Importation of Baby Squash, *Cucurbita maxima* Duchesne, and Baby Courgettes, *C. pepo* L., from Zambia into the Continental United States

A Qualitative, Pathway-Initiated Risk Assessment

November 2007

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Executive Summary

This report documents risks associated with the importation of fresh baby squash, *Cucurbita maxima*, and courgettes, *C. pepo*, from the Republic of Zambia into the United States. A search of both print and electronic sources of information revealed thirteen quarantine significant pests of *Cucurbita* exist in Zambia. Of those, ten insects could potentially be introduced into the United States with commodity shipments: *Aulacaspis tubercularis; Dacus ciliatus* [also: *D. bivitattus*, *D. frontalis*, *D. lounsburyii*, *D. punctatifrons*, and *D. vertebratus*); *Diaphania indica; Helicoverpa armigera;* and *Spodoptera littoralis.*

All of these pests pose phytosanitary risks to U.S. agriculture. *Helicoverpa armigera* and *Spodoptera littoralis* were given pest risk ratings of high, while the others were estimated to be of medium risk. Port-of-entry inspections, as a sole mitigative measure, are considered insufficient to safeguard U.S. agriculture from these pests, and additional phytosanitary measures appear necessary to reduce risks to acceptable levels.

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A. Introduction
This risk assessment was prepared for the United States Department of Agriculture (USDA), Animal and Plant Health Inspection Service (APHIS), Plant Protection and Quarantine (PPQ), Center for Plant Health Science and Technology (CPHST) to examine plant pest risks associated with importing baby squash, *Cucurbita maxima*, and courgettes, *C. pepo*, from Zambia into the United States. This is a qualitative pest risk assessment that expresses risk in terms of high, medium, or low. Importing a new commodity gives exotic pests a potential pathway into the United States. This risk assessment is "pathway-initiated" in response to that threat.

The International Plant Protection Convention (IPPC) of the United Nations Food and Agriculture Organization (FAO) provides guidance for conducting pest risk analyses. The methods used to initiate, conduct, and report this pest risk assessment are consistent with guidelines provided by the FAO (IPPC, 1996). Biological and phytosanitary terms (e.g., *introduction*, *quarantine pest*) conform with those outlined in International Standards for Phytosanitary Measures Publication No. 5, "Glossary of Phytosanitary Terms" (IPPC, 2005).

The IPPC defines *pest risk assessment* (*for quarantine pests*) as "Evaluation of the probability of the introduction and spread of a pest and of the associated potential economic consequences;" *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" (IPPC, 2005). Thus, pest risk assessments should consider both the consequences and likelihood of introduction of quarantine pests. These issues are addressed in this document.

Pest risk assessment is one component of an overall pest risk analysis. The IPPC describes three stages in pest risk analysis (IPPC, 1996): initiation (stage 1), risk assessment (stage 2), and risk management (stage 3). This document satisfies the requirements of stages 1 and 2. Details of the methodology and rating criteria used in this document can be found in the publication "Guidelines for Pathway-Initiated Pest Risk Assessments, Version 5.02" (USDA, 2000).

B. Risk Assessment

1. Initiating Event: Proposed Action
The USDA developed this risk assessment in response to a request by the Republic of Zambia for a permit to import Baby Squash (*Cucurbita maxima*) and Courgettes (*C. pepo*) into the United States. The USDA has the authority to regulate imports of fruits and vegetables from foreign countries into the United States under Title 7, Part 319, Section 56 of the United States Code of Federal Regulations (7 CFR §319.56). The purpose of this risk assessment is to determine if it is likely that exotic plant pests would enter the United State with this commodity.

2. Assessment of Weed Potential of *Cucurbita maxima* and *C. pepo*.
The potential of the commodity to become a weed after it enters the United States was examined in this step. A pest-initiated risk assessment was not conducted because the analysis did not indicate that the commodity had a significant weed potential.

Table 1. Assessment of the Weed Potential of *Cucurbita maxima* and *C. pepo*

Commodity: Baby squash, *Cucurbita maxima* and Courgettes, *C. pepo*

Phase 1: *Cucurbita maxima* and *C. Pepo* are widely cultivated in the United States (CABI, 2003; NASS, 2003).

Phase 2: Is the species listed in:

- No *Geographical Atlas of World Weeds* (Holm *et al.*, 1979), *Cucurbita pepo* is listed as a weed in Jamaica and West Polynesia, although the status is unknown.
- No *World Weeds: Natural Histories and Distribution* (Holm, 1997)
- 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 (WSSA, 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: *Cucurbita maxim*a and *C. pepo* are widely prevalent in the United States. Because the answer to the questions in Phase 2 are "No" (CABI, 2003; NASS, 2003), a pest-initiated risk assessment for the species is not necessary.

3. Previous Risk Assessments, Current Status, and Pest Interceptions

Decision History for *Cucurbita maxima* and *C. pepo* from Zambia

Decision History

There is no decision history with regard to cucurbit importation from Zambia or any other African country. In 1996, a pest risk assessment for fresh cucurbits from South Korea recommended mitigating *Bactrocera depressa*, *Diaphania indica*, *Ostrinia furnacalis*, *Tetranychus karzawai*, and Cucumber Green Mosaic Virus; of these, only *D. indica* and Cucumber green mosaic virus are listed in Zambia (CABI, 2003), but the virus is not a quarantine pest at this time.

Pest Interceptions

Between 1985 and 2003, U.S. agricultural inspectors intercepted 81 specimens of eight potential cucurbit pests from Zambia (Table 2). All of the pests intercepted from Zambia arrived on species other than *Cucurbita*, but they were deemed potential pests because they had been previously intercepted on *Cucurbita* from other parts of the world.

4. Pest Categorization–Identification of Quarantine Pests and Quarantine Pests Likely to Follow the Pathway

Common pests associated with *Cucurbita maxima* and *C. pepo* that occur in Zambia are listed in Table 3. This list includes information on the presence or absence of these pests in the United States, the affected plant part(s), the quarantine status of the pest with respect to the United States, an indication of the pest-host association, and pertinent references for pest distribution and biology.

Table 2. Pests intercepted from Zambia that have also been intercepted from other origins on *Cucurbita maxima* or *C. pepo*. Only pests identified to genus are included.

Pest	Interceptions
Aulacaspis tubercularis Newstead Insecta-Hemiptera-Diaspididae	32
Helicoverpa sp. Insecta-Lepidoptera-Noctuidae	23
Phoma sp. Fungi	13
Helicoverpa armigera Hubner Insecta-Lepidoptera-Noctuidae	4
Trogoderma granarium Everts Insecta-Coleoptera-Dermestidae	4
Pseudaonidia trilobitiformis (Green) Insecta-Hemiptera-Diaspididae	2
Opogona sp. Insecta-Lepidoptera-Tineidae	2
Thrips sp. Insecta-Thysanoptera-Thripidae	1

Table 3. Pests in Zambia Associated with *Cucurbita maxima* and *C. pepo*

Pest	Geographic Distribution	Plant part affected	Quarantine Pest	Follow Pathway	References
ARTHROPODS					
Acari					
Brevipalpus californicus Banks Tenuipalpidae	US, Zambia	Leaf	No	No	CABI, 2003; Mukuka *et al.*, 2002
Eutetranychus orientalis Klein Tetranychidae	Zambia	Leaf	Yes	No	CABI, 2003; PIN, 2003
Tetranychus urticae Kotch Tetranychidae	US, Zambia	Leaf	No	No	CABI, 2003; Meyer, 1996
Polyphagotarsonemus latus Banks Tarsonemidae	US, Zambia	Leaf	No	No	CABI, 2003; Meyer, 1996
INSECTA					
Coleoptera					
Aulacophora foveicollis Lucas Chrysomelidae	Zambia	Flower, fruit, leaf, root, stem	Yes	No[1]	CABI, 2003
Heteronychus arator (Fabricius) Scarabaeidae	Zambia	Stem, whole plant	Yes	No[1]	CABI, 2005; EPPO, 2005
Diptera					
Atherigona orientalis Schiner Muscidae	US, Zambia	Fruit, leaf, root, stem	No	Yes	CABI, 2003
Dacus bivittatus (Bigot) Tephritidae	Zambia[2]	Fruit	Yes	Yes	White and Elson-Harris,

Pest	**Geographic Distribution**	**Plant part affected**	**Quarantine Pest**	**Follow Pathway**	**References**
					1992
Dacus ciliatus Loew Tephritidae	Zambia	Fruit	Yes	Yes	CABI, 2003; White and Elson-Harris, 1992
Dacus frontalis Becker Tephritidae	Zambia[3]	Fruit	Yes	Yes	White and Elson-Harris, 1992
Dacus lounsburyii Coquillett Tephritidae	Zambia[4]	Fruit	Yes	Yes	White and Elson-Harris, 1992
Dacus punctatifrons Karsch Tephritidae	Zambia	Fruit	Yes	Yes	White and Elson-Harris, 1992
Dacus vertebratus Bezzi Tephritidae	Zambia	Fruit	Yes	Yes	White and Elson-Harris, 1992
Liriomyza trifolii Burgess in Comstock Agromyzidae	US, Zambia	Leaf	No	No	CABI, 2003
Hemiptera					
Acyrthosiphon pisum Harris Aphididae	US, Zambia	Leaf, stem	No	No	CABI, 2003; Millar, 1994
Aonidiella orientalis Newstead Diaspidae	US (FL), Zambia	Fruit, leaf	Yes	No[5]	CABI, 2003
Aphis fabae (Scopoli) Aphididae	US, Zambia	Flower, leaf, stem	No	No	CABI, 2003; Millar, 1994; Mukuka *et al.*, 2002
Aphis gossypii Glover Aphididae	US, Zambia	Flower, leaf, stem,	No	No	CABI, 2003; Millar, 1994; Mukuka *et al.*, 2002
Aulacaspis tubercularis Newstead Diaspidae	US, Zambia	Fruit, leaf, stem	Yes[6]	Yes	CABI, 2003; EPPO, 2003
Bemisia tabaci Gennadius Aleyrodidae	US, Zambia	Leaf	No	No	CABI, 2003; Mukuka *et al.*, 2002
Coccus hesperidum Linnaeus Coccidae	US, Zambia	Leaf, stem	No	No	CABI, 2003; Mukuka *et al.*, 2002

Pest	Geographic Distribution	Plant part affected	Quarantine Pest	Follow Pathway	References
Dysmicoccus brevipes Cockerell Pseudococcidae	US, Zambia	Fruit, leaf, stem	No	Yes	CABI, 2003
Ferrisia virgata Cock Pseudococcidae	US, Zambia	Fruit, leaf, stem	No	Yes	CABI, 2003
Macrosiphum euphorbiae Thomas Aphididae	US, Zambia	Flower, leaf, stem	No	No	CABI, 2003; Millar, 1994
Myzus persicae Sulzer Aphididae	US, Zambia	Flower, leaf, stem,	No	No	CABI, 2003; Millar, 1994
Parasaissetia nigra Nietner Coccidae	US, Zambia	Leaf, stem	No	No	CABI, 2003
Pseudaonidia trilobitiformis (Green) Diaspididae	Zambia	Flower, fruit, leaf, stem,	Yes	No[7]	Fabres, 1974; PIN, 2003
Rhopalosiphum rufiabdominale Sasaki Aphididae	US, Zambia	Leaf, root	No	No	CABI, 2003; Millar, 1994
Trialeurodes vaporariorum Westwood Aleyrodidae	US (FL, HI), Zambia	Leaf	Yes	No	CABI, 2003; Mukuka *et al.*, 2002
Lepidoptera					
Agrotis segetum Denis & Schiffermüller Noctuidae	Zambia	Leaf, root, stem	Yes	No	CABI, 2003; Mukuka *et al.*, 2002; PIN, 2003
Diaphania indica Saunders = *Margaronia indica* Pyralidae	US (FL), Zambia	Fruit, leaf	Yes	Yes	CABI, 2003; PIN, 2003; Talhouk, 2002
Helicoverpa armigera (Hubner) Noctuidae	Zambia	Fruit	Yes	Yes	NIN, 1998; PIN, 2003
Opogona sp. Tineidae	Zambia	Fruit	Yes	Yes	PIN, 2003
Spodoptera littoralis (Boisduval) Noctuidae	Zambia	Fruit, leaf	Yes	Yes	CABI, 2003

Pest	Geographic Distribution	Plant part affected	Quarantine Pest	Follow Pathway	References
Thysanoptera					
Thrips sp. Thripidae	US, Zambia	Flower, fruit, leaf, stem,	Yes	Yes	PIN, 2003
BACTERIA					
Pseudomonas syringae pv. *syringae* van Hall Pseudomonadales	US, Zambia	Fruit, leaf, stem,	No	No	CABI, 2003; Raemaekers *et al*., 1991; Whiteside, 1966
Rhizobium radiobacter (Beij. & v. Deld.) Pribram Rhizobiales	US, Zambia	Fruit, stem, root	No	Yes	CABI, 2003
FUNGI					
Alternaria cucumerina (Ell. & Ev.) Elliott	US, Zambia	Leaf	No	No	CABI, 2003; Raemaekers *et al*., 1991; Whiteside, 1966
Alternaria tenuissima (Kunze) Wiltshire	US, Zambia	Leaf	No	No	CABI, 2003; Farr *et al.*, 2003; Whiteside, 1966
Botrytis cinerea Pers.: Fr -Leotiales-Sclerotiniaceae	US, Zambia	Fruit, leaf, stem	No	Yes	CABI, 2003; Farr *et al.*, 2003; Whiteside, 1966
Cercospora apii Fres.	US, Zambia	Leaf	No	No	CABI, 2003; Farr *et al.*, 2003; Whiteside, 1966
Cladosporium cucumerinum Ellis & Arthur	US, Zambia	Fruit, leaf, stem	No	Yes	CABI, 2003; Whiteside, 1966; Zitter *et al*., 1996
Colletotrichum capsici (Syd.) E.J. Butler & Bisby	US, Zambia	Fruit, leaf, stem	No	Yes	CABI, 2003; Farr *et al.*, 2003; Whiteside, 1966

Pest	**Geographic Distribution**	**Plant part affected**	**Quarantine Pest**	**Follow Pathway**	**References**
Colletotrichum orbiculare (Berk. & Mont.) Arx	US, Zambia	Fruit, leaf, stem	No	Yes	CABI, 2003; Farr *et al.*, 2003; Whiteside, 1966; Zitter *et al.*, 1996
Corticium rolfsii Curzi (Syn= *Sclerotium rolfsii*) Stereales-Corticiaceae	US, Zambia	Fruit, leaf, root, seed, stem	No	Yes	CABI, 2003; Raemaekers *et al.*, 1991; Zitter *et al.*, 1996
Didymella bryoniae (Auersw.) Rehm (Syn = *Mycosphaerella melonis*) - Ascomycota-Dothideales	US, Zambia	Fruit, leaf, stem	No	Yes	CABI, 2003; Whiteside, 1966; Zitter *et al.*, 1996
Erysiphe cichoracearum DC. - Erysiphales-Erysiphaceae	US, Zambia	Fruit, leaf, stem	No	Yes	CABI, 2003; Farr *et al.*, 2003; Whiteside, 1966
Fusarium scirpi Lambotte & Fautrey (Syn = *Gibberella acuminate*) - Hypocreales-Hypocreaceae	US, Zambia	Fruit, leaf, stem	No	Yes	CABI, 2003; Whiteside, 1966; Zitter *et al.*, 1996
Gibberella zeae (Schwein.) Petch - Hypocreales-Hypocreaceae	US, Zambia	Leaf, root, stem	No	No	CABI, 2003
Leptosphaerulina trifolii (Rostrup) Petrak -Dothideales-Pleosporaceae	US, Zambia	Fruit, leaf, stem	No	Yes	CABI, 2003; Farr *et al.*, 2003; Whiteside, 1966
Leveillula taurica (Lév.) G. Arnaud - Erysiphales-Erysiphaceae	US, Zambia	Leaf, stem	No	No	CABI, 2003; Farr *et al.*, 2003; Whiteside, 1966

Pest	**Geographic Distribution**	**Plant part affected**	**Quarantine Pest**	**Follow Pathway**	**References**
Macrophomina phaseolina (Tassi) Goid -Coelomycetes	US, Zambia	Leaf, root, seed, stem	No	No	CABI, 2003; Farr *et al.*, 2003; Raemaekers *et al.*, 1991; Zitter *et al.*, 1996
Oidium sp.	Zambia	Leaf	Yes	No	Farr *et al.*, 2003
Phytophthora cactorum (Lebert & Cohn) Schröter	US, Zambia	Fruit, leaf, root, stem	No	Yes	CABI, 2003; Farr *et al.*, 2003; Whiteside, 1966
Phytophthora citrophthora (R.H. Sm. & E. Sm.) Leonian -Pythiales-Pythiaceae	US, Zambia	Fruit, leaf, root, stem	No	Yes	CABI, 2003; Farr *et al.*, 2003; Whiteside, 1966
Pseudoperonospora cubensis (Berk. & M.A. Curtis) Rostovtzev 1903 Oomycetes-Peronosporales-Peronosporaceae	US, Zambia	Leaf, whole plant	No	Yes	CABI, 2003
Pythium aphanidermatum (Edson) Fitzp. -Pythiales-Pythiaceae	US, Zambia	Fruit, leaf, root, stem	No	Yes	CABI, 2003; Farr *et al.*, 2003; Whiteside, 1966
Pythium ultimum Trow -Pythiales-Pythiaceae	US, Zambia	Fruit, leaf, root, stem	No	Yes	CABI, 2003; Farr *et al.*, 2003; Whiteside, 1966
Rhizopus stolonifer -Mucorales-Mucoraceae	US, Zambia	Fruit, leaf, root, stem	No	Yes	CABI, 2003; Farr *et al.*, 2003; Whiteside, 1966

Pest	**Geographic Distribution**	**Plant part affected**	**Quarantine Pest**	**Follow Pathway**	**References**
Septoria apiicola (Syn= *Septoria apii*)	US, Zambia	Fruit, leaf	No	Yes	CABI, 2003; Farr *et al.*, 2003; Whiteside, 1966
Septoria cucurbitacearum Sacc.	US, Zambia	Fruit, leaf,	No	Yes	CABI, 2003; Farr *et al.*, 2003; Whiteside, 1966; Zitter *et al.*, 1996
NEMATODA					
Meloidogyne hapla Chitwood Nematoda	US, Zambia	Root	No	No	CABI, 2003; Thies and Fery, 2002
Meloidogyne incognita (Kofoid & White) Chitwood Nematoda	US, Zambia	Root	No	No	CABI, 2003
VIRUSES					
Bean Yellow Mosaic Virus Potyviridae	US, Zambia	Leaf	No	No[8]	CABI, 2003
Cucumber Green Mottle Mosaic Virus	Zambia	Leaf	Yes	No	CABI, 2004; Whiteside, 1966
Cucumber Mosaic Virus Bromoviridae	US, Zambia	Leaf	No	No[8]	CABI, 2003; Whiteside, 1966
Turnip Mosaic Virus Bunyaviridae	US, Zambia	Leaf, seed, stem, whole plant	No	Yes	CABI, 2003

[1] Only adults of *Aulacophora foveicollis* and *Heteronychus arator* feed on the fruits (CABI, 2003). Both beetles feed externally (CABI, 2003) and are not expected to remain with the fruit through harvest and post-harvest processing. Additionally, neither beetle has been intercepted on fruit of any kind (PIN 309, 2003).

[2] There is no information in the scientific literature stating that *Dacus bivitattus* occurs in Zambia; however, it does occur in Angola, Malawi, Mozambique, Tanzania, and Zimbabwe (White and Elson-Harris, 1992), each country directly borders Zambia.

[3] There is no information in the scientific literature stating that *Dacus frontalis* occurs in Zambia; however, it does occur in Tanzania and Zimbabwe (White and Elson-Harris, 1992) and both countries directly border Zambia.

[4] There is no information in the scientific literature stating that *Dacus lounsburyii* occurs in Zambia; however, it does occur in Angola and Zimbabwe (White and Elson-Harris, 1992) and both countries directly border Zambia.

[5] *Cucurbita spp*. are often used to mass rear scale insects for parasitoid studies, but there is no evidence that *Cucurbita* is a natural or common host of *Aonidiella orientalis* (Rosen, 1990; search of CAB abstracts, 2003). This insect has not been intercepted on *Cucurbita* (PIN309, 2003).

[6] *Aulacaspis tubercularis* is listed as reportable (PIN, 2003) and has a limited distribution in the United States (EPPO, 2003).

[7] U.S. agricultural inspectors intercepted *Pseudaonidiella trilobitiformis* over 12,000 times between 1985 and 2003, but only two of those interceptions were found on the genus *Cucurbita*, both of these were from the Caribbean region (PIN, 2003). It is unlikely that this pest will enter the United States on *Cucurbita* from Zambia.

[8] Since squash and courgettes will be harvested at an immature stage, the few seeds present will not germinate, and pose little risk of seed transmission of the virus since they will be consumed (Brunt *et al.,* 2006).

Quarantine pests that are expected to follow the pathway, *i.e*. be included in shipments of baby squash and courgettes, were subjected to steps 5-7 (USDA, 2000) in the following sections of this risk assessment (Table 4). Other organisms included on the pest list (Table 3), but not chosen for further scrutiny, may be potentially detrimental to agriculture in the United States, but were not further analyzed for any of the following reasons:

1. They are well established and widespread in the United States.
2. They are associated mainly with plant parts other than the commodity.
3. They may be associated with the commodity, but it was not considered reasonable to expect these pests to remain with the commodity during processing.
4. They have been intercepted on rare occasions, as biological contaminants, by U.S. agricultural inspectors, but would not be expected to be found frequently with commercial shipments.

The pests identified only to genus or higher taxa were not considered for further analysis. Many genera are very broad and it is unrealistic to analyze an entire genus in which many species may not be pests. If pests identified only to higher taxa are intercepted in the future, the USDA may reevaluate their risk. Intercepted pests are sometimes not identified to the species level because the current taxonomic knowledge is limited, the pest is too immature, or the specimen is in poor condition. By necessity, pest risk assessments focus on the organisms for which biological information is available. The lack of identification at the species level does not rule out the possibility that a high-risk quarantine pest was intercepted or that the intercepted pest was not a quarantine pest. Conversely, detailed assessments for known pests that inhabit a variety of ecological niches, such as the surfaces or interiors of fruit, stems or roots, allow effective mitigation measures to eliminate the known organisms as well as similar, but incompletely identified organisms that inhabit the same niche.

Table 4. Quarantine Pests Selected for Further Analysis.

Aulacaspis tubercularis Newstead	Insecta-Hemiptera-Diaspidae
Dacus bivitattus (Bigot)	Insecta-Diptera-Tephritidae
Dacus ciliatus Loew	Insecta-Diptera-Tephritidae
Dacus frontalis Becker	Insecta-Diptera-Tephritidae
Dacus lounsburyii Coquillett	Insecta-Diptera-Tephritidae
Dacus punctatifrons Karsch	Insecta-Diptera-Tephritidae
Dacus vertebratus Bezzi	Insecta-Diptera-Tephritidae
Diaphania indica Saunders	Insecta-Lepidoptera-Pyralidae
Helicoverpa armigera (Hubner)	Insecta-Lepidoptera-Noctuidae
Spodoptera littoralis (Boisduval)	Insecta-Lepidoptera-Noctuidae

5. Consequences of Introduction—Economic/Environmental Importance

Potential Consequences of Introduction were rated using five risk elements:

1. Climate-Host Interaction
2. Host Range
3. Dispersal Potential
4. Economic Impact
5. 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., 2000). A Cumulative Risk Rating is then calculated by summing all risk element values. The values determined for the Consequences of Introduction for each pest are summarized in Table 5.

Risk Element #1- Climate-Host Interactions

If a species encounters a suitable climate and host in the area where it is introduced, the organism may survive and achieve pest status in the new environment. This risk element is evaluated on the minimum number of U.S. Plant Hardiness Zones in which the species might achieve pest status (USDA, 1990). Risk ratings were based on the following criteria:

Low (1): the species is only likely to become established in one hardiness zone
Medium (2): the species is likely to become established in two or three hardiness zones
High (3): the species is likely to become established in four or more hardiness zones

Risk Element #2- Host Range

The risk posed by a plant pest depends on both its ability to establish a viable, reproductive population and its potential to injure plants. For arthropods, risk was assumed to be positively correlated with host range. For pathogens, risk was assumed to depend on host range, aggressiveness, virulence and pathogenicity; for simplicity, risk was rated as a function of host range. The risk element for insects and pathogens is rated as follows:

Low (1): pest attacks a single species or multiple species within a single genus
Medium (2): pest attacks multiple species within a single plant family
High (3): pest attacks multiple species among multiple plant families

Risk Element #3-Dispersal Potential

A pest may disperse after arriving in a new area. The following items were considered: reproductive patterns of the pest (*e.g.*, voltinism, biotic potential); inherent powers of movement; factors facilitating dispersal, wind, water, presence of vectors, humans, *etc*.

Low (1): pest has neither high reproductive potential nor rapid dispersal capability

Medium (2): pest has either high reproductive potential OR the species is capable of rapid dispersal

High (3): Pest has high biotic potential, *e.g.*, many generations per year, many offspring per reproduction ("r-selected" species), AND evidence exists that the pest is capable of rapid dispersal, *e.g.*, over 10km/year under its own power; via natural forces, wind, water, vectors, *etc*., or human-assistance.

Risk Element #4-Economic Impact

Introduced pests can cause a variety of direct and indirect economic impacts. These were divided 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 foreign or domestic markets due to presence of a new quarantine pest.

Low (1): pest causes any one or none of the above impacts

Medium (2): pest causes any two of the above impacts

High (3): pest causes all three of the above impacts

Risk Element #5- Environmental Impact

A pest may cause significant, direct consequences to the environment, *e.g.*, cause an ecological disaster or reduce biodiversity. In the context of the National Environmental Policy Act (NEPA) (7CFR§372), significance is qualitative and encompasses the likelihood and severity of an environmental impact. The act describes an environmental pest as: "expected to have direct impacts on species listed by Federal Agencies as endangered or threatened (50CFR§17.11 and §17.12), by infesting/infecting a listed plant. If the pest attacks other species within the genus or other genera within the family, and preference/no preference tests have not been conducted with the listed plant and the pest, then the plant was assumed to be a host; pest is expected to have indirect impacts on species listed by Federal Agencies as endangered or threatened by disrupting sensitive, critical habitat; introduction of the pest would stimulate chemical or biological control programs."

Low (1): none of the above would occur

Medium (2): one of the above would occur

High (3): two or more of the above would occur.

Consequences of Introduction of *Aulacaspis tubercularis* Newstead Insecta-Hemiptera-Diaspididae	**Risk Value**
Risk Element #1: Climate-Host Interaction *Aulacaspis tubercularis* is widespread in the mango-growing areas of the world and mango is its primary host (CABI, 2003). It is present throughout Africa, in South and Southeast Asia, the Caribbean, and in northern South America, with disjunct populations in Europe (Italy) and the south Pacific (CABI, 2003). The regions occupied by *A. tubercularis* correspond to USDA Plant Hardiness Zone 10 (CABI, 2003), so the Climate-Host Interaction rating is Low (1).	Low (1)
Risk Element #2: Host Range The mango scale attacks hosts in at least seven plant families (Hamon, 2002). The preferred host is *Mangifera indica* (Anacardiaceae) (CABI, 2003). Other hosts include *Cocos nucifera* (Arecaceae), *Citrus* spp. (Rutaceae), *Persea americana* (Lauraceae), *Zingiber officinale* (Zingiberaceae), and *Cucurbita* spp. (Cucurbitaceae) (CABI, 2003).	High (3)
Risk Element #3: Dispersal Potential Fecundity ranges as high as 80-200 eggs per female on mango; there may be several generations per year (CABI, 2003). First-instar crawlers may be dispersed locally on wind currents (CABI, 2003); longer-distance spread would be accomplished on infested plant materials. It appears the pest spread into the south Pacific on plant materials (CABI, 2003).	High (3)
Risk Element #4: Economic Impact Cucurbit species have been used to rear laboratory colonies of *Aulacaspis tubercularis* (Villers and De Villers, 1990), but the scale insect does not appear to be a pest of commercially grown cucurbits (CABI, 2003). The insect is primarily a pest of mangoes which, in the continental United States, are grown commercially only in Florida and not for export. This species causes leaf death, which may affect the yield and vitality of younger trees, and the presence of scale feeding marks may lower the value of mangoes (CABI, 2005) so the pest is rated Medium.	Medium (2)
Risk Element #5: Environmental Impact This pest has the potential to attack endangered or threatened plants in the United States (*e.g.*, *Cucurbita okeechobeensis* ssp. *okeechobeensis*, a Florida cucurbit listed as Endangered in 50 CFR §17.12).	Medium (2)

Consequences of Introduction of *Dacus ciliatus* Loew Insecta-Diptera-Tephritidae (Due to very limited information available on *Dacus bivitattus, D. frontalis, D. lounsburyii, D. punctatifrons,* and *D. vertebratus, D. ciliatus* is used as a representative species of this genus.)	**Risk Value**
Risk Element #1: Climate-Host Interaction This insect occurs in most parts of sub-Saharan Africa, Egypt, the Arabian peninsula, the Middle East and India (CABI, 2003; White and Elson-Harris, 1992). These regions correspond to USDA Plant Hardiness Zones 10.	Low (1)
Risk Element #2: Host Range All of the primary hosts of *Dacus ciliatus* are species of Cucurbitaceae. There are scattered reports of hosts from other plant families; however, these are questionable (CABI, 2003; White and Elson-Harris, 1992).	Medium (2)
Risk Element #3: Dispersal Potential This insect can have up to ten generations per year in Saudi Arabia (Talhouk, 1983). Dispersal is generally through adult flight or fruit movement, or potentially movement of soil could contain puparia (CABI, 2003).	High (3)
Risk Element #4: Economic Impact If uncontrolled, this fruit fly can cause considerable yield loss and lower market value (CABI, 2003).	Medium (2)
Risk Element #5: Environmental Impact *Dacus ciliatus* attack fruit the genus *Cucurbita*, which contains the endangered plant species *Cucurbita okeechobeensis* ssp. *Okeechobeensis* (USFWS, 2002).	Medium (2)

Consequences of Introduction of *Diaphania indica* (Saunders) Insecta-Lepidoptera-Pyralidae	**Risk Value**
Risk Element #1: Climate-Host Interaction The species occurs in Australia, India, South Asia, Japan, Venezuela, Paraguay (Whittle and Ferguson., 1987), and the Middle East (Talhouk, 2002). The regions inhabited by *D. indica* include the USDA Plant Hardiness Zone 10 (USDA, 2003, 1987)	Low (1)
Risk Element #2: Host Range *Diaphania indica* attacks multiple hosts in the genera: Malvaceae, Cucurbitaceae, Oleaceae, Solanaceae, Chenopodiaceae (Whittle and Ferguson., 1987).	High (3)
Risk Element #3: Dispersal Potential In India, the female has been known to lay 22-366 eggs (average of 159), singly or in groups on the underside of leaves. A report from China recorded females laying up to 1,053 eggs on *Cucurbita* (Ke *et al.*, 1986). In tropical regions, this insect breeds throughout the year, but in Japan only three broods are annually produced (Whittle and Ferguson., 1987).	Medium (2)
Risk Element #4: Economic Impact The caterpillar attacks newly set fruits, bores into their ovaries and destroys them. This insect destroys up to 15% of the yearly watermelon crop in Saudi Arabia (Talhouk, 1983). This pest appears to cause economic damage by decreasing yield and increasing the cost of production.	Medium (2)
Risk Element #5: Environmental Impact *Diaphania indica* attacks the genus *Cucurbita*, which contains the endangered plant species *Cucurbita okeechobeensis ssp. okeechobeensis* (USFWS, 2002).	Medium (2)

Consequences of Introduction of *Helicoverpa armigera* (Hubner) Insecta-Lepidoptera-Noctuidae	**Risk Value**
Risk Element #1: Climate-Host Interaction This insect is widely distributed and known to occur in all parts of Europe, Middle East, Central and South Asia, Far East, Africa, Australia, and Oceania (CABI, 2003). Establishment is possible in U.S. Plant Hardiness Zones 5-10.	High (3)
Risk Element #2: Host Range *Helicoverpa armigera* is polyphagous. It is a major pest of cotton (*Gossypium* spp.), pigeon pea (*Cajanus cajan*.), chickpea (*Cicer arietinum*.), tomato (*Lycopersicum esculentum*), sorghum (*Sorghum spp.*) and cowpea (*Vigna unguiculata*). Other hosts include groundnut (*Arachis hypogaea*), okra (*Abelmoschus esculentus*), peas (*Pisum* sativum), soybeans (*Glycine max)*, other legumes, tobacco (*Nicotiana tabacum)*, potatoes (*Solanum tuberosum*), maize (*Zea mays*), flax (*Linum usitatissimum*), a number of fruits (*Prunus* spp. and *Citrus* spp.), forest trees and a range of vegetable crops (CABI, 2003).	High (3)
Risk Element #3: Dispersal Potential Females in south Africa lay an average of 730 eggs, with a maximum of 1,600 over an oviposition period that varies from 10-23 days (Matthews and Tunstall, 1994); they may produce two to six generations depending on the climatic conditions (Smith *et al.*, 1997). Larvae have limited mobility, but adults are capable of flight (CABI, 2003; Smith *et al.*, 1997).	High (3)
Risk Element #4: Economic Impact *Helicoverpa armigera* is a pest of major importance in areas where it is present; it can damage a wide variety of food, fiber, oilseed, fodder and horticultural crops (CABI, 2003). This pest appears to be particularly well adapted to exploit agricultural ecosystems (CABI, 2003). It is mobile and polyphagus, has a rapid and high reproductive rate, and undergo diapause to evade adverse conditions (CABI, 2003). Establishment of this pest in the United States could result in the loss of markets.	High (3)
Risk Element #5: Environmental Impact A wide range of wild plant species support larval development of *H. armigera*. Among others, larvae can feed on the genera *Allium*, *Amaranthus*, *Helianthus*, *Helianthus*, *Prunus*, *Solanum*, and *Vigna* (CABI, 2003)), which contain threatened or endangered species (Table 5) (USFWS, 2002). *Pinus* spp., a major host for *H. armigera*, is a major component of several ecosystems in the United States, and as such may be impacted by the establishment of *H. armigera*.	High (3)

Table 5. Threatened or endangered plant species in genera containing hosts of *Helicoverpa* zea.

Latin name	**Common Name**	**Historic Range**	**Listing status**
Allium munzii	Munz's onion	U.S.A. (CA)	Endangered
Amaranthus brownii	No common name	U.S.A. (HI)	Endangered
Amaranthus pumilus	Seabeach amaranth	U.S.A. (DE, MA, MD, NC, NJ, NY, RI, SC, VA)	Threatened
Helianthus eggertii	Eggert's sunflower	U.S.A. (AL, KY, TN)	Threatened
Helianthus paradoxus	Pecos (=puzzle, =paradox) sunflower	U.S.A. (NM, TX)	Threatened
Helianthus schweinitzii	Schweinitz's sunflower	U.S.A. (NC, SC)	Endangered
Prunus geniculata	Scrub plum	U.S.A. (FL)	Endangered
Solanum drymophilum	Erubia	U.S.A. (PR)	Endangered
Solanum incompletum	Popolo ku mai	U.S.A. (HI)	Endangered
Solanum sandwicense	`Aiakeakua, popolo	U.S.A. (HI)	Endangered
Vigna o-wahuensis	No common name	U.S.A. (HI)	Endangered

Consequences of Introduction of *Spodoptera littoralis* (Boisduval) Insecta-Lepidoptera-Noctuidae	
Risk Element #1: Climate-Host Interaction This insect is found in Africa, southern Europe, and the Middle East (CABI, 2003). It could become established in U.S. Plant Hardiness Zones 8-10.	Medium (2)
Risk Element #2: Host Range The host range of *S. littoralis* covers over 40 families, containing at least 87 species of plants of economic importance (CABI, 2003). For example: cotton (*Gossypium spp*.), tobacco (*Nicotiana tabacum*), potato (Solanum tuberosum), tomato (*Lycopersicum esculentum*), onion (*Allium cepa*), citrus (*Citrus* spp.), beans (*Phaseolus* spp.), carrots *(Daucus carota*), peppers (*Capsicum annuum*), grapes (*Vitis* spp.), alfalfa (*Medicago sativa*) and various grasses (CABI, 2003).	High (3)
Risk Element #3: Dispersal Potential Noctuids can disperse over long distances (Farrow and Daly, 1987). Adult *S. litttoralis* fly at night, with a flight range of 1.5 km in a 4-hour period (CABI, 2003). In optimal climates, the pest can have up to 7 overlapping generations per year, with an average of 20-1000 eggs produced by each female (CABI, 2003).	High (3)
Risk Element #4: Economic Impact *Spodoptera littoralis* is one of the most destructive agricultural lepidopterous pests within this subtropical and tropical range (CABI, 2003). It can attack numerous economically important crops throughout the year. It lowers crop yield, increases production costs, and will cause market loss as a new quarantine pest.	High (3)
Risk Element #5: Environmental Impact Threatened and endangered and species of *Allium*, *Solanum*, *Vigna*, *Amaranthus*, *Prunus*, *Hibiscus*, *Trifolium* and *Quercus* may be at risk since these genera are known to be hosts for *S. littoralis*. In the event of establishement by *S. littoralis*, several ecosystems may be impacted since its host range includes *Opuntia* spp. (prickly pear and cholla cacti), *Populus alba* (Silver-leaf poplar) and a European species of *Quercus* (oak).	High (3)

Table 6. Risk Rating for Consequences of Introduction (*Cucurbita maxima* and *C. pepo* from Zambia).

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
Aulacaspis tubercularis Newstead Insecta-Hemiptera-Diaspidae	1	3	3	2	2	Medium (11)
Dacus ciliatus Loew [including: *D. bivitattus* (Bigot), *D. frontalis* Becker, *D. lounsburyii* Coquillett, *D. punctatifrons* Karsch, *D. vertebratus* Bezzi] Insecta-Diptera-Tephritidae	1	2	3	2	2	Medium (10)
Diaphania indica Saunders Insecta-Lepidoptera-Pyralidae	1	3	2	2	2	Medium (10)
Helicoverpa armigera (Hubner) Insecta-Lepidoptera-Noctuidae	3	3	3	3	3	High (15)
Spodoptera littoralis (Boisduval) Insecta-Lepidoptera-Noctuidae	2	3	3	3	3	High (14)

6. 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. Five criteria are used to evaluate the Likelihood of Introduction (USDA, 2000) (Table 7). The rating for the quantity imported annually usually was based on the export estimate of the exporting country, and was converted into standard units of 40-foot-long shipping containers.

Quantity imported annually

The Zambian government expects that around 400 tons of fresh cucurbits would be imported into the United States annually. Assuming a capacity of roughly 27.5 tons per sea container, this volume translates into 14.5 containers, which represents a Medium (2) volume of importation.

Survive post harvest treatment

The Zambian government wants to export fresh cucurbits as part of shrink wrapped, ready-to-eat, individual meals. The quality standards are very high for this market.

The produce will be limited to winter squash and the courgette varieties of Raven and Commander. These fruit will not be fully mature at the time of harvest. Typically summer squashes are picked when still very young, from 2 to 7 days after flowering (see Fortin 1996, p.96). Hence, we expect that all fruit that does not fall within the dimensions 20 – 25 mm diameter and 90 – 100 mm length will be discarded. The produce will be graded and must meet the following specifications in order to be shipped: mid to dark green in color, firm, crisp and turgid, straight and cylindrical, fresh looking. Fruit exhibiting the following quality defects will be culled: mechanical damage, bruising and scarring, disease and pests on fruit , pest and disease damaged fruit (fruit fly), dehydration, immature fruit, over- sized fruit, seeded fruit, decay and tissue break down, deformities, splitting, heavy soiling, all skin blemishes (Duncan, 2003; Makwabara, 2003).

When harvesting, all flower tips should be removed from the fruit in order to prevent rotting and facilitate easy deflowering during processing. Pickers are to handle fruit carefully in order to prevent mechanical damage. Pickers are to watch out for foreign bodies and extraneous vegetable matter in trays. Trays of produce are to be brought to the packing facility following harvesting to prevent temperatures from rising (Duncan, 2003; Makwabara, 2003).

The fruit is transported in closed trucks. If an open truck is to be used in transporting the fruit to the packing house, cloth should cover crates to prevent dehydration and dust from entering the vicinity (Duncan, 2003; Makwabara, 2003).

Upon arriving at the shed, the fruit will be blast cooled for 30 minutes, or long enough to bring the temperature down to 8°C. They will then be put into cold storage following cooling. The storage temperature will be 8 – 10^{o}C. There is a maximum three day storage time prior to processing the fruit (Duncan, 2003; Makwabara, 2003).

A concerted effort by harvest and processing personnel to cull contaminated fruit will remove many potential insect pests from the pathway. The degree to which personnel are successful depends on how obvious insect damage is. It should be noted that even thought fruit is blast cooled at 8°C, this method will probably not harm insects feeding on the fruit (Duncan, 2003; Makwabara, 2003).

Aulacaspis tubercularis Newstead Insecta-Hemiptera-Diaspidae

*Aulacaspis tuberculari*s secretes a protective wax and would probably survive blast cooling. This insect is an external feeder and is likely to be detected during culling due to the white scale and blemishes associated with feeding (CABI, 2003). Low (1)

Dacus ciliatus Loew [including: *D. bivitattus* (Bigot), *D. frontalis* Becker, *D. lounsburyii* Coquillett, *D. punctatifrons* Karsch, and *D. vertebratus* Bezzi) Insecta-Diptera-Tephritidae

Dacus ciliatus is an internal feeder (CABI, 2003) and will probably survive culling and blast cooling. Fruit flies are difficult to detect in fruit (Gould, 1995). Rating: High (3)

Diaphania indica Saunders Insecta-Lepidoptera-Pyralidae

Diaphania indica is an internal feeder and would probably survive post-harvest treatment (Whittle and Ferguson., 1987). Thorough inspections would be necessary to detect *D. indica* larvae. Rating: Medium (2)

Helicoverpa armigera (Hubner) Insecta-Lepidoptera-Noctuidae

Helicoverpa armigera larvae feed internally on vegetable hosts, but leave entry holes (CABI, 2003) that could be detected by careful inspection. Rating: Medium (2)

Spodoptera littoralis (Boisduval) Insecta-Lepidoptera-Noctuidae

Spodoptera littoralis larvae feed internally and cause fruit to drop prematurely (CABI, 2003). The tendency for infected fruit to drop early lessens the probability that *S. littoralis* larvae would be present in harvested fruit. Infected fruit that do not drop may be difficult to detect however, so the rating is Medium (2)**.**

Survive shipment

All genera of the pests analyzed have been intercepted from various countries as they entered the United States, proving that they can survive shipment. Between 1985 and 2003, interceptions were as follows: *Aulacaspis* sp. 47,018 ; *Dacus* sp. 2,769; *Diaphania* sp. 4,408; *Helicoverpa* sp. 4,678; *Spodoptera* sp. 1,978. Estimates for surviving shipment for each species are: *Aulacaspis tubercularis* Newstead: High (3); *Dacus* spp.: High (3); *Diaphania indica* Saunders: High (3); *Helicoverpa armigera* (Hubner): High (3) and *Spodoptera littoralis* (Boisduval): High (3).

Not detected at port-of-entry

Aulacaspis tubercularis Newstead Insecta-Hemiptera-Diaspidae

Hemipterous insects feed on the fruit's surface; *A. tubercularis* is visible as a white scale on a dark background. Rating: Low (1)

Dacus ciliatus Loew [including: *D. bivitattus* (Bigot), *D. frontalis* Becker, *D. lounsburyii* Coquillett, *D. punctatifrons* Karsch, and *D. vertebratus* Bezzi) Insecta-Diptera-Tephritidae

Inspectors cutting mango failed to detect larvae of *Anastrepha supensa*, a fruit fly in the same family as *Bactrocera spp*., 71.6% of the time (Gould, 1995). These findings underscore the high likelihood that fruit flies will go undetected. Rating: High (3)

Diaphania indica Saunders Insecta-Lepidoptera-Pyralidae

This insect creates tunnels in the fruit, usually originating at the stem end, but sometimes creates irregularly shaped holes all over the fruit (Whittle and Ferguson., 1987). An inspection that examined the stem end of the fruit for larval feeding and cut fruit to expose larval tunnels in the pulp would be likely to discover *D. indica* (Whittle and Ferguson., 1987). A thorough inspection of all fruit is unlikely because of the quantity received upon entry. Rating: Medium (2)

Helicoverpa armigera (Hubner) Insecta-Lepidoptera-Noctuidae

Helicoverpa armigera larvae feed internally on vegetable hosts, but leave entry holes (CABI, 2003) that could be detected by careful inspection. Rating: Medium (2)

Spodoptera littoralis (Boisduval) Insecta-Lepidoptera-Noctuidae

Spodoptera littoralis larvae feed internally on fruit (CABI, 2003), but entry holes and fruit rot may aid in detection. Rating: Medium (2).

Moved to suitable habitat

Aulacaspis tubercularis Newstead Insecta-Hemiptera-Diaspidae

Aulacaspis tubercularis is widespread in the mango-growing areas of the world. It is present throughout Africa, in South and Southeast Asia, the Caribbean, and in northern South America, with disjunct populations in Europe (Italy) and the south Pacific (CABI, 2003). From this warm temperate to tropical distribution, it is estimated that this species would be able to survive in the warmer regions of the U.S. corresponding to Plant Hardiness Zones 8-10. *Aulacaspis tubercularis* has been shown to move long distances via infected fruits (CABI, 2003). Rating: High (3)

Dacus ciliatus Loew [including: *D. bivitattus* (Bigot), *D. frontalis* Becker, *D. lounsburyii* Coquillett, *D. punctatifrons* Karsch, and *D. vertebratus* Bezzi) Insecta-Diptera-Tephritidae

This insect occurs in most parts of sub-Saharan Africa, Egypt, the Arabian Peninsula, the Middle East and India (CABI, 2003), corresponding to USDA Plant Hardiness Zones 10 and above. Dispersal is generally through adult flight or fruit movement (CABI, 2003). Rating: Medium (2)

Diaphania indica Saunders Insecta-Lepidoptera-Pyralidae

The species occurs in Australia, India, South Asia, Japan, Venezuela, Paraguay (Whittle and Ferguson., 1987), and the Middle East (Talhouk, 2002). The regions inhabited by *D. indica* include the USDA Plant Hardiness Zones 8-10 (USDA, 2003; Whittle and Ferguson., 1987). Other species of *Diaphania* are strong fliers (CABI, 2003). Rating: High (3)

Helicoverpa armigera (Hubner) Insecta-Lepidoptera-Noctuidae

This insect is widely distributed and occurs in all parts of Europe, the Middle East, Central and South Asia, the Far East, Africa, Australia, and Oceania (CABI, 2003). Establishment is possible in U.S. Plant Hardiness Zones 5-10. The adult moth is capable of migrating up to 155 miles (250 km) (Shanower *et al.*, 1999). Rating: High (3)

Spodoptera littoralis (Boisduval) Insecta-Lepidoptera-Noctuidae

The insect is recorded from Africa, southern Europe, and the Middle East. Based on its northern distribution in Europe, *S. littoralis* could become established in U.S. Plant Hardiness Zones 8-10. The exact distance that *S. littoralis* is capable of migrating is unclear from the literature; however, the insect is widespread and will survive on a wide variety of hosts indicating that it is capable of extensive movement (CABI, 2003; Salama *et al.*, 1971). Rating: High (3)

Contact with host material

The vegetables imported for human consumption are unlikely to come into direct (or near) contact with susceptible hosts. To contact a new host, the insects (other than *Aulacaspis tubercularis*) would have to complete larval development, pupate, find a mate, and then move to a new host to oviposit or begin feeding. For *A. tubercularis*, either eggs or crawlers would have to be present, because the adult female is sedentary. The commodity will be kept refrigerated until it reaches the end-user. It is not expected that any pest insects associated with the commodity will become liberated until food is discarded. Uneaten food could be disposed of as garbage or in compost outside of the home, in which case the insects could potentially find a host.

Aulacaspis tubercularis Newstead Insecta-Hemiptera-Diaspidae. Scale crawlers emerging in garbage or compost piles are unlikely to find host plants. Crawlers often balloon long distances to new hosts (Greathead, 1989), but this reproductive strategy works only for large numbers of crawlers. The number of crawlers leaving a few small vegetables would not give a high probability that any crawler would land on a host. Rating: Low (1)

Dacus ciliatus Loew [including: *D. bivitattus* (Bigot), *D. frontalis* Becker, *D. lounsburyii* Coquillett, *D. punctatifrons* Karsch, and *D. vertebratus* Bezzi) Insecta-Diptera-Tephritidae. *Dacus ciliatus* has three larval instars, which take 4.40±0.55, 6.80±0.89 and 3.75±0.95 days to develop, respectively (Patel and Patel, 1998). Pupation lasts from 9-14 days. If multiple larvae develop in a single food package, it is conceivable that flies could complete development in garbage or compost, mate and fly to a new host. Rating: Medium (2)

The lepidopterous insects *Spodoptera littoralis, Helicoverpa armigera*, and *Diaphania indica* have similar life histories. It is unknown whether they can complete their development on rotting fruit alone. All three species are mobile as larvae and would likely leave the host plant to find a new host, especially as fifth and sixth instar larvae (CABI, 2003). Hosts of *H. armigera* and *S. litura* include temperate-zone or widely cultivated plants, which should be available throughout the potential geographic range of these pests in the United States. If host plants were located near compost piles, larvae could reach the new host. *Spodoptera littoralis* and *H. armigera* pupate in the soil, but *D. indica* pupates in rolled leaves of its host plant. For these reasons, *D. indica* is rated Low (1) and *H. armigera* and *S. littoralis* are rated High (3).

Table 6. Risk Rating for Likelihood of Introduction.

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**
Aulacaspis tubercularis Newstead Insecta-Hemiptera-Diaspidae	2	1	3	1	3	1	Medium (11)

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
Dacus ciliatus Loew [including: *D. bivitattus* (Bigot), *D. frontalis* Becker, *D. lounsburyii* Coquillett, *D. punctatifrons* Karsch, and *D. vertebratus* Bezzi) Insecta-Diptera-Tephritidae	2	3	3	3	2	2	High (15)
Diaphania indica Saunders Insecta-Lepidoptera-Pyralidae	2	2	3	2	3	1	Medium (13)
Helicoverpa armigera (Hubner) Insecta-Lepidoptera-Noctuidae	2	2	3	2	3	3	High (15)
Spodoptera littoralis (Boisduval) Insecta-Lepidoptera-Noctuidae	2	2	3	2	3	3	High (15)

7. Conclusion—Pest Risk Potential and Pests Requiring Phytosanitary Measures

Pest Risk Potential. The summation of the values for the Consequences of Introduction and the Likelihood of Introduction yields Pest Risk Potential values (Table 8). This is an estimate of the risks associated with this importation.

Table 8. Pest Risk Potential.

Pest	**Consequences of Introduction**	**Likelihood of Introduction**	**Pest Risk Potential**
Aulacaspis tubercularis Newstead Insecta-Hemiptera-Diaspidae	11	11	Medium (22)
Dacus ciliatus Loew [including: *D. bivitattus* (Bigot), *D. frontalis* Becker, *D. lounsburyii* Coquillett, *D. punctatifrons* Karsch, and *D. vertebratus* Bezzi) Insecta-Diptera-Tephritidae	10	15	Medium (25)
Diaphania indica Saunders Insecta-Lepidoptera-Pyralidae	10	13	Medium (23)
Helicoverpa armigera (Hubner) Insecta-Lepidoptera-Noctuidae	15	15	High (30)
Spodoptera littoralis (Boisduval) Insecta-Lepidoptera-Noctuidae	14	15	High (29)

Pests with a Pest Risk Potential value of Low do not require mitigation measures, while 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. The choice of appropriate phytosanitary measures to mitigate risks is undertaken as part of Risk Management, and was not addressed, *per se*, in this document.

All of these pests pose phytosanitary risks to American agriculture. *Helicoverpa armigera* and *Spodoptera littoralis* were given pest risk ratings of high, while the others were estimated to be of medium risk. Port-of-entry inspections, as a sole mitigative measure, are considered insufficient to safeguard U.S. agriculture from these pests, and additional phytosanitary measures appear necessary to reduce risks to acceptable levels.

Risk Mitigation. There are several options available for mitigating the pests of concern from baby squash and baby courgettes from Zambia. A systems approach may consist of a combination of measures including monitoring and management programs to achieve and maintain greenhouse sanitation, low pest prevalence, packinghouse inspection and treatments, quarantine treatments, and maintenance of consignment security and traceability in transit, is most feasible. Options for risk mitigation are summarized in Appendix 1.

This document does not purport to establish specific work plans or to evaluate the quality of a specific program or systems approach. It identifies risks and provides information regarding known mitigation measures. The specification and implementation of measures, as would be present in an operational work plan, is beyond the scope of this document.

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D. Literature Cited

Brunt, A.A., Crabtree, K., Dallwitz, M.J., Gibbs, A.J., Watson, L. and Zurcher, E.J. (eds.) (1996 onwards). `Plant Viruses Online: Descriptions and Lists from the VIDE Database. Version: 20th August 1996.' URL http://biology.anu.edu.au/Groups/MES/vide/ <*last accessed* 2 August 2006>

CABI. 2003. Crop Protection Compendium. CAB International, Wallingford, UK.

CABI. 2004. Crop Protection Compendium. CAB International, Wallingford, UK.

CABI. 2005. Crop Protection Compendium. CAB International, Wallingford, UK.

Duncan, R. A. 2003. Zambia TDY Trip Report May-July 2003 (internal document). United States Department of Agriculture-Animal and Plant Health Inspection Service, Plant Protection and Quarantine, Center for Plant Health Science and Technology, Raleigh, North Carolina.

EPPO. 2003. Plant quarantine database (version 2.2). European and Mediterranean Plant Protection Organization. <http://www.eppo.org/> *last accessed* 15 December 2003.

Fabres, G. 1974. A new species of the genus *Habrolepis* (Hym. Chalcidoidae Encyrtidae), a parasite of *Pseudaonidia trilobitiformis* (Homoptera Diaspididae) in New Caledonia. Entomophaga, 19(1): 55-60: 55-60.

Farr, D. F., Rossman, A. Y., Palm, M. E., and McCray, E. B. 2003. Fungal Databases. Systematic Botany & Mycology Laboratory, ARS, USDA. <http://nt.ars-grin.gov/fungaldatabases/> *last accessed* December 2003.

Farrow, R. A., and Daly, J. C. 1987. Long-range movements as an adaptive strategy in the genus *Heliothis* (Lepidoptera: Noctuidae): a review of its occurrence and detection in four pest species. Australian Journal of Zoology, 35: 1-24.

Fortin, F. 1996. Encyclopédie visuelle des aliments -- The Visual Food Encyclopedia (English)

See page 72 which states "summer squashes are picked when still very young, from 2 to 7 days after flowering..... the zucchini, *(C. pepo*) is probably the best-known member of the summer squash family."

Gould, W. P. 1995. Probability of detecting Carribbean fruit fly (Diptera: Tephritidae) infestations by fruit dissection. Florida Entomologist, 78: 502-507.

Greathead, D. J. 1989. Crawler behaviour and dispersal, pp. 305-308. *In* D. Rosen [ed.], Armored scale insects. Their biology, natural enemies and control. Elsevier Scientific Publishers., Amsterdam.

Gunn, C. R., and Ritchie, C. 1982. Report of the Technical Committee to Evaluate Noxious Weeds; Exotic Weeds for Federal Noxious Weed Act (unpublished).

Holm, L. G. 1997. World weeds: natural histories and distribution. John Wiley & Sons, N.Y. pp.1129.

Holm, L. G., Pancho, J. V., Herberger, J. P., and Plucknett, D. L. 1979. Geographical atlas of world weeds. John Wiley and Sons, N.Y. pp.391.

Hopper, B. E. 1995. Compendium of Phytosanitary Terms. North American Plant Protection Organization, Nepean, Ontario, Canada.

IPPC. 1996. Guidelines for pest risk analysis. International Standards for Phytosanitary Measures Publication No. 2. Rome: Secretariat of the International Plant Protection Convention, United Nations Food and Agriculture Organization.

IPPC. 2005. Glossary of phytosanitary terms. International Standards for Phytosanitary Measures Publication No. 5. Rome: Secretariat of the International Plant Protection Convention, United Nations Food and Agriculture Organization.

Ke, L. D., Li, Z. Q., Xu, L. X., and Zheng, Q. F. 1986. A brief report of a study on *Diaphania indica*. Zhejiang Agricultural Science, 3: 139-142.

Makwabara, S. 2003. Raw material specification. Agriflora (Z) Limited.

Matthews, G. A., and Tunstall, J. P. 1994. Insect Pests of Cotton. CAB International, Wallingford, UK.

Meyer, M. K. P. 1996. Mite pests and their predators on cultivated plants in southern Africa, vegetables and berries. Agricultural Research Council of South Africa, Pretoria, South Africa. pp.90.

Millar, I. M. 1994. A Catalogue of the Aphids (Homoptera: Aphidoidea) of sub-Saharan Africa: Plant Protection Research Institute Handbook No. 4. Agricultural Research Council of South Africa, Pretoria, South Africa. pp.130.

Mukuka, J., Sumani, A. J., and Chalabesa, A. 2002. Agricultural Field Insects of Zambia and Their Management. Republic of Zambia, Ministry of Agriculture and Co-Operatives, Lusaka, Zambia. pp.59.

NASS. 2003. Census of Agriculture. National Agricultural Statistics Service, United States Department of Agriculture. <http://www.nass.usda.gov/census/> *last accessed* December 2003.

NIN. 1998. Nomina Insecta Nearctica. Nearctica.com. <http://www.nearctica.com/nomina/nomina.htm> *last accessed* 15 December 2003.

Patel, R. K., and Patel, C. B. 1998. Biology of fruit fly, Dacus ciliatus Loew (Tephritidae: Diptera) infesting little gourd, Coccinia indica W. & A. Gujarat Agricultural University Research Journal, 23: 54-60.

PIN. 2003. Pest Interception Network. United States Department of Agriculture - Animal and Plant Health Inspection Service.

Raemaekers, R. H., Nawa, I. N., Chipili, J., and Sakala, A. 1991. Revised Checklist of Plant Diseases in Zambia. General Administration for Development Cooperation, Brussels, Belgium. pp.119.

Reed, C. F. 1977. Economically important foreign weeds, potential problems in the United States, pp. 746, Agriculture Handbook No. 498. Agricultural Research Service, Animal and Plant Health Inspection, U.S. Dept. of Agriculture, Washington, D.C.

Salama, H. S., Dimetry, N. A., and Salem, S. A. 1971. On the host preference and biology of the cotton leaf worm *Spodoptera littoralis* Bois. Zeitscrift Angewandte Entomolgie, 67: 261-266.

Shanower, T. G., Romeis, J., and Minja, E. M. 1999. Insect pests of pigeionpea and their management. Ann. Rev. Entomol., 44: 77-96.

Smith, I. M., McNamara, D. G., Scott, P. R., and Holderness, M. 1997. Quarantine pests for Europe. CAB International., Wallingford, UK. pp.1425.

Talhouk, A. M. 2002. Insects and mites injurious to crops in Middle Eastern countries, 2nd ed. American University of Beirut Press, Beirut, Lebanon. pp.269.

Talhouk, A. S. 1983. Important insect pests of Cucurbitaceae in Saudi Arabia. Anzeiger fur Schadlingskunde Pflanzenschutz Umweltschutz, 56: 6-9.

Thies, J. A., and Fery, R. L. 2002. Evaluation of a core of the U.S. *Capsicum* germplasm collection for reaction to the northern root-knot nematode. HortScience, 37: 805-810.

USDA. 1990. United States National Arboretum, web version of USDA Plant Hardiness Zone Map. United States Department of Agriculture-Agricultural Research Service (ARS). Miscellaneous Publication No. 1475. USDA-ARS, Washington, D.C. <http://www.usna.usda.gov/Hardzone/ushzmap.html? > *last accessed* 16 Nov 2007.

USDA. 2000. Guidelines for Pathway-Initiated Pest Risk Assessments, Version 5.02. United States Department of Agriculture, Animal and Plant Health Inspection Service.

USDA. 2003. Plant Hardiness Zones in China. United States Department of Agriculture. <http://www.ars-grin.gov/> *last accessed* October 2003.

USFWS. 2002. Threatened and endangered species system (TESS). U. S. Fish and Wildlife Service. <http://endangered.fws.gov/> *last accessed* 20 November 2003.

Villers, E. A. d., and De Villers, E. A. 1990. Mass rearing of the mango scale, Aulacaspis tubercularis Newstead (Hemiptera: Diaspididae). Inlightingsbulletin Navorsingsinstituut vir Sitrus en Subtropiese Vrugte: 17-19.

White, I. M., and M. M. Elson-Harris. 1992. Fruit Flies of Economic Significance: Their identification and bionomics. International Institutes of Entomology, CAB International. London, UK. 601 pp.

Whiteside, J. O. 1966. A Revised List of Plant Diseases in Rhodesia. Kirkia, 5: 87-196.

Whittle, K., and Ferguson., D. C. 1987. Pumpkin caterpillar. Pests not known to occur in the United States or of limited distribution. United States Department of Agriculture.

WSSA. 1989. Composite List of Weeds. Weed Science Society of America. pp.112.

Zitter, T. A., Hopkins, T. A., and Thomas, C. E. 1996. Compendium of cucurbit diseases. APS Press, St. Paul, Minnesota. pp.87.

Appendix 1. Summary of risk mitigation options (baby squash and baby courgette from Zambia).		
Measure(s)	**Pests**	**Efficacy**
Pest-free areas or places of production	All	Satisfies requirements for appropriate level of protection
Control measures at production site: Pest-free, insect-proof greenhouses	Medium to large pests including *Aulacaspis tubercularis, Dacus bivitattus, D. ciliatus, D. frontalis, D. lounsburyii, D. punctatiforns, D. vertebratus, Diaphania indica, Helicoverpa armigera, Spodoptera littoralis* Should be used with other measures including inspection and monitoring, and proper packing house procedures	This measure can be very effective if plants are grown solely in a greenhouse in which sanitary procedures are adequate to exclude plant pests. Sanitation effectively controls or eliminates all types of pests directly by eliminating the pests, and indirectly by eliminating safe hiding places and reducing food sources and inoculum levels (Agrios, 1997; Bessin, 2001; Greer and Diver, 2000; Jones and Benson, 2001; Roosjen, *et al.*, 1999). Adults of *Dacus* sp., *Diaphania indica, Helicoverpa armigera, Spodoptera littoralis* are relatively large (CABI, 2004; USDA, 1982; Whittle, 1986) and would easily be excluded by 1.6 mm mesh screening. Entryways equipped with automatically closing doors exclude flying adults of these pests (Kahn and Mathur, 1999). Also, maintaining a sound greenhouse structure is necessary to help ensure pest exclusion. There are no approved treatments for *Aulacaspis tubercularis, Dacus bivitattus, D. ciliatus, D. frontalis, D. lounsburyii, D. punctatifrons, D. vertebratus, Diaphania indicia*, or *Spodoptera littoralis*; therefore, these pests will have to be carefully monitored and screened out by manual inspection. ** Regular inspections should be included as an important part of a pest management program (Kahn and Mathur, 1999).
Control Measures at other production sites		More research is required to determine effective control measures for each pest of concern.

Appendix 1. Summary of risk mitigation options (baby squash and baby courgette from Zambia).		
Measure(s)	**Pests**	**Efficacy**
Inspections and monitoring	All, but must be used in combination with other measures	The relatively large size of *Diaphania indica, Helicoverpa armigera, Spodoptera littoralis* allow detection of these pests at least during some stages of their development (CABI, 2006; USDA, 1982; Whittle, 1986). *Aulacaspis tubercularis* is visible as a white scale on a dark background. *Diaphania indica* creates tunnels in the fruit, usually originating at the stem end, but sometimes creates irregularly shaped holes all over the fruit (Whittle and Ferguson, 1987). An inspection that examined the stem end of the fruit for larval feeding and cut vegetable to expose larval tunnels in the pulp would be likely to discover this pest. *Helicoverpa armigera* and *Spodoptera* larvae feed internally on vegetable hosts, but leave entry holes (CABI, 2003) that could be detected by careful inspection. Visual inspection does not work for fruit flies. There is a high likelihood all of the *Dacus* species will go undetected. e.g., inspectors cutting mango failed to detect larvae of *Anastrepha suspensa*, a fruit fly in the same family as *Bactrocera* spp., 71.6% of the time (Gould, 1995).
Packinghouse procedures	All, but should be used in combination with other measures	Potential procedures for squash include washing, waxing, blast cooling, and cold storage. Additionally, squash and courgettes should be culled with quality defects such as: mechanical damage, bruising, scarring, disease or pest presence, dehydration, or immature, over-sized, seeded, decaying, deformed, split, heavily soiled, or blemished fruit (Duncan, 2003). The efficacy of the elimination of pests is unknown and would require additional research.

Appendix 1. Summary of risk mitigation options (baby squash and baby courgette from Zambia).		
Measure(s)	**Pests**	**Efficacy**
Vapor heat treatment	Fruit flies	There are no approved treatments for *Dacus* spp. Vapor heat treatment is approved for other fruit flies, such as *Bactrocera* spp. which is closely related to *Dacus* spp. For example, vapor heat treatment T106-b-6 (112° F for 8.75 hours) is approved for *Ceratitis capitata*, *Bactrocera dorsalis*, and *B. cucurbitae* (USDA, 2004). However, research on efficacy would be needed on these pests.
Irradiation combined with low pest prevalence	Fruit flies	**The approved treatment for irradiation of fruit flies on fruits and vegetables is T105-b-4, which includes a minimum of 150 Gray (15 krad) and not to exceed 1000 Gray (100 krad) (USDA, 2004).**
Irradiation combined with low pest prevalence	External and internal pests including *Aulacaspis tubercularis, Diaphania indica, Helicoverpa armigera*, and *Spodoptera littoralis*	PPQ-recognized generic dose (400 Gray) quarantine treatment on all regulated plant articles for all insect pests except for Lepidopteran pupae and adults.
Methyl bromide fumigation	External pests	**The approved treatment for external feeders and leaf miners on multiple commodities is T104-a-1; 40^{o} F at 4 lbs/1000ft^{3} methyl bromide for 2 hours (USDA, 2004).** Because this treatment is approved for *Helicoverpa armigera*, it could possibly be used for the remaining Lepidopteran pests. Additional research would be needed on these pests.

References:

Agrios, G.N. 1997. Plant pathology. 4th Edition. Academic Press, San Diego, California.

Bessin. 2001. Controls for greenhouse ornamental insect pests. Univ. Kentucky Cooperative Extension Service Web page: http://www.uky.edu/Agriculture/Entomology/entfacts/trees/ef421.htm. [l*ast accessed 9 August, 2005*].

CABI. 2004. Crop Protection Compendium. CAB International, Wallingford, UK.

CABI. 2006. Crop Protection Compendium. CAB International, Wallingford, UK.

Duncan, R. Trip report from Zambia including baby squash and baby courgettes. USDA,APHIS, PPQ. August 2003.

Greer, L. and Diver, S. 2000. Greenhouse IPM: Sustainable Thrips Control. National Center for Appropriate Technology, National Sustainable Agriculture Information Service

Publication #IP148/63. http://attra.ncat.org/attra-pub/PDF/ghthrips.pdf. [l*ast accessed August 21 2005*].
Gould, W. P. 1995. Probability of detecting Carribbean fruit fly (Diptera: Tephritidae) infestations by fruit dissection. Florida Entomologist, 78: 502-507.
IAEA, 2003. Trapping Guidelines for Area-wide Fruit Fly Programmes. International Atomic Energy Agency. Insect Pest Control Section. Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture. IAEA, Vienna. TG/FFP. http://www-naweb.iaea.org/nafa/ipc/public/trapping-web.pdf [last accessed June 2005].
Jones, R. K. and D. M. Benson. 2001. Diseases of Woody Ornamentals and Trees in Nurseries. APS Press, American Phytopathological Society, St. Paul, MN.
Kahn, R. P. and S. B. Mathur. 1999. Containment Facilities and Safeguards. American Phytopathological Society, St. Paul, MN. 213 pp.
Roosjen, M.G., Stigter, M. and Oomen, P.A. 1999. Greenhouse Pest Exclusion and Eradication Safeguards and Principles. In: Kahn, R.P. and Mathur, S.B., eds. Containment Facilities and Safeguards for Exotic Plant Pathogens and Pests. St. Paul, MN: APS Press. Pgs. 182-185.
USDA. 1982. Pests Not Known to Occur in the United States or of Limited Distribution, No. 24: Rice Cutworm. USDA, APHIS, PPQ, Hyattsville, MD. 8 pp.
USDA. 2004. Treatment Manual. USDA-APHIS, PPQ; https://manuals.cphst.org/Tindex/treatmentSearch.cfm [last accessed Nov 2007].
USEPA 2006 Federal Insecticide, Fungicide, and Rodenticide Act: Pesticide Emergency Exemptions. US
Environmental Protection Agency, Washington DC http://www.epa.gov/opprd001/section18 [last accessed 13 April 2006].
Whittle, K. 1986. Pests Not Known to Occur in the United States or of Limited Distribution No. 74: Cabbage
Moth- *Mamestra brassicae* L. September 1986. USDA, APHIS, PPQ. Hyattsville, MD. 15 pp.
Whittle, K., and Ferguson., D. C. 1987. Pumpkin caterpillar. Pests not known to occur in the United States or of limited distribution. Eggplant borer. USDA APHIS Rpt 81.50. USDA, APHIS, PPQ. Hyattsville, MD.