on beef extract agar are round, range from hay yellow to amber in color, are slightly elevated, lustrous with continuous margins and viscid. Characteristic growth of *X. axonopodis* pv. *citri* colonies on potato produce a yellow, lustrous colony surrounded by a narrow white zone that subsequently disappears leaving the entire potato slice enveloped in a thick yellow slime (Kothekar, 1978).

Detection and inspection methods

Serological tests using polyclonal and monoclonal antibodies, bacteriophage sensitivity assays, plasmid DNA content analysis, genomic DNA fingerprinting, restriction fragment polymorphism analysis, SDS polyacrlamide gel electrophoresis and fatty acid composition analysis have all been successfully employed to detect or identify *X. axonopodis* pv. *citri*. Despite recent technological advances, conclusive identification of *X. axonopodis* pv. *citri* is based on pathogenicity tests using inoculation of *Citrus* spp.

MEANS OF MOVEMENT AND DISPERSAL

Short distance dispersal of the pathogen in groves occurs primarily by wind driven rain. Rain and wind in excess of 6 - 8 m/sec cause the water soaking in leaves necessary for infection and cause entrance wounds when shoots are injured by wind whipping. Overhead irrigation may also play a role in short distance spread as may mechanical equipment used in grove maintenance (Ferguson, *et al.*, 1985; Swings & Civerolo, 1993).

Long distance spread of *X. axonopodis* pv. *citri* has occurred primarily through the movement of infected planting and propagating materials. Long distance spread via animals, birds and insects has been suggested but not confirmed. Seed transmission is not known. Infested personnel, clothing, equipment, tools, field boxes, trucks and other items used in harvest and post harvest could potentially facilitate long distance spread of *X. axonopodis* pv. *citri* . The pathogen could potentially move long distances on diseased fruit, but there is no authenticated example of a disease outbreak that initiated from diseased fruit. Untreated, infected culled fruit or pulp could also provide a pathway for long distance spread (Anonymous, 1997; Swings & Civerolo, 1993).

PEST SIGNIFICANCE

Economic impact

Citrus canker is a severe disease adversely affecting all of the above ground plant parts of citrus trees. *X. axonopodis* pv. *citri* causes leaf and twig spotting , rind blemishes and in severe cases, premature fruit drop. In all countries where it is reported, canker is one of the most damaging diseases of citrus, especially where defoliation and fruit drop occur. Internal quality of fruit that matures on the tree is unaffected, but the fresh market value is greatly reduced and the lesions provide entry wounds for secondary fruit rotting organisms (Anonymous, 1997). In the 23 years from 1910 to 1933 when *X. axonopodis* pv. *citri* was eradicated in Florida, over $6 million was spent on the program and 258,000 grove trees and 3 million nursery trees were destroyed (Ferguson, *et al.*, 1985). In the four years following the outbreak of first citrus bacterial spot and then citrus canker in Florida, over 20 million trees were destroyed at a cost of nearly $94 million (Graham & Gottwald, 1991).

Control

The most effective control of citrus canker disease, where it has become established, is supplementing the use of resistant planting material with preventive cultural practices. In Japan, one of the single most effective control measures is the use of windbreaks (Kuhara, 1978). Removal of overwintering inoculum by pruning infected shoots and defoliation or eradication of infected trees can reduce inoculum for primary and secondary infections. Avoidance of working trees when wet, disinfestation of tools and equipment , protective sprays of copper- containing pesticides during periods when leaves and fruit are susceptible, and control of leaf miners and the wounds they cause, may all serve to reduce the incidence of citrus canker disease (Anonymous, 1997).

Phytosanitary risk

X. axonopodis pv. *citri* is listed as a quarantine pest by EPPO, IAPSC, JUNAC and NAPPO. *X. axonopodis* pv. *citri* is listed as a quarantine pest by the United States and fruit, nursery stock and plant parts are regulated (7CFR § 301.75. 1994, 7CFR § 301.83. 1994, 7CFR § 319.19. 1994 & 7CFR § 319.28. 1994) (Anonymous, 1994a, 1994b, 1994c, 1994d).

PHYTOSANITARY MEASURES

All plant parts of rutaceous hosts of *X. axonopodis* pv. *citri* for planting (except seeds and tissue cultures) should be prohibited from countries where the bacterium occurs. Fruit may also be prohibited or may be allowed entry provided it is free of leaves and/or peduncles and are produced in areas free from the bacterium.

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Appendix VI: Pest Data Sheet, *Elsinöe australis*

PEST DATA SHEET

ELSINÖE AUSTRALIS

SWEET ORANGE SCAB

IDENTITY

Name: *Elsinöe australis* Bitancourt & Jenkins

Synonyms: None

Anamorph: *Sphaceloma australis* Bitancourt & Jenkins (=*Sphaceloma fawcettii* Jenkins var. *viscosa* Jenkins)

Taxonomic position: Fungi: Ascomycetes, Dothideales

Common names: Sweet orange scab, navel orange scab, sarna del naranjo duice, scabbia delle arance, sweet orange verrugosis, and verruga (Knorr 1963).

MAIN DISEASE

Sweet orange scab is a disease that causes disfigurement of the fruits and generally affects the fresh market production. Also shoot infection can be severe enough to cause stunting of susceptible rootstock seedlings in seedbeds and nurseries. The fungus does infect the leaves and in highly susceptible cultivars causes much distortion through the formation of scab pustules (Whiteside *et al.*, 1988)

HOST RANGE

***Citrus* spp. including sweet orange (*C. sinensis*), lemon (*C. limon*), mandarin (*C. reticulata*), tangerine (*C. reticulata*), satsuma orange (*C. reticulata*), kumquat (*Fortunella margarita*), lime (*C. latifolia*), grapefruit (*C. paradisi*) and pointed leaf papeda (*C. hystrix*) (Sivanesan & Critchett 1969)**

GEOGRAPHIC DISTRIBUTION

The fungus appears to be restricted to South America (Argentina, Bolivia, Brazil, Paraguay, and Uruguay). The introduction into Sicily in 1957 apparently died out as it has not been detected during the following years (Director General, Ministry of Ag. 1994). There is much confusion in the identification of the different scab diseases, and knowledge of their world distribution is incomplete (Whiteside *et al.*, 1988).

BIOLOGY

The fungus overwinters on the tree canopy. Its survival depends on the ability of existing scab pustules to retain their inoculum-producing capacity until new susceptible young shoots or fruits appear.

In culture, *E. australis* has an optimum growth temperature of 24.5-29°C (PNKTO).

DETECTION AND IDENTIFICATION

Symptoms

The lesions of sweet orange fruit scab are more nearly rounded and less spongy than those of sour orange scab and become so numerous and confluent as to cover the scab surface with a corky layer of buff-to-black elevations. Leaf lesions are also slightly larger and more regularly craterlike than those of sour orange scab (Klotz 1978).

Morphology

Rarely seen: Ascomota globose, separate or aggregated, pseudoparenchymatous, epidermal to subepidermal, up to 150 microns in diameter. Asci in the upper part of the ascoma, elliptical to subglobose, 8 spored, 15-30 x 12-20 μm. Ascospores hyaline, straight or curved, 1-3

septate, slightly constricted at the septa, but the upper middle cell may become longitudinally septate, 12-20 x 4-9 µm.

Acervuli similar in appearance to ascomata. Conidiogenous cells formed directly from the upper cells of the pseudoparenchyma or from 0-3 septate conidiophorous, hyaline to pale brown, monophialidic to polyphialidic, terminal, integrated, determinate, 6-8 x 4-5 µm. Conidia hyaline, aseptate, 4-6 x 2-4 µm (PNKTO). The conidia are indistinguishable from those of *E. fawcettii* (Whiteside *et al.*, 1988)

Detection and inspection methods

Sometimes confused with sour orange scab but the two diseases differ in host range and in the relative susceptibility of fruits and leaves to attack. They may sometimes also be distinguished by their respective fruit lesions, those of *E.. australis* being generally larger, less elevated, smoother, more circular, not becoming warty or protuberant as frequently found with *E. fawcettii* (Sivanesan, 1974).

MEANS OF MOVEMENT AND DISPERSAL

Under natural conditions this fungus spread by wind and rain splash (Sivanesan & Critchett, 1969). In international trade the movement of nursery stock presents the greatest risk.

PEST SIGNIFICANCE

Economic impact

Scabby fruits have a reduced fresh fruit market value. Culling the diseased fruits increases handling costs and effects the volume available for export.

Phytosanitary risk

The fungus is listed as a quarantine pest by the United States and nursery stock and plant parts are regulated (CFR 319.19 1994 & CFR 319.28 1994).

PHYTOSANITARY MEASURES

Imported citrus plants should be dormant and come from the best source possible and then held in quarantine until determined to be pest free.

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Appendix VII: Pest Data Sheet, Guignardia citricarpa

PEST DATA SHEET

GUIGNARDIA CITRICARPA

BLACK SPOT OF CITRUS

IDENTITY

Name: ***Guignardia citricarpa*** **Kiely**

Synonym: **None**

Anamorph: ***Phyllosticta citricarpa*** **(McAlpine) van der Aa**
(Anamorph)

(=*Phyllostictina citricarpa* (McAlp.) Petrak)
(=*Phoma citricarpa* McAlp.)

Taxonomic position: **Fungi: Ascomycetes, Dothideales**

Common name: **Citrus black spot (CBS)**

MAIN DISEASE

Citrus black spot is a severe disease of the rind affecting mature citrus fruits in the orchard and during storage (Hall 1973).

HOST RANGE

Except for sour orange (*C. aurantium*) and its hybrids, all commercially grown *Citrus* spp. are susceptible to *G. citricarpa*. Lemons (*C. limon*) are particularly susceptible and heavy losses may occur on Valencia and Navel oranges (*C. sinensis*) and grapefruit (*C. paradisi*).

GEOGRAPHIC DISTRIBUTION

The pathogenic form of the fungus has been reported from Africa (Kenya, South Africa [Natal & Transvaal], Zambia, Zimbabwe); Asia (Bhutan, Peoples Republic of China, Hong Kong, Indonesia, Java, Philippines, Taiwan); Australasia & Oceania (Australia, New Hebrides, New Zealand) (CMI 1990); South America (Argentina, Brazil)(Whiteside *et al.*, 1988). The disease has been intercepted at U. S. ports from countries from which there are no official reports of the disease.

BIOLOGY

Guignardia citricarpa infects fruits and leaves of its hosts. Pycnidia usually form on the fruits late in the season, particularly when fruits are fully mature and the temperature rises. The sunken necrotic lesions turn brown to brick red at the periphery. Numerous pycnidia develop in the brown sunken lesions within a few days. Perithecia develop on fallen dead leaves and the ascospores are the main source of inoculum once the disease has reached the epidemic stage.

DETECTION AND IDENTIFICATION

Symptoms

Kiely (1949) described three types of fruit lesions. Hard spot and shot-hole spot are numerous circular lesions, brown with slight depressions, later more depressed in the center which turns grey-white, margin black and surrounded by a ring of green rind tissue. Freckle spot develops after the hard spot phase with abundant lesions, small, deep orange to brick red, becoming brown, lacking a green ring. Virulent spot is characterized by lesions which are irregular, confluent, rapidly spreading, black in the center where pycnidia are produced, brown nearer the edge, becoming brick red at the periphery forming the margin of the sunken lesion.

Morphology

The fungus is morphologically identical to another *Guignardia* sp. which is latent in citrus and many other hosts. In culture, the pycnidia of *Guignardia citricarpa* appear 6-7 days after plating and are abundant, black, spherical, with indistinct pores. Slender, hyaline conidiophores, conidia hyaline, non septate, smooth, thin walled, ovate to pyriform, granular, 8-10.5 x 5.5-7 µm with a hyaline gelatinous appendage (Whiteside *et al.*, 1988). The ascocarps are amphigenous on dead leaves, solitary or aggregated, globose, immersed, dark brown to black, 100-175 µm in diameter, bitunicate asci clavate-cylindrical, shortly stipitate, 8-spored, 40-65 x 12-15 µm (Sutton *et al.*, 1966). The ascospores are aseptate, hyline, multiguttulate, and clindrical but swollen in the middle (12.5-16 x 4.5-6.5 µm), with obtuse ends, each having a colorless appendage (Whiteside *et al.*, 1988).

Detection and inspection methods

Symptoms of the disease are most noticeable on mature fruit. CBS may be confused with Septoria spot (*Septoria citri* Pass.), but Septoria spot results in lesions with a persistent reddish-purple tinge (Hall 1973). When surveying in the field, samples should be taken from the warmer side of the tree, the upper half and from older or stressed trees where light exposure is increased due to reduced foliage. Each tree selected should be examined initially for evidence of leaf or fruit symptoms. If symptoms are suspected, representative living leaves or fruits as well as leaf litter below suspect trees should be collected and confirmed.

MEANS OF MOVEMENT AND DISPERSAL

Under natural conditions this fungus spreads short distances by rain splashed conidia moving from fruit to fruit when mature diseased fruits remain on the tree. The ascospores are air borne and disperse short distances. However, the greatest danger for long distance dispersal exists in the movement and planting of infected trees and the importation of citrus leaves (Santacroce 1982).

PEST SIGNIFICANCE

Economic impact

In South Africa and Australia, areas where climatic conditions favor black spot, more than 90 percent of the fruit from unprotected trees may be unfit for export.

Control

The fruit is susceptible to infection for about six months after blossoming, and the duration of protection required depends on the presence of mature ascospores in the orchard during this period. Several fungicides are effective in controlling the disease. The number of applications varies with the fungicide; some fungicides accentuate minor fruit lesions. Results with benomyl were excellent requiring only one application in South Africa (Kotze 1981). Hebert and Grech (1985) reported on the development of a resistant benomyl strain of *G. citricarpa*.

Phytosanitary risk

The fungus is listed as a quarantine pest by the United States and nursery stock and plant parts are regulated (CFR 319.19 1994 & CFR 319.28 1994).

PHYTOSANITARY MEASURES

Importation of all plant parts, except seed, of *Citrus* spp. should be prohibited from countries where the disease occurs. Imported citrus

plants should be dormant and come from the best source possible and maintained in quarantine until determined to be pest free.

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