USDA Animal and Plant Health Inspection Service
Plant Protection and Quarantine

Movement of Dragon Fruit (*Hylocereus*, *Selenicereus)* from Hawaii into the Continental United States

A Qualitative Pathway-initiated Risk Assessment

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Executive Summary

This document assesses the risks associated with the movement of fresh dragon fruit, *Hylocereus*, *Selenicereus*, and associated genera of Cactaceae, including *Acanthocereus*, *Cereus*, *Echinocereus*, *Lemairocereus*, *Marshallocereus*, *Pachycereus*, and *Stenocereus*, from Hawaii into the continental United States. A search of both print and electronic sources of information identified five pests of quarantine significance that exist in Hawaii and could be introduced into the continental United States in shipments of fresh dragon fruit.

Quarantine-significant pests likely to follow the pathway:

Bactrocera dorsalis (Hendel) (Diptera: Tephritidae)
Ceratitis capitata (Wiedemann) (Diptera: Tephritidae)
Dysmicoccus neobrevipes (Beardsley) (Homoptera: Pseudococcidae)
Maconellicoccus hirsutus (Green) (Homoptera: Pseudococcidae)
Pseudococcus cryptus Hempel (Homoptera: Pseudococcidae)

The quarantine pests were analyzed based on international principles and internal guidelines as described in the PPQ Guidelines for Pathway-Initiated Pest Risk Assessments, Version 5.02 (USDA, 2005a). This document examined pest biology in the context of the Consequences and Likelihood of Introduction. The pests that are likely to follow the pathway pose phytosanitary risks to U.S. agriculture. The two fruit flies, *Bactrocera dorsalis* and *Ceratitis capitata*, have a High Pest Risk Potential. The three Homopterans, *Dysmicoccus neobrevipes*, *Maconellicoccus hirsutus*, and *Pseudococcus cryptus*, received a Pest Risk Potential of Medium. Port-of-entry inspection, as a sole mitigative measure, is insufficient to safeguard U.S. agriculture from these pests; additional phytosanitary measures are necessary to reduce risk.

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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 of fresh dragon fruit from Hawaii into the continental United States. This risk assessment examines the genera *Hylocereus*, *Selenicereus,* and associated genera of Cactaceae (cactus), because the terms “pitaya” and “pitahaya” commonly refer to a number of taxonomically related genera (Jacobs, 1999; Mizrahi *et al*., 1997; Popenoe, 1939). This risk assessment considers the risks associated with “pitahaya,” “pitajaya,” “pitajuia,” “pitalla” or “pithaya” (Popenoe, 1939; *see* Section C for the complete listing with synonymies). The plant pest risk for these crops, and any hybrids among these plants (Mejia *et al*., 2002; Mizrahi and Nerd, 1999; Raveh *et al*., 1993; Tel-Zur *et al*., 2001; Tel-Zur *et al*., 1999; Weiss *et al*., 1995), is assessed within this document. The term “dragon fruit” is used throughout this document to refer to all of these botanically related cacti that produce edible fruit, except for the species of *Opuntia* (USDA, 2005b). The cacti referred to as “dragon fruit” and assessed in this document include the following genera: *Acanthocereus*, *Cereus*, *Echinocereus*, *Hylocereus*, *Lemairocereus*, *Marshallocereus*, *Pachycereus*, *Selenicereus*, and *Stenocereus*.

This qualitative pest risk assessment estimates risk in the qualitative terms of “High,” “Medium” and “Low” rather than probabilities or frequencies. The details of the methodology and rating criteria can be found in the document: *Pathway-Initiated Pest Risk Assessment: Guidelines for Qualitative Assessments, Version 5.02* (USDA, 2005a).

International plant protection organizations, such as the North American Plant Protection Organization (NAPPO) and the International Plant Protection Convention (IPPC) of the United Nations Food and Agriculture Organization (FAO), provide guidance for conducting pest risk analyses. The methods used for initiating, conducting and reporting information in this pest risk assessment are consistent with these guidelines. Biological and phytosanitary terms are taken from the NAPPO Glossary of Phytosanitary Terms (Anonymous, 1999b) and the Definitions and Abbreviations (Introduction Section) in International standards for Phytosanitary Measures, Import Regulations: Guidelines for Pest Risk Analysis (IPPC, 1996) and the Glossary of Phytosanitary Terms (IPPC, 2005).

II. Risk Assessment

Pest risk assessment is a component of an overall pest risk analysis. The Guidelines for Pest Risk Analysis (IPPC, 1996) describe three stages in pest risk analysis. This document satisfies the requirements of FAO Stages 1, Initiation and 2, Risk Assessment, by separately considering each area of inquiry.

2.1 Initiating Event

This pest risk assessment is commodity-based or “pathway-initiated” because the USDA was requested by the Hawaii Department of Agriculture to authorize importations of fresh dragon fruit from Hawaii into the continental United States. This is a potential pathway for the introduction of plant pests on the fruit. The authority to regulate the movement of fruit and vegetable from Hawaii into the continental United States is codified at 7 C.F.R. § 318.13.

2.2 Assessment of the Weediness of Dragon fruit

If dragon fruit poses a risk as a weed pest, then a “pest-initiated” pest risk assessment is initiated. The cacti that produce dragon fruit fruit pose a risk of becoming weeds from abandoned plants; however, APHIS believes the risk of weediness associated with the consumption of dragon fruit is Low.

Introductions of the "Night-blooming Cereus," *H. undatus* (Haw.) Britton & Rose, became naturalized stands in 10 parks/preserves in six counties in south Florida; these stands were treated and are no longer a factor affecting the native plant community; *H. undatus* was reclassified from a Category II invasive species to the "to be watched" list (Burks, 2001). The naturalized stands in Florida grew from abandoned cultivation or discarded landscaping material (Burks, 2001). In the 1800's, this plant was introduced into Hawaii as an ornamental, but was not listed as a weed (Morton, 1987).

This same species (*H. undatus*) is naturalized in Vietnam and called "thanh long" (Mizrahi *et al*., 1997). It is cultivated in many tropical and subtropical areas, and considered to be an escape from cultivation in parts of Latin America (Kimnach, 1984). Australia permits four species of *Hylocereus* (*H. guatemalensis*, *H. ocamponis, H. polyrhizus*, and *H. undatus*) into the country, but bans other members of the genus. The exception is the state of Western Australia, which restricts all members of the genus, except for the cultivated *H. undatus* as an ornamental (Randall, 2001).

Table 1. Assessment of the Weediness Potential

Commodity: Fruit from *Hylocereus* species (Cactaceae)

Phase 1: Species of *Hylocereus* are not native in Hawaii. The following species of *Hylocereus* produce dragon fruit: *H. costaricensis* (synonym = *Cereus trigonus* var. *costaricensis*), *H. ocamponis* (= *C. ocamponis*), *H. polyrhizus* (= *C. polyrhizus* and *H. lemairei*), and *H. undatus* (Haw.) Britton & Rose (= *C. triangularis, C. tricostatus, C. trigonus* var. *guatemalensis, C. undatus, H. guatemalensis, Cactus triangularis*, and *H. tricostatus*). The members of this genus are not native to the United States, but *H. undatus* was introduced as a cultivated ornamental (ARS, 2001; Solomon, 2002). Native populations of other genera are distributed within the United States (*Acanthocereus tetragonus*, *Stenocereus thurberi*); and *Cereus hildmannianus* (= *Cactus peruvianus, = C. uruguayanus*) is on the Hawaiian Noxious Weed and Seed list (ARS, 2005).

Phase 2: Is the species listed in:

No	Geographical Atlas of World Weeds (Holm *et al*., 1979)
No	World's Worst Weeds (Holm *et al*., 1977; Holm *et al*., 1997)
No	Report of the Technical Committee to Evaluate Noxious Weeds for Federal Noxious Weed Act (Gunn and Ritchie, 1982)
No	Economically Important Foreign Weeds (Reed, 1977)
No	Weed Science Society of America list (WSSA, 1989)
Yes	Are there any references indicating weediness? *e.g.*, AGRICOLA, CAB, Biological Abstracts, AGRIS; search on "species name" combined with "weed."

Phase 3: Some members of the dragon fruit genera are listed and known to be weeds, including *H. undatus*. Populations of this plant became weedy in Florida until it was eradicated (Burks, 2001). Discarded fruits are not known to cause problems as weeds, but abandoned plants can naturalize in suitable environments. There is evidence that seeds can pass through the human digestive system intact (Nabhan, 1985), but the viability of the seed is unknown. If the rejected fruit is properly disposed of and edible fruit is consumed, then the potential for these cacti to demonstrate weediness will be low.

2.3 Previous Risk Assessments, Decision History, and Pest Interceptions
There are no previous risk assessments for dragon fruit from Hawaii.

In 1997, the entry of *Hylocereus undatus* from Vietnam was denied because of the lack of an approved treatment for *Bactrocera dorsalis* and *B. cucurbitae*.

In 1996, the entry of *Acanthocereus* from Nicaragua was denied because of *Ceratits capitata*.

In 1992, the entry of *Acanthocereus* spp., *Hylocereus* spp., *Lemaireocereus* spp., and *Selenicereus* spp. from Belize were denied entry as the result of the lack of an approved treatment for *Anastrepha* spp., *A. ludens*, and *C. capitata*.

In 1988, the entry of *Hylocereus* spp. from Colombia was denied because of the lack of an approved treatment for *C. capitata*.

Pest interceptions under the name *Hylocereus* reflect only a portion of the total interceptions on imported dragon fruit (PIN 309, 2005). Port officers are likely to ascribe the interception to the genus *Acanthocereus*; this is typically based on a good faith reliance on the illustrated fruit guide in the manual for non-propagative material (USDA, 2004), which states that the fruit of *H. undatus* is *Acanthocereus* fruit. With an unsettled botanical nomenclature, there are many synonyms (ARS, 2005; Solomon, 2002). The fruit of cacti referred to as “dragon fruit” are assessed in this document, and include the following genera: *Acanthocereus*, *Cereus*, *Echinocereus*, *Hylocereus*, *Lemairocereus*, *Marshallocereus*, *Pachycereus*, *Selenicereus*, and *Stenocereus*.

Table 2. Pests intercepted on dragon fruit from other parts of the world and present in Hawaii (PIN 309, 2005)

Pest	Host	Country, Dates[1]
Cactoblastis cactorum	Cactaceae	Haiti, 1993 (2)
Ceratitis capitata	Cactaceae	Argentina, 1994; Greece, 1989; Italy, 1989 (2); Portugal, 1989
Dysmicoccus neobrevipes	*Hylocereus*	Hong Kong, 2004; Unknown, 2003; Vietnam, 2001, 2002, 2003
	Acanthocereus	Vietnam, 1994 (2), 1998; Cambodia, 1995; Singapore, 1995; Thailand, 2003
Maconellicoccus hirsutus	*Acanthocereus*	Cambodia, 1995
	Cereus	Mexico, 1994 (2), 1995, 1997, 1998, 1999 (7), 2000 (6), 2001 (6), 2002 (2), 2003 (2)
	Echinocereus	Mexico, 1995 (2), 1996 (3), 1997, 1999 (2), 2002
Pseudococcus cryptus	*Acanthocereus*	Vietnam, 2003

[1]The number of interceptions is seen in parentheses if more than one interception occurred that year.

2.4 Pest Categorization—Identification of pests associated with dragon fruit in Hawaii

In this risk assessment, Table 3 reports the pests associated with dragon fruit if, and only if, populations of that pest are also reported in Hawaii. This table should not be interpreted to infer that all pests known to affect dragon fruit are listed. This table only presents information of a pest's prevalence relative to the risks associated with the importation of dragon fruit from Hawaii, along with host associations, and regulatory data used to select the quarantine pests (given detailed biological analysis).

Table 3: Summary of pests associated with dragon fruit in Hawaii.

Organism	Geographic Distribution[1]	Plant Part(s)	Quarantine Pest	Follow Pathway	References
ARTHROPODA					
ACARI					
Tetranychidae					
Tetranychus desertorum Banks	HI, US	Fruit, Leaves	No	Yes	Bolland, *et al.*, 1998
COLEOPTERA					
Anthribidae					
Anthribidae sp.[2]	HI, US	Fruit, Flower, Leaves, Stem	No	Yes	CPC, 2004; HTAC, 2004; PIN 309, 2004
DIPTERA					
Drosophilidae					
Drosophila melanogaster Meigen	HI, US	Fruit	No	No	CPC, 2004: HTAC, 2004
Tephritidae					
Bactrocera dorsalis (Hendel)	HI	Fruit	Yes	Yes	Conant, 2004; GPDD, 2005
Ceratitis capitata (Wiedemann)	HI	Fruit	Yes	Yes	GPDD, 2005; Hill, 1994; Liquido *et al.*, 1998; PIN 309, 2004

Organism	Geographic Distribution[1]	Plant Part	Quarantine Pest	Follow Pathway	References
HOMOPTERA					
Aphidae					
Aphis gossypii Glover	HI, US	Fruit, Flower, Leaves, Stem	No	Yes	CPC, 2004; Conant, 2004; HTAC, 2004; PIN 309, 2005
Diaspididae					
Diaspis echinocacti (Bouché)	HI, US	Fruit, Leaves, Stem	No	Yes	HTAC, 2004; ARS-SEL, 2005
Lopholeucaspis cockerelli (Grandpré & Charmoy)	HI, US	Fruit, Leaves, Stem	No	Yes	HTAC, 2004; ARS-SEL, 2005
Eriococcidae					
Eriococcus coccineus Cockerell	HI, US	Fruit, Leaves, Stem	No	Yes	Hill, 1994; HTAC, 2004; ARS-SEL, 2005
Pseudococcidae					
Dysmicoccus neobrevipes (Beardsley)	HI	Fruit	Yes	Yes	CPC, 2004; GPDD, 2005; HTAC, 2004; PIN 309, 2005
Maconellicoccus hirsutus (Green)	HI, (US Virgin Islands)	Fruit, Flower, Leaves, Stem	Yes	Yes	CPC, 2004; Hill, 1994; HTAC, 2005; ARS-SEL, 2005
Pseudococcus cryptus Hempel	HI, (US Virgin Islands)	Fruit, Flower, Leaves, Stem	Yes	Yes	CPC, 2004; Hill, 1994; HTAC, 2005; ARS-SEL, 2005
Pseudococcus longispinus Targioni and Tozzetti	HI, US	Fruit, Flower, Leaves, Stem	No	Yes	CPC, 2004; Hill, 1994; HTAC, 2004
Pseudococcus viburni (Signoret)	HI, US	Fruit, Flower, Leaves, Stem	No	Yes	Conant, 2004; HTAC, 2004; ARS-SEL, 2004

Organism	**Geographic Distribution**[1]	**Plant Part**	**Quarantine Pest**	**Follow Pathway**	**References**
LEPIDOPTERA					
Noctuidae					
Agrotis ipsilon (Hufnagel) (Lepidoptera: Noctuidae)	HI, US	Fruit, Stem	No	Yes	CPC, 2004; HTAC, 2004
LEPIDOPTERA					
Gracillariidae					
Gracillariidae sp.[2]	HI, US	Fruit, Stem	No	Yes	Borror *et al.*, 1992; HTAC, 2004; PIN 309, 2004
THYSANOPTERA					
Phlaeothripidae					
Hoplothrips sp.[2]	HI	Flower, Fruit	No	Yes	Conant, 2004
MOLLUSCA					
Milax gagates (Draparnaud) (Mollusca: Milacidae)	HI, US	Fruit, Stem	No	Yes	HTAC, 2004; MREC, 2005
BACTERIA					
Erwinia carotovora subsp. *carotovora* (Jones 1901) Bergey *et al.* 1923 (Proteobacteria: Enterobacteriaceae)	HI, US	Leaves, Roots, Stem	No	No	Anonymous, 1994; Castillo-Martinez *et al.*, 1996; CPC, 2004
Rhizobium radiobacter (Beijerinck van Delden 1902) Young *et al.* 2001 =*Agrobacterium tumefaciens* (E. F. Sm. & Town.) Conn. (Proteobacteria: Rhizobiaceae)	HI, US	Roots, Stem	No	No	CPC, 2004
Rhizobium rhizogenes (Riker et al. 1930) Young et al. 2001 (Proteobacteria: Rhizobiaceae)	HI, US	Roots, Stem	No	No	CPC, 2004
FUNGI					
Fusarium oxysporum (Schlechtend. ex Fries) (Ascomycota: Helotiales)	HI, US	Roots, Stem	No	No	CPC, 2004; Farr, *et al.*, 1989; Farr, *et al.*, 2005

Organism	**Geographic Distribution[1]**	**Plant Part**	**Quarantine Pest**	**Follow Pathway**	**References**
Gibberella fujikuroi (Sawada) Ito in Ito & K. Kimura [teleomorph] =*Fusarium moniliforme* J. Sheld. [anamorph] (Ascomycota: Hypocreales)	HI, US	Whole plant	No	Yes	CPC, 2004; Farr, *et al.*, 1989; Farr, *et al.*, 2005
Glomerella cingulata (Stoneman) Spaulding & Schrenk [teleomorph] =*Colletotrichum gloeosporioides* Penz. & Sacc. [anamorph] (Ascomycota: Phyllachorales)	HI, US	Fruit, Flower, Leaf, Stem, Seed	No	No	CPC, 2004; Farr *et al.*, 1989
Phomopsis sp.[2] (Sacc.) Bubák [anamorph] (Coelomycete)	HI, US	Fruit, Flower, Stem	No	Yes	Farr, 2005; CABI Bioscience Databases, 2005
Phytophthora cactorum (Lebert & Cohn) Schröter (Oomycota: Pythiales)	HI, US	Whole plant	No	Yes	CPC, 2004; Raabe *et al.*, 1981
Pichia cactophila (Ascomycota: Saccharomycetales)	HI, US	Fruit, Flower, Stem	No	Yes	Farr, 2005; Fogleman and Starmer, 1985
Sclerotinia sclerotiorum (Lib.) de Bary (Ascomycota: Helotiales)	HI, US	Whole plant	No	Yes	Bibliowicz and Hernandez, 1998; CPC, 2004; Farr *et al.*, 1989
NEMATODA					
Criconemoides sp.[2] (Tylenchida: Criconematidae)	HI, US	Root	Yes	No	CPC, 2004; USDANC, 2005
Helicotylenchus dihystera (Cobb) Sher (Tylenchida: Hoplolaimidae)	HI, US	Root	No	No	CPC, 2004; Castaña, *et al.*, 1991; USDANC, 2005
Meloidogyne incognita (Kofoid & White, 1919) Chitwood 1949 (Tylenchida: Meloidogynidae)	HI, US	Root	No	No	Castaña, *et al.*, 1991; CPC, 2004; USDANC, 2005
Trichodorus sp.[2] (Dorylaimida: Trichodoridae)	HI, US	Root	No	No	CPC, 2004

Organism	**Geographic Distribution**[1]	**Plant Part**	**Quarantine Pest**	**Follow Pathway**	**References**
Tylenchorhynchus annulatus (Cassidy 1930) Golden 1971 =*Tylenchorhynchus martini* Fielding 1956 (Tylenchida: Dolichodoridae)	HI, US	Root	No	No	CPC, 2004; Castaña, *et al.*, 1991; USDANC, 2005

[1]HI = Hawaii; US = United States
[2]Quarantine pests identified to the order, family or generic levels are not further analyzed in this risk assessment (*See* Section 2.5 discussion).

2.5 Quarantine Pests that are Likely to Follow the Pathway
The quarantine pests of *Hylocereus* and *Selenicereus* spp. that are reasonably expected to follow the pathway on fruit are further analyzed in this risk assessment (Table 4). Other organisms included on the pest list, but (Table 3) were not chosen for further scrutiny for one or more of the following reasons: they are well established and widespread in the United States; they are associated mainly with plant parts other than the commodity; they may be associated with the commodity, but it was not considered reasonable to expect these pests to remain with the commodity during processing; or they have been intercepted on rare occasions as biological contaminants by APHIS-PPQ Officers during inspections of the commodity and would not be expected to be commonly found with commercial shipments. Although organisms listed in Table 3 (at the genus level) are quarantine pests, they are not considered for further analysis because their identity is not clearly defined in order to insure that the risk assessment is performed on that distinct organism (IPPC, 2005).

Table 4. Quarantine Pests Likely to Follow the Pathway and Selected for Further Analysis

Bactrocera dorsalis (Hendel) (Diptera: Tephritidae)
Ceratitis capitata (Wiedemann) (Diptera: Tephritidae)
Dysmicoccus neobrevipes (Beardsley) (Homoptera: Pseudococcidae)
Maconellicoccus hirsutus (Green) (Homoptera: Pseudococcidae)
Pseudococcus cryptus Hempel (Homoptera: Pseudococcidae)

2.6 Consequences of Introduction—Economic/Environmental Importance
Potential Consequences of Introduction are rated using five Risk Elements: Climate-Host Interaction, Host Range, Dispersal Potential, Economic Impact, and Environmental Impact. These elements reflect the biology, host ranges, and climatic/geographic distributions of the pests. For each Risk Element, pests are assigned a rating of Low (1 point), Medium (2 points), or High (3 points) (USDA, 2005a). A Cumulative Risk Rating is then calculated by summing all Risk Element values. Table 5 summarizes the values determined for the Consequences of Introduction for each pest.

Consequences of Introduction: ***Bactrocera dorsalis*** **(Hendel) (Diptera: Tephritidae)**	**Risk Value**
Risk Element #1: Climate-Host Interaction Except for adventive populations in Guam and Hawaii, *B. dorsalis* is restricted to subtropical and tropical Asia (White & Elson-Harris, 1992). It is estimated that this species could become established in the continental United States in areas corresponding to Plant Hardiness Zones 9-11.	Medium (2)
Risk Element #2: Host Range This species is extremely polyphagous. Recorded hosts include *Coffea* sp. (Rubiaceae), *Ficus* sp. (Moraceae), *Prunus* spp. (Rosaceae), *Eugenia uniflora* (Myrtaceae), *Mangifera* spp. (Anacardiaceae), *Citrus* spp. (Rutaceae), *Areca catechu* (Arecaceae), *Chrysophyllum cainito* (Sapotaceae), *Cucumis* spp. (Cucurbitaceae), *Dimocarpus longan* (Sapindaceae), *Diospyros kaki* (Ebenaceae), *Flacourtia indica* (Flacourtiaceae), *Punica granatum* (Punicaceae), *Ziziphus* spp. (Rhamnaceae), *Annona* spp. (Annonaceae), *Averrhoa carambola* (Oxalidaceae), *Carica papaya* (Caricaceae), *Malpighia glabra* (Malpighiaceae), *Muntingia calabura* (Elaeocarpaceae), *Persea americana* (Lauraceae), *Terminalia catappa* (Combretaceae), *Musa* x *paradisiaca* (Musaceae) (CPC, 2004); *Passiflora mollisima* (Passifloraceae), *Juglans hindsii* (Juglandaceae), *Quassia simarouba* (Simaroubaceae), *Solanum seaforthianum* (Solanaceae), and *Clausena lansium* (Rutaceae) (White & Elson-Harris, 1992).	High (3)
Risk Element #3: Dispersal Potential Females deposit 3-30 eggs per host fruit; total fecundity per female may exceed 1000 eggs (Fletcher, 1989a). There are several generations per year. Adult flight (*B. dorsalis)* is capable of flying distances up to 65 km (Fletcher, 1989b), and the transport of infested fruit are the major means of movement and dispersal to previously uninfested areas (CPC, 2004). Like other dacine tephritids, *B. dorsata* exhibits high reproductive and dispersal potentials.	High (3)
Risk Element #4: Economic Impact There are three kinds of economic losses that result from this pest (Harris, 1989): downgrading of fruit quality, which is caused by oviposition "stings" that spoil the fruits' appearance, including those unfavorable for larval survival; fruit spoilage caused by larval tunneling and the entry of organisms that cause decay; and indirect damage in the form of lost markets resulting from the imposition of quarantine restrictions. In Hawaii, annual losses in major fruit crops caused by *B. dorsalis* may exceed 13%, or $3 million (Culliney, 2002).	High (3)
Risk Element #5: Environmental Impact Because of its extremely broad host range, *B. dorsalis* represents a potential threat to plants listed as Threatened or Endangered in Title 50, Part 17, Section 12 of the United States Code of Federal Regulations (50 CFR §17.12), and that occur in southern areas of the United States (*e.g*., *Prunus geniculata*, *Ziziphus celata*). As the species is a pest of numerous crops of economic significance in the continental United States (*e.g*., apple, peach, pear, citrus), its entry and establishment could stimulate the initiation of chemical or biological control programs, as has occurred in Hawaii.	High (3)

Consequences of Introduction: ***Ceratitis capitata*** **(Wiedemann) (Diptera: Tephritidae)**	**Risk Value**

Risk Element #1: Climate-Host Interaction *Ceratitis capitata* is found in southern Europe and west Asia, throughout Africa and South and Central America (CPC, 2004), and in northern Australia (Hassan, 1977). This species has the capacity to tolerate colder climates better than most other fruit fly species (Weems, 1981). It is estimated that *C. capitata* could establish in areas of the United States corresponding to Plant Hardiness Zones 8-11.	High (3)
Risk Element #2: Host Range This pest has been recorded from a wide variety of host plants in several families, including *Coffea* sp. (Rubiaceae), *Capsicum annuum* (Solanaceae), *Citrus* spp. (Rutaceae), *Malus pumila*, *Prunus* spp. (Rosaceae), *Ficus carica* (Moraceae), *Psidium guajava* (Myrtaceae), *Theobroma cacao* (Sterculiaceae), *Phoenix dactylifera* (Arecaceae), and *Mangifera indica* (Anacardiaceae) (CPC, 2004).	High (3)
Risk Element #3: Dispersal Potential Females may deposit as many as 800 eggs in a lifetime, although 300 is the more typical number (Weems, 1981). Eggs are inserted into host fruit in small batches of one to 10. Breeding is continuous throughout the year, the species exhibits several overlapping generations (Hassan, 1977). Adult flight (with a range of 20 km or more) and the transport of infested fruit are the major means of movement and dispersal to previously uninfested areas (CPC, 2004).	High (3)
Risk Element #4: Economic Impact *Ceratitis capitata* is an important pest in Africa and has spread nearly worldwide to become the single most important pest species in its family. In Mediterranean countries, it is particularly damaging to citrus and peach crops. It may also transmit fruit-rotting fungi (CPC, 2004). The species is of quarantine significance worldwide, especially in Japan and the United States. Its presence, even as temporary adventive populations, can lead to severe additional constraints for the export of fruits to uninfested areas in other parts of the world. In this respect, *C. capitata* is one of the most significant quarantine pests for any tropical or warm temperate areas in which it is not yet established (CPC, 2004).	High (3)
Risk Element #5: Environmental Impact As it represents a significant threat to citrus and peach production, the wider establishment of *C. capitata* in the continental United States would undoubtedly trigger the initiation of chemical or biological control programs, as has occurred in California and Hawaii. This species is highly polyphagous and, thus, has the potential to attack plants listed as Threatened or Endangered (*e.g., Opuntia treleasei, Prunus geniculata*).	High (3)

Consequences of Introduction: *Dysmicoccus neobrevipes* Beardsley (Homoptera: Pseudococcidae)	**Risk Value**
Risk Element #1: Climate-Host Interaction *Dysmicoccus neobrevipes* occurs throughout Central America, northern South America, the Caribbean, Indo-China, the Philippines, and Oceania (ARS-SEL, 2005; CPC, 2004). Outside of greenhouse or other artificial situations, this species should be able to survive in the warmer, southern parts of the continental United States (Plant Hardiness Zones 9-11).	Medium (2)
Risk Element #2: Host Range This species is extremely catholic in its host plant preferences, which extend across at least 31 families. Hosts include *Ananas comosus* (Bromeliaceae), *Malus pumila* (Rosaceae) (CPC, 2004); *Colocasia esculenta* (Araceae), *Ficus* sp. (Moraceae), *Musa paradisiaca* (Musaceae), *Opuntia ficus-indica* (Cactaceae), *Pritchardia* sp. (Arecaceae), *Acacia koa* and *Samanea*	High (3)

saman (Fabaceae), *Helianthus annuus* (Asteraceae) (Nakahara, 1981); *Agave sisalana* (Agavaceae), *Cucurbita maxima* (Cucurbitaceae), *Zea mays* (Poaceae), *Heliconia latispatha* (Heliconiaceae), *Citrus* spp. (Rutaceae), and *Lycopersicon esculentum* (Solanaceae) (ARS-SEL, 2005).	
Risk Element #3: Dispersal Potential Ito (1938) reported females of the "gray form" of *D. brevipes* (considered by Beardsley (1959) to be *D. neobrevipes*) to produce an average of 347 progeny. Their life span averaged about 95 days, with several generations per year. The main dispersal stage of mealybugs is the first-instar crawler, which may be locally transported by wind or other animals. All life stages may be dispersed over longer distances through the movement of infested plant materials in commerce.	High (3)
Risk Element #4: Economic Impact *Dysmicoccus neobrevipes* attacks a number of valuable commercial crops, and is a particularly serious pest of pineapple, *Ananas comosus*. Like *D. brevipes*, it is a vector of the virus causing pineapple wilt disease (Rohrbach *et al*., 1988). Feeding by large mealybug populations may cause a loss of host plant vigor. Also, honeydew deposited on leaves and fruit by mealybugs serves as a medium for the growth of black sooty molds, which interfere with photosynthesis, and reduce the market value of the crop. Biological and chemical controls are often implemented to control these mealybugs (or the attending ants) that aid in their spread, and interfere with their biological control. Because many of the host plants attacked by *D. neobrevipes* are commercially or environmentally important to the states of Texas, Arizona, and California, introduction might cause the loss of international and domestic markets.	High (3)
Risk Element #5: Environmental Impact The introduction of *D. neobrevipes* would likely result in the initiation of chemical or biological control programs, as has occurred in Hawaii. The species is polyphagous, and has the potential to infest plants listed as Threatened or Endangered in the continental United States (*e.g.*, *Opuntia treleasei*, *Cucurbita okeechobeensis* ssp. *okeechobeensis*).	High (3)

Consequences of Introduction: *Maconellicoccus hirsutus* (Green) (Homoptera: Pseudococcidae)	**Risk Value**
Risk Element #1: Climate-Host Interaction *Maconellicoccus hirsutus* is probably native to southern Asia (CPC, 2004). Its range extends from south Asia through southeast and east Asia, the Philippines, Indonesia, Oceania, and southern Australia. It occurs as far north as Lebanon, Africa, northern South America, Central America, and the Caribbean. It should only be able to become established in the southern United States (Plant Hardiness Zones 9-11).	Medium (2)
Risk Element #2: Host Range This species is extremely polyphagous. It has been recorded on plants in over 200 genera from 73 families, showing some preference for hosts in the Malvaceae, Fabaceae, and Moraceae (CPC, 2004). Primary hosts include the species of *Hibiscus* and *Gossypium* (Malvaceae), *Glycine max* (Fabaceae), *Artocarpus* spp. (Moraceae), *Persea americana* (Lauraceae), *Annona* spp. (Annonaceae), *Citrus* spp. (Rutaceae), *Averrhoa carambola* (Oxalidaceae), *Passiflora edulis* (Passifloraceae), *Musa paradisiaca* (Musaceae), *Theobroma cacao* (Sterculiaceae), *Vitis vinifera* (Vitaceae), *Bougainvillea* sp. (Nyctaginaceae), and *Boehmeria nivea* (Urticaceae). Included among secondary hosts are *Asparagus officinalis* (Liliaceae), *Brassica oleracea* (Brassicaceae), *Codiaeum variegatum* (Euphorbiaceae), *Malus pumila* and	High (3)

Prunus insititia (Rosaceae), *Coffea arabica* (Rubiaceae), *Lycopersicon esculentum* (Solanaceae), *Phoenix* spp. (Arecaceae), *Terminalia catappa* (Combretaceae), *Syzygium cumini* (Myrtaceae), *Cucurbita moschata* (Cucurbitaceae), *Opuntia* sp. (Cactaceae), *Zea mays* (Poaceae), *Parthenium hysterophorus* (Asteraceae), and *Chenopodium album* (Chenopodiaceae).	
Risk Element #3: Dispersal Potential Fecundity ranges from 150-600 eggs per female (CPC, 2004). There may be as many as 15 generations per year. Local dispersal is accomplished by the first-instar crawler, most efficiently via air, water, or on animals (CPC, 2004). All stages may be dispersed over longer distances through the transport of infested plant materials.	High (3)
Risk Element #4: Economic Impact *Maconellicoccus hirsutus* attacks a wide range of (usually woody) plants, including agricultural, horticultural, and forest species (CPC, 2004). Feeding on young growth causes severe stunting and leaf distortion, the thickening of stems, and a bunchy-top appearance of shoots; in severe cases, the leaves may prematurely fall. Honeydew and sooty mold contamination of fruit may reduce its value. In Grenada, the estimated annual losses to crops and the environment from this mealybug were $3.5 million before biological controls were implemented (CPC, 2004). Other crops seriously damaged by *M. hirsutus* include cotton in Egypt, with growth sometimes virtually halted; tree cotton in India, with reduction in yield; the fiber crop *Hibiscus sabdariffa* var. *altissima* (roselle) in India and Bangladesh, with reduction in yields of between 21 and 40%; and grapes in India, with up to 90% of bunches destroyed.	High (3)
Risk Element #5: Environmental Impact Because of its extreme polyphagy, this pest poses a threat to plants in the continental United States listed as Threatened or Endangered (*e.g.*, *Cucurbita okeechobeensis* ssp. *okeechobeensis*, *Opuntia treleasei*, *Prunus geniculata*). As it is a potential threat to a number of crops of considerable economic value in the United States (*e.g.*, soybean, cotton, corn; CPC, 2004), its introduction into additional mainland states would likely lead to the initiation of chemical or biological control programs.	High (3)

Consequences of Introduction: *Pseudococcus cryptus* Hempel (Homoptera: Pseudococcidae)	**Risk Value**
Risk Element #1: Climate-Host Interaction This species exhibits a subtropical to tropical distribution (ARS-SEL, 2005). It occurs in Kenya and Zanzibar in Africa; from Israel to Japan in Asia; South and Central America; the Caribbean; and various island groups in the Pacific. It should be able to establish in the warmer, southern parts of the continental United States (Plant Hardiness Zones 9-11).	Medium (2)
Risk Element #2: Host Range *Pseudococcus cryptus* has been recorded on hosts in more than 20 families, including *Mangifera indica* (Anacardiaceae), *Plumeria* sp. (Apocynaceae), *Dahlia* sp. (Asteraceae), *Hevea brasiliensis* (Euphorbiaceae), *Persea americana* (Lauraceae), *Erythrina* sp. (Fabaceae), *Crinum asiaticum* (Liliaceae), *Artocarpus altilis* (Moraceae), *Musa* sp. (Musaceae), *Psidium guajava* (Myrtaceae), *Cocos nucifera* (Arecaceae), *Pandanus upoluensis* (Pandanaceae), *Passiflora foetida* (Passifloraceae), *Piper methysticum* (Piperaceae), *Coffea* spp. (Rubiaceae), *Citrus* spp. (Rutaceae) (ARS-SEL, 2005); *Hibiscus* sp. (Malvaceae), and various Orchidaceae (Hill, 1994). In laboratory tests, the species has been found to complete development on *Pyrus* spp., *Malus pumila*, and *Cydonia oblonga* (Rosaceae), *Solanum tuberosum* (Solanaceae), *Aralia cachemirica* (Araliaceae), and *Eugenia* spp. (Avidov & Harpaz, 1969).	High (3)

Risk Element #3: Dispersal Potential Avidov & Harpaz (1969) outlined the reproductive biology of this species. Fecundity ranges from 200-500 eggs per female; at least six generations per year are recorded. The insect is only capable of limited dispersal under its own power. Long-distance spread would be accomplished via the movement of infested plant materials.	High (3)
Risk Element #4: Economic Impact *Pseudococcus cryptus* is a major pest of citrus (Hill, 1994). The insect produces copious quantities of honeydew, on which sooty molds develop, sometimes reaching a thickness of 5-8 mm (Avidov & Harpaz, 1969). In heavy infestations, entire trees may be contaminated, and leaves and fruit will prematurely shed. High population densities on coconut palm may cause the drying of the inflorescence and button shedding (Moore, 2001). In Israel, both biological and chemical controls have succeeded in maintaining populations below economically damaging densities (Avidov & Harpaz, 1969; Blumberg *et al*., 2001).	High (3)
Risk Element #5: Environmental Impact Although it attacks a broad range of plant species, *P. cryptus* is not expected to pose a threat to vulnerable native plants in the continental United States, although close relatives of some of its known hosts that occur in Puerto Rico (*i.e*., *Eugenia haematocarpa*, *E. woodburyana*, *Solanum drymophilum*) are listed as Endangered in 50 CFR §17.12. As it is a known pest of citrus, its introduction into citrus-growing regions of the United States could spur the initiation of biological or chemical control programs.	Medium (2)

Table 5. Risk Rating for Consequences of Introduction (Dragon fruit from Hawaii).

Pest	Risk Element 1 Climate/ Host Interaction	Risk Element 2 Host Range	Risk Element 3 Dispersal Potential	Risk Element 4 Economic Impact	Risk Element 5 Environmental Impact	Cumulative Risk Rating
Bactrocera dorsalis (Hendel)	Medium (2)	High (3)	High (3)	High (3)	High (3)	High (14)
Ceratitis capitata (Wiedemann)	High (3)	High (3)	High (3)	High (3)	High (3)	High (15)
Dysmicoccus neobrevipes Beardsley	Medium (2)	High (3)	High (3)	High (3)	High (3)	High (14)
Maconellicoccus hirsutus (Green)	Medium (2)	High (3)	High (3)	High (3)	High (3)	High (14)
Pseudococcus cryptus Hempel	Medium (2)	High (3)	High (3)	High (3)	Medium (2)	High (13)

2.7 Likelihood of Introduction—Quantity Imported and Pest Opportunity

Likelihood of Introduction is a function of both the quantity of the commodity imported annually and pest opportunity, which consists of five criteria that consider the potential for pest survival along the pathway (USDA, 2005a) (Table 6).

Quantity imported annually

The rating for the quantity imported annually is based on the amount reported by the exporter, and is then converted into standard units of 40-foot long shipping containers. The projected initial volume of dragon fruit to be shipped from Hawaii to the mainland United States is estimated to be no more than 100 cases (Conant, 2005), which would not fill a single standard 40-foot long shipping container.

Survive post-harvest treatment

Both fruit flies *(Bactrocera dorsalis* and *Ceratitis capitata)* are internal pests and would be expected to survive minimal post-harvest treatment, such as washing and culling, especially if infestation damage was obvious. The remaining pests, scale insects *Dysmicoccus neobrevipes, Maconellicoccus hirsutus*, and *Pseudococcus cryptus*, are external feeders, and would have less of a probability of surviving post-harvest treatments; however, depending on their stage (egg, larva or nymph, adult) or instar, these diminutive insects might find shelter on fruit. For example, many scales prefer tight, protected areas, such as cracks and crevices (Kosztarab, 1996). Their cryptic behavior, small size (most scales are less than 5 mm long) (Gullan & Kosztarab, 1997), and water-repellent, waxy coverings make them difficult to see or dislodge, particularly if dragon fruit is harvested with sepals attached.

Survive shipment

Dragon fruit is typically stored at 10°C (Wall, 2005). Under such benign conditions, all of the pests are expected to have a High probability of surviving shipment.

Not detected at port-of-entry

As with assessing the risk of dragon fruit pests surviving post-harvest treatment, estimating the risk that these pests will not be detected at a port-of-entry involves consideration of pest size, mobility, and degree of concealment. Again, depending on the age of infestation, the internal feeders could have a high probability of escaping detection at a port-of-entry, unless the fruit is cut open. *Bactrocera dorsalis* and *C. capitata,* in particular, might readily evade detection, as fruit fly-infested fruit commonly go unrecognized (White & Elson-Harris, 1992). Large, conspicuous infestations could lead to the easy detection of the scale insects; however, sparser populations of these small insects, particularly if concealed on fruits or in packing materials, would be more difficult to discover.

Moved to suitable habitat

Based on their distribution in warm temperate to tropical environments, it is estimated that climates suitable for the establishment of permanent pest populations can only be in a rather narrow swath of territory in the south, and along the west coast of the continental United States. These regions would comprise an estimated 10-12% of the total land area of the country.

Contact with host material

Hosts of the highly polyphagous species (*i.e*., *B. dorsalis*, *C. capitata*, *D. neobrevipes*, *M. hirsutus*, *P. cryptus*, and *T. florum*), in addition to citrus, include temperate-zone or widely cultivated plants (USDA, 2003) that should be available throughout the potential geographic range in the continental United States.

Even if hosts are available for colonization, biological attributes of some of the arthropods reduce their probability of successful establishment. Specifically, the sessile nature of the scales would severely limit their chances of coming into contact with hosts (Miller, 1985; Gullan & Kosztarab, 1997). Successful establishment of these insects in a new environment is contingent on the likelihood of at least two necessary conditions occurring: close proximity of susceptible hosts and their presence on the imported fruit of crawlers or other mobile forms to transfer to new hosts. Since these circumstances are highly unlikely to co-occur (Miller, 1985), these particular pests receive a risk rating of Low.

Table 6. Risk Rating for Likelihood of Introduction (Dragon fruit from Hawaii).

Pest	Quantity imported annually	Survive post-harvest treatment	Survive shipment	Not detected at port-of-entry	Moved to suitable habitat	Contact with host material	Cumulative Risk Rating
Bactrocera dorsalis (Hendel)	Low (1)	High (3)	High (3)	High (3)	Medium (2)	High (3)	High (15)
Ceratitis capitata (Wiedemann)	Low (1)	High (3)	High (3)	High (3)	Medium (2)	High (3)	High (15)
Dysmicoccus neobrevipes Beardsley	Low (1)	Medium (2)	High (3)	Medium (2)	Medium (2)	Low (1)	Medium (11)
Maconellicoccus hirsutus (Green)	Low (1)	Medium (2)	High (3)	Medium (2)	Medium (2)	Low (1)	Medium (11)
Pseudococcus cryptus Hempel	Low (1)	Medium (2)	High (3)	Medium (2)	Medium (2)	Low (1)	Medium (11)

2.8 Conclusion—Pest Risk Potential and Pests Requiring Phytosanitary Measures

The summation of the values for the Consequences of Introduction and the Likelihood of Introduction yield Pest Risk Potential values (USDA, 2005a) (Table 7). This is an estimate of the risks associated with importation.

Table 7. Pest Risk Potential

Pest	Consequences of Introduction	Likelihood of Introduction	Pest Risk Potential
Bactrocera dorsalis (Hendel)	High (14)	High (15)	High (29)
Ceratitis capitata (Wiedemann)	High (15)	High (15)	High (30)
Dysmicoccus neobrevipes Beardsley	High (14)	Medium (11)	Medium (25)
Maconellicoccus hirsutus (Green)	High (14)	Medium (11)	Medium (25)
Pseudococcus cryptus Hempel	High (13)	Medium (11)	Medium (24)

Pests with a Pest Risk Potential value of Low do not require mitigation measures, whereas a value within the Medium range indicates that specific phytosanitary measures may be necessary. The PPQ Guidelines state that a High Pest Risk Potential means that specific phytosanitary measures are strongly recommended, and that port-of-entry inspection is not considered sufficient to provide phytosanitary security.

Risk Mitigation Options

1. Irradiation treatment at a dose of 400 Gy (7 CFR §305.31a) for all quarantine-significant insect pests.

2. Irradiation treatment at a dose of 150 Gy (7 CFR §305.31a) for *Bactrocera dorsalis* and C*eratitis capitata*; warm, soapy water wash and brushing, T102-c (PPQ Treatment Manual), for *Dysmicoccus neobrevipes*, *Maconellicoccus hirsutus*, and *Pseudococcus cryptus*.

3. Irradiation treatment at a dose of 150 Gy (7 CFR §305.31a) for *Bactrocera dorsalis* and *Ceratitis capitata*; inspection for *Dysmicoccus neobrevipes*, *Maconellicoccus hirsutus, and Pseudococcus cryptus*.

4. Vapor heat, T106-e (PPQ Treatment Manual), for *Bactrocera dorsalis* and *Ceratitis capitata*; inspection for *Dysmicoccus neobrevipes*, *Maconellicoccus hirsutus*, *and Pseudococcus cryptus*.

5. Methyl bromide fumigation, T101-e-3 (PPQ Treatment Manual), for *Bactrocera dorsalis* and *Ceratitis capitata*; inspection for *Dysmicoccus neobrevipes*, *Maconellicoccus hirsutus*, *and Pseudococcus cryptus*.

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