Mini Risk Assessment
Passionvine mealybug: *Planococcus minor* (Maskell)
[Pseudococcidae: Hemiptera]

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March 2, 2004

Introduction

Planococcus minor is a significant pest of more than 250 host plants in the Afrotropical, Australasian, Nearctic, Neotropical, and Oriental regions (Williams 1985, Ben-Dov 1994, USDA 2000, CAB 2003). Banana, citrus, cocoa, coffee, corn, grape, mango, potato and soybean are among the more notable agricultural crops that may be affected by this pest.

The likelihood and consequences of establishment by *P. minor* in the US have been evaluated previously in commodity-based pest risk assessments. Previous analyses have concluded that the likelihood of this pest becoming established in the US is high and the consequences of its establishment would be severe. This new document is intended to provide useful information about whether *P. minor* should be the focus of a pest survey, and if so, to identify and evaluate available survey techniques.

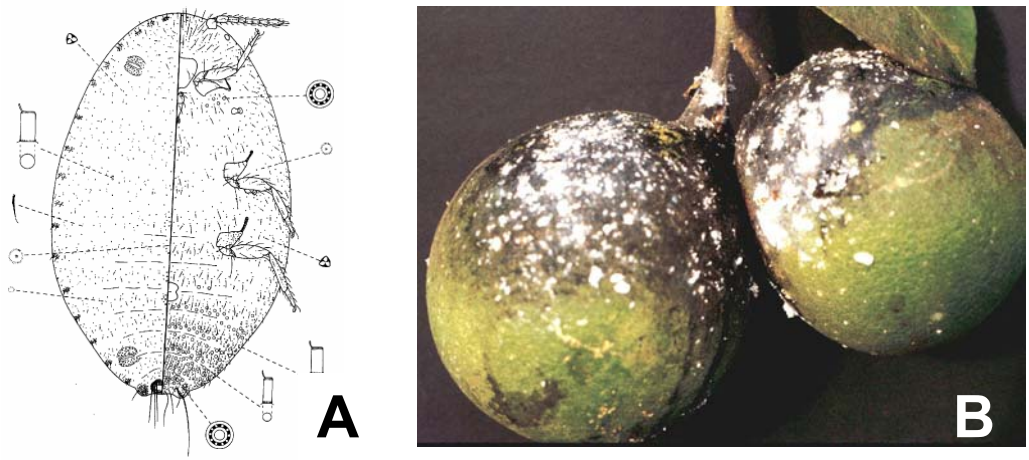

Figure 1. A. Line drawing of an adult *Planococcus minor* [Reproduced from Cox, 1989]. B. Citrus infested with *Pseudococcus* sp. [Image from http://floriculture.tamu.edu:81/syllabi/422/pics/arthropd/cm.htm]

1. **Ecological Suitability. Rating: Medium.** *Planococcus minor* is considered widespread through much of its geographic range, primarily in the tropics and subtropics (Williams 1985, Williams and Watson 1988, Cox 1989, Williams and Granara de Willink 1992, Ben-Dov 1994, USDA 2000). *Planococcus minor* is thought to be one of six species with origins in the Old World, and likely introduced to the Neotropics by trade (Cox 1989) The currently reported global distribution of *P. minor* suggests that the pest may be most closely associated with biomes characterized as desert and xeric shrubland; temperate grassland,

savannahs, and shrubland; and tropical and subtropical moist broad leaf forest. Consequently, we estimate that approximately 52% of the continental US would have a suitable climate for *P. minor* (Fig. 2). See Appendix A for a more complete description of this analysis.

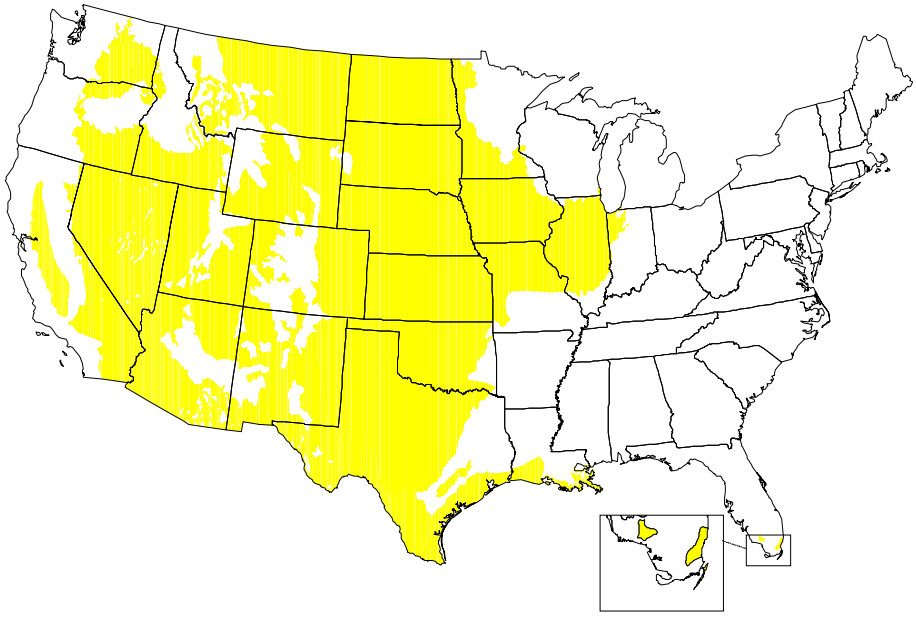

Figure 2. Predicted distribution of *Planococcus minor* in the continental US.

2. **Host Specificity/Availability. Rating: High/High.** This pest is highly polyphagous and feeds on a variety of wild and cultivated plants. There are more than 250 reported host plants in nearly 80 families, including:

Acanthaceae:
- *Aphelandra* sp.
- *Graptophyllum* sp.
- *Justica carnea*
- *Odontonema* sp.
- *Pachystachys cocineae*

Agavaceae:
- Mauritius hemp (*Furcraea foetida* [=*gigantea*])

Amaranthaceae:
- *Amaranthus* sp.
- cock's comb (*Celosia* sp.)

Anacardiaceae:
- cashew (*Anacardium occidentale*)
- Jewish plum (*Spondias dulcis*)
- mango (*Mangifera indica*)
- *Rhus* sp.

Annonaceae:
- custard apple (*Annona reticulata*)
- ilang-ilang (*Cananga odorata*)
- soursop (*Annona muricata*)
- sugar apple (*Annona squamosa*)

Apiaceae:
- wild celery (*Apium graveolens*)

Apocynaceae:
- templetree (*Plumeria rubra*)

Araceae:
- *Aglaonema* sp.
- *Anthurium* sp.
- arrowleaf elephant's ear (*Xanthosoma sagittifolium*)
- centipede tongavine (*Epipremnum pinnatum*)
- coco yam (*Colocasia esculenta* [=*antiquorum*])
- *Cryptosperma chamissonis*
- *Dieffenbachia* sp.

giant taro (*Alocasia macrorrhizos* [=*macrorhiza*])
Philodendron fonzii
purplestem taro (*Xanthosoma violaceum* [=*nigrum*])
Rhaphidophora vitiensis
taro (*Alocasia* sp.)
water lettuce (*Pistia stratiotes*)

Araliaceae:
Aralia sp.
geranium aralia (*Polyscias guilfoylei*)
ivy (*Hedera* sp.)
Schefflera actinphylla

Asclepiadaceae:
bladder flower (*Araujia sericofera*)
Hoya sp.

Asteraceae:
Emilia sonifolia
ironweed (*Vernonia* sp.)

Balsaminaceae:
Impatiens sultani
spotted snapweed (*Impatiens balsamina*)

Barringtoniaceae:
Barringtonia asiatica

Bischofiaceae:
Bischofia javanica

Boraginaceae:
Assyrian plum (*Cordia myxa*)
Spanish elm (*Cordia alliodora*)
Tournefortia argentata

Bromeliaceae:
pineapple (*Ananas comosus*)

Burseraceae:
Canarium harveyi
Canarium indicum

Cactaceae:
Harrisia portaricensis

Cannaceae:
Canna sp.

Casuarinaceae:
Casuarina equisetifolia

Combretaceae:
Lumnitzera coccinea
Terminalia catappa
Terminalia sp.

Commelinaceae:
Commelina sp.
Tradescantia sp.

Compositae:
beggarticks (*Bidens pilosa*)
Cichorium endivia
climbing hempvine (*Mikania scandens*)
Dahlia sp.
elegant zinnia (*Zinnia violacea* [=*elegans*])
Emilia sonchifolia
French marigold (*Tagetes patula*)
Helianthus sp.
nodeweed (*Synedrella nodiflora*)
sweetscent (*Pluchea odorata*)
Tithonia sp.
Wedelia biflora

Convolvulaceae:
Ipomoea pes-caprae
Merremia peltata
sweet potato(*Ipomoea batatas*)

Corynocarpaceae:
Corynocarpus sp.

Cruciferae:
cabbage (*Brassica oleracea*)
Chinese cabbage/pak choi (*Brassica chinensis*)
radish (*Raphanus sativus*)

Cucurbitaceae:
cantaloupe (*Cucumis melo*)
chayote (*Sechium edule*)
crookneck squash (*Cucurbita moschata*)
cucumber (*Cucumis sativus*)
pumpkin (*Cucurbita pepo*)
sinkwa towelsponge (*Luffa actangula*)
watermelon (*Citrullus lanatus*)
winter squash (*Cucurbita maxima*)

Cyperaceae:
nutgrass (*Cyperus rotundus*)

Dioscoreaceae:
water yam (*Dioscorea alata*)

Ebenaceae:

mabolo (*Diospyros blancoi* [=*discolor*])

Ehretiaceae:

Euphorbiaceae:

Acalypha godseffiana
Acalypha tricolor
Antidesma sp.
bristly copperleaf (*Acalypha hispida*)
Indian walnut (*Aleurites moluccana*)
barbados nut (*Jatropha curcas*)
Cassava utilissima
castor bean (*Ricinus communis*)
Croton sp.
Euphorbia atoto
Excoecaria agallocha
gale of the wind (*Phyllanthus niruri*)
garden croton (*Codiaeum variegatum*)
Glochidion ramiflorum
Macaranga aleuritoides
Macaranga harveyana
Macaranga macrophylla
Mallotus japonicus
Mexican fireplant (*Euphorbia heterophylla* [=*geniculata*])
paraso leaf tree (*Macaranga tanarius*)
poinsettia (*Euphorbia pulcherrima*)
rubber tree (*Hevea brasiliensis*)
tapioca (*Manihot esculenta*)

Fabaceae:

Acacia holosericea
Acacia sp.
Acacia spirobis
black mimosa (*Mimosa pigra*)
blackeyed pea (*Vigna unguiculata*)
Cassia imperialis
cowitch (*Mucuna pruriens*)
crybaby tree (*Erythrina crista-galli*)
emperor's candlesticks (*Senna alata* [=*Cassia alata*])
Erythrina brasiliensis
Erythrina sp.
Flemingia sp.
flor de conchitas (*Centrosema pubescens*)
Gliricidia maculata
Gliricidia sepium
hoarypea (*Tephrosia* sp.)
Inocarpus fagifer
kidney bean (*Phaseolus vulgaris*)
lima bean (*Phaseolus lunatus*)
Napoleon's plume (*Bauhinia monandra*)
notched cowpea (*Vigna marina*)
peanut (*Arachis hypogaea*)
pigeonpea (*Cajanus cajan* [=*indicus*])
purple bushbean (*Macroptilium atropurpureum* [=*Phaseolus atropurpureus*])
quickstick (*Gliricidia sepium*)
red beadtree (*Adenanthera pavonina*)
shameplant (*Mimosa pudica*)
small Philippine acacia (*Acacia confusa*)
soybean (*Glycine max*)
stickpea (*Calliandra houstoniana*)
sweet acacia (*Acacia farnesiana*)
tamarind (*Tamarindus* sp.)
Vigna sp.
white leadtree (*Leucaena leucocephala* [=*glauca*])
winged bean (*Psophocarpus tetragonolobus*)
Wisteria sp.

Geraniaceae:

Geranium sp.

Gramineae:

corn (*Zea mays)*
sugarcane (*Saccharum officinarum*)

Guttiferae:

Alexandrian laurel (*Calophyllum inophyllum*)

Heliconiaceae:

Heliconia aurantiaca

Iridaceae:

Gladiolus sp.

Lamiaceae:

Anisomeles indica [=*Epimeredi indicus*]
Coleus sp.
comb bushmint (*Hyptis pectinata*)
common coleus (*Coleus scutellaroides* [=*blumei*])
holy basil (*Ocimum tenuiflorum* [=*sanctum*])
sweet basil (*Ocimum basilicum*)

Lauraceae:

avocado (*Persea americana*)

Liliaceae:

Caesia parviflora
common asparagus fern (*Asparagus setaceus* [=*plumosus*])
Dracaena sp.
poisonbulb (*Crinum asiaticum*)

Loganiaceae:

Fagraea racemosa

Lythraceae:

crapemyrtle (*Lagerstroemia indica*)
Pemphis acidula

Magnoliaceae:

Michelia figo

Malvaceae:

cotton (*Gossypium* sp.)
Hibiscus manihot
Indian mallow (*Abutilon* sp.)
Portia tree (*Thespesia populnea*)
sea hibiscus (*Hibiscus tiliaceus*)
swampmallow (*Pavonia* sp.)

Marantaceae:

Maranta sp.

Moraceae:

breadfruit (*Artocarpus altilis* [=*communis*])
Castilloa elastica
Ficus congesta
Ficus opositica
fig, edible (*Ficus carica*)

Moraceae (continued):

Indian rubberplant (*Ficus elastica*)
jackfruit (*Artocarpus heterophyllus*)
Morus sp.
paper mulberry (*Broussonetia papyrifera*)
weeping fig (*Ficus benjamina*)
white mulberry (*Morus alba*)

Musaceae:

French plantain (*Musa* **x***paradisiaca* (pro sp.) [*acuminata* **x***balbisiana*] [=*M. sapientum*])
hairy banana (*Musa velutina*)

Myristiaceae:

Myristica macrantha

Myrtaceae:

guava (*Psidium guajava*)
Indonesian gum (*Eucalyptus deglupta*)
Java plum (*Syzygium cumini* [=*Eugenia cumini*])
Malaysian plum (*Syzygium* malaccense [=*Eugenia malaccensis*])

Nyctaginaceae:

red spiderling (*Boerhavia diffusa*)

Oleaceae:

jasmine (*Jasminum* sp.)

Onagraceae:

Mexican primrose-willow (*Ludwigia octovalis*)

Orchidaceae:

Dendrobium veratrifolium

Palmae:

Balaka seemanni
betel palm (*Areca catechu*)
butterfly palm (*Dypsis* [=*Chrysalidocarpus*] sp.)
coconut palm (*Cocos nucifera*)
sentrypalm (*Howeia forsteriana*)

Pandanaceae:

Pandanus edulis
Pandanus foetida
Pandanus maliformis

Tahitian screwpine (*Pandanus tectorius* [=*odoratissimus*])

Passifloraceae

purple granadilla (*Passiflora edulis*)

Periploaceae:

Monidia citrifolia

Piperaceae:

black pepper (*Piper nigrum*)
higuillo de hoja menuda (*Piper aduncum*)
kava (*Piper methysticum*)
Piper puberulum

Poaceae:

bamboo (*Bambusa* sp.)
rice (*Oryza sativa*)

Polygonaceae:

Rumex sp.

Proteaceae:

macadamia nut (*Macadamia tetraphylla*)

Rhamnaceae:

Alphitonia zizyphoides

Rosaceae:

Chinese pear (*Pyrus* pyrifolia [=*serotina*])
Chinese rose (*Rosa chinensis*)
strawberry (*Fragaria* sp.)

Rubiaceae:

arabian coffee (*Coffea arabica*)
cape jasmine (*Gardenia angusta* [=*jasminoides*])
Gardenia sp.
Guettarda speciosa
Indian mulberry (*Morinda citrifolia*)
Ixora sp.
Liberian coffee (*Coffea liberica*)
Randia heterophylla
Randia tahitensis
robusta coffee (*Coffea canephora* [=*robusta*])
scarlet jungleflame (*Ixora coccinea*)

Rubiaceae (continued):

woodland false buttonweed (*Spermacoce assurgens* [=*Borreria laevis*])

Rutaceae:

Evodia hortensis
grapefruit (*Citrus* **x***paradisi* (pro.sp.) [*maxima* x *sinensis*])
lemon (*Citrus limon*)
lime (*Citrus aurantifolia*)
orange, Mexican (*Choisya* sp.)
orange, sour (*Citrus aurantium*)
orange, sweet (*Citrus sinensis*)
shaddock (*Citrus* maxima [=*grandis*])

Sapindaceae:

rambutan (*Nephelium lappaceum*)

Sapotaceae:

Pometia pinnata
sapodilla (*Manilkara zapota*)

Scrophulariaceae:

fountainbrush (*Russelia equisetiformis*)

Solanaceae:

angel's-tears (*Brugmansia* [=*Datura*] *suaveolens*)
Brunfelsia hispida
eggplant (*Solanum melongena*)
Indian nightshade (*Solanum indicum*)
pepper/cayenne pepper (*Capsicum annuum* [=*frutescens*])
potato (*Solanum tuberosum*)
pricklyburr (*Datura inoxia* [=*metel*])
Solanum grandiflorum
tomato (*Solanum lycopersicum* [=*Lycopersicon esculentum*])
turkey berry (*Solanum torvum*)

Sterculiaceae:

cacao (*Theobroma cacao*)
guest tree (*Kleinhovia hospita*)

Theaceae:

tea (*Camellia sinensis*)

Thunbergiaceae:

Thunbergia sp.

Tiliaceae:
- diamond burrbark (*Triumfetta rhomboidea*)

Urticaceae:
- false nettle (*Boehmeria* sp.)
- *Leucosyris* sp.
- *Pipturus argenteus*
- *Procris pedunculata*

Verbenaceae:
- *Clerodendrum disparifolium*
- *Clerodendrum fallax*
- *Clerodendrum paniculatum*
- *Clerodendrum thompsonae*
- porterweed (*Stachytarpheta* sp.)
- *Premna obtusifolia*
- *Premna* sp.
- *Premna taitensis*
- simpleleaf chastetree (*Vitex trifolia*)
- teak (*Tectona grandis*)
- *Verbena* sp.[possible genera = *Verbena* or *Glandularia*])

Vitidaceae:
- grape (*Vitis vinifera*)

Zingiberaceae:
- *Alpinia nutans*
- cardamom (*Elettaria cardamomum*)
- ginger (*Zingiber officinale*)
- *Nicolaia speciosa*
- red ginger (*Alpinia purpurata*)
- white garland-lily (*Hedychium coronarium*)

References: (Hill 1983, Williams 1985, Batra et al. 1987, Waterhouse and Norris 1987, Cox 1989, Buckley and Gullan 1991, Ben-Dov 1994, Sugimoto 1994, Koya et al. 1996, Reddy et al. 1997, Lit et al. 1998, USDA 2000{Williams, 1992 #42, CAB 2003).

Although *Planococcus minor* has a very broad host range, not all host records are necessarily reliable. Recent literature suggests that earlier records may be erroneous in certain regions due to misidentification of easily confused mealybugs, namely *P. citri* (Batra et al. 1987, Cox 1989, Williams and Granara de Willink 1992, Santa Cecilia et al. 2002). Plant host susceptibility to *P. minor* can also vary widely. Infestation levels can fluctuate spatially, even on plants in close proximity, and can vary from one year to the next (Miller and Kosztarab 1979).

3. Survey Methodology. Rating: Low. In the US, surveys for mealybugs other than *P. minor* require "time-consuming and often laborious examination of plant material for the presence of live mealybugs" (Millar et al. 2002). No simple, alternative techniques are available (Millar et al. 2002). The same holds true for *P. minor* surveys in other parts of the world. In India, a regional survey for scales and mealybugs, including *P. minor*, was based on visually examining 25 branches or leaves on each of 15 plants collected from each of 3 field sites in 162 locations (=25 x 15 x 3 x 162 = 182,250 leaves examined).

Researchers also depend on visual inspections to assess densities of *P. minor*. In a study of *P. minor* [=*P. pacificus*] population dynamics, populations of the mealybug were evaluated by visual inspection of citrus leaves (specifically 10-15 leaves from 10 randomly selected plants, Bhuiya et al. 2000). Reddy et al. (1997) followed a similar protocol for coffee.

Bigger (1976) developed a passive trapping system for male mealybugs in which water trays (0.25 m^2 or ~20x20 in) are placed under infested trees. Males fall into the

traps in preparation for pupation. The effectiveness of this trapping method for *P. minor* was not specifically evaluated.

No pheromones have yet been identified for *P. minor*. However, previous research on closely related mealybug species suggests that the identification of a sex pheromone and subsequent development of a pheromone-baited trap is highly feasible. Gravitz and Wilson (1968) first extracted and demonstrated the biological activity of sex pheromones from *P. citri*. The active compounds were not identified at the time. These results were confirmed by Rotundo and Tremblay (Rotundo and Tremblay 1976). Moreno et al. (1984) demonstrated that males were attracted to caged females in the morning (0600 – 0800) and that intermediate periods (5-15 hr) of exposure to light reduced the responsiveness of males. Female bated traps placed at 2.4 or 3.7 m captured significantly more females than traps at 1.2 m (Moreno et al. 1984). Based on the flight capacity of *P. citri*, Moreno et al. (1984) recommend a density of 1 trap per 11 ha. More recently, Millar et al. (2002) identified lavandulyl senecioate as the sex pheromone for *P. ficus* and subsequently demonstrated that rubber septa impregnated with 100 μg of the compound were highly attractive to males for 12 weeks. Pheromone baited traps for *P. ficus* had an effective range of >50m, suggesting that 1 traps could be placed every 1.3 ha (Millar et al. 2002). We recommend development of a pheromone lure for *P. minor*.

4. Taxonomic Recognition. **Rating: Medium.** *Planococcus* species are not easily distinguishable from one another, especially when immature. A level of complexity is added with variable morphological characters in some species; distinguishing morphological characters can change depending on environmental conditions such as temperature (Cox 1983, 1989). *Planococcus citri* and *P. minor* have been taxonomically confused and routinely misidentified as adults are similar in appearance and share similar hosts and geographic range (Williams 1985, Cox 1989, Williams and Granara de Willink 1992, Ben-Dov 1994). Adults (females) can be identified based upon close examination of morphological characters by a taxonomist. Distinguishable morphological features of closely related mealybug species are described by Cox (1981, 1985, 1989). Electrophoretic and serological techniques have been used to help distinguish between closely related species, though much of this work has been focused on *P. citri* (Rotundo and Tremblay 1980, Williams 1985)

For a detailed description of the morphology and taxonomy of *P. minor*, including synonyms, see Appendix C.

5. Entry Potential. Rating: High. As of February 2004, interceptions of *P. minor* or "*Planococcus* sp." have been reported 5,299 times since 1984. Annually, about 240 (± 47 standard error of the mean) interceptions are reported (USDA 2004). Interceptions haven been associated primarily with international airline passengers (75%) and permit cargo (16%). The majority of interceptions have been reported from Los Angeles (41%); San Francisco (12%); San Juan, Puerto Rico (10%); JFK International Airport (8%); Miami (4%); Honolulu (3%); and Ft. Lauderdale (3%). These ports are the first points of entry for cargo or international airline passengers

coming into the US and do not necessarily represent the final destination of infested material. Movement of potentially infested material is characterized more fully in the next section.

Interceptions of *P. minor* or "*Planococcus* sp." have been reported from 311 plant taxa (USDA 2004). Interceptions have been reported most frequently from plants in the genera *Nephelium* (19%), *Anona* (17%), *Sechium* (7%), *Syzgium* (6%), *Psidium* (5%), *Garcinia* (5%), and *Musa* (4%).

Japan also reported international movement of *P. minor* into its country on bananas from the Philippines (Sugimoto 1994).

6. Destination of Infested Material. Rating: High. When an actionable pest is intercepted, officers ask for the intended final destination of the conveyance. Material infested with *P. minor* or "*Planococcus* sp." was destined for 40 states in the contiguous US, including the District of Columbia (USDA 2004). The most commonly reported destinations were California (55%), New York (12%), Florida (10%), and Texas (3%). With the exception of New York, we note that some portion of each of these states has a climate and hosts that would be suitable for establishment by *P. minor*.

7. Potential Economic Impact. Rating: High. *Planococcus minor* is among several polyphagous economically important pests of numerous crops. It has a similar host range and geographical distribution as other mealybugs, including *P. citri* (Cox 1989). For example, *Planococcus minor* is a well known pest, co-occurring with other closely related species, in cocoa growing regions (Cox 1989). Because multiple species may occur on a plant host, it is difficult to estimate the economic impact of *P. minor* alone. For instance, *P. minor* (formerly *P. pacificus* reported as *P. citri* in 1966) reportedly made up approximately 90% of a scale complex on coffee in New Guinea and caused an estimated yield reduction of 70-75 percent (Williams and Watson 1988).

Planococcus minor is a phloem feeder, and in general this may cause reduced yield, reduced plant or fruit quality; stunting, discoloration and defoliation. Indirect or secondary damage is caused by sooty mold growth on honeydew produced by the mealybug. Important plant viruses may also be vectored by *P. minor* (Williams 1985, Cox 1989).

8. Potential Environmental Impact. Rating: High. In general, newly established species may adversely affect the environment in a number of ways. Introduced species may reduce biodiversity, disrupt ecosystem function, jeopardize endangered or threatened plants, degrade critical habitat, or stimulate use of chemical or biological controls. *Planococcus minor* is likely to affect the environment in many of these ways.

Historically, the introduction of invasive agricultural pests has initiated control measures to avoid lost production (National Plant Board, 1999). Consumer preferences for unblemished, high quality produce encourage the use of pesticides, while at the same time, negative public opinion regarding the use of pesticides on fruits and vegetables is a market concern (Bunn et al., 1990). Therefore, the establishment of any new pests of fruits and vegetables destined for fresh markets is likely to stimulate greater use of either chemical or biological controls to ensure market access.

Planococcus minor has a broad host range and is considered a non-discriminate feeder within a number of plant families (see #2-Host Range). Appendix D summarizes federally listed threatened or endangered plant species (USDA 2004) found within plant genera known to be hosts for *P. minor*. Plants listed in Appendix D might be suitable hosts for *P. minor*, and, thus, could be adversely affected by this insect.

9. Establishment Potential. Rating: High. Cox (1989)states, "Most serious outbreaks of mealybugs occur when they are transported to new countries where their natural enemies do not occur, but in these cases biological control programs have been generally effective." Release from natural enemies is likely to facilitate establishment of this pest.

The necessity of a mating pair for establishment of *P. minor* is less certain than with other insect species. Both males and females do occur in populations (Cox 1989, Sahoo and Ghosh 2001). However, for some mealybugs (e.g., *P. citri*), reproduction may be achieved asexually through parthenogenesis; experimental observations have conflicted on this point (reviewed in Williams 1985). Asexual reproduction certainly would increase the likelihood of *P. minor* becoming established in the US in accidentally introduced.

Planococcus minor has not been reported in the wild in the US. However, significant portions of the US are likely to provide suitable climate and hosts. Moreover, the pest is frequently intercepted at US ports of entry. Consequently, there is a high probability of the insect becoming established in the US.

See Appendix E for a more detailed description of the biology of *P. minor*.

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Appendix A. Comparison of climate zones. To determine the potential distribution of a quarantine pest in the US, we first collected information about the worldwide geographic distribution of the species (USDA 2003)**.** We then identified which biomes (i.e., habitat types), as defined by the World Wildlife Fund (Olson et al. 2001), occurred within each country or municipality reported for the distribution of the species. Biomes were identified using a geographic information system (e.g., ArcView 3.2). An Excel spreadsheet summarizing the occurrence of biomes in each nation or municipality was prepared. The list was sorted based on the total number of biomes that occurred in each country/municipality. The list was then analyzed to determine the minimum number of biomes that could account for the reported worldwide distribution of the species. Biomes that occurred in countries/municipalities with only one biome were first selected. We then examined each country/municipality with multiple biomes to determine if at least one of its biomes had been selected. If not, an additional biome was selected that occurred in the greatest number of countries or municipalities that had not yet been accounted for. In the event of a tie, the biome that was reported more frequently from the entire species' distribution was selected. The process of selecting additional biomes continued until at least one biome was selected for each country. The set of selected biomes was compared to the occurrence of those biomes in the US.

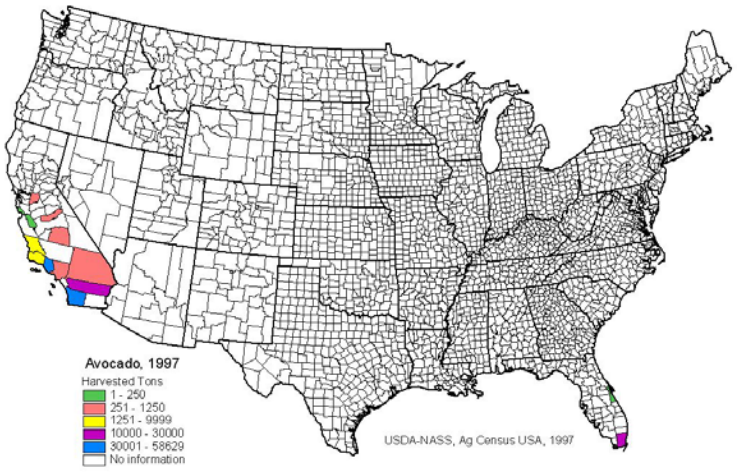
Planococcus minor has been reported from:

American Samoa
Austral Islands, French Polynesia
Bangladesh
Barbuda, Antigua and Barbuda
Bermuda
Brazil
Buenos Aires, Argentina
Burma (=Myanmar)
Colombia
Cook Islands
Costa Rica
Cuba
Dominica
Entre Rios, Argentina
Fiji
French Polynesia
Galapagos Islands
Grenada
Guadeloupe
Guatemala
Guyana
Haiti
Honduras
India
Irian Jaya, Indonesia
Jamaica
Kalimantan (=Borneo)
Kiribati
Luzon, Philippines
Madagascar
Malaysia
Mexico
New Caledonia
New South Wales, Australia
Niue
Northern Territory, Australia
Papua New Guinea
Philippines
Queensland, Australia
Rodriques Island
Saint Lucia
Singapore
Society Islands, French Polynesia
Solomon Islands
South Australia
Sumatra, Indonesia
Suriname
Taiwan
Thailand
Tokelau
Tonga
Trinidad,
Tucuman, Argentina
U.S. Virgin Islands
Uruguay
Vanuatu (=New Hebrides)
Western Samoa

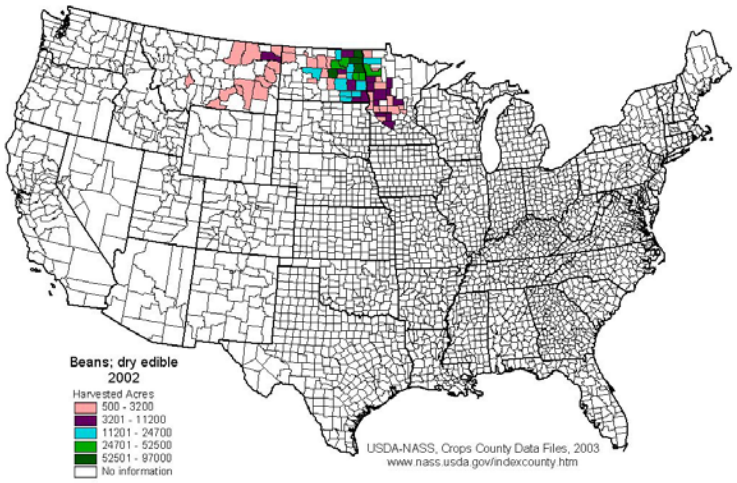
The analysis suggests that *P. minor* might be found in the North Central US because of its association with temperate grassland, savannah, and shrubland in Argentina and Bermuda. Additional research is needed to establish cold tolerances of *P. minor*, but it seems unlikely that the insect could withstand the continental climate of central North America.

Appendix B. Commercial production of hosts of *Planococcus minor* in the continental US.

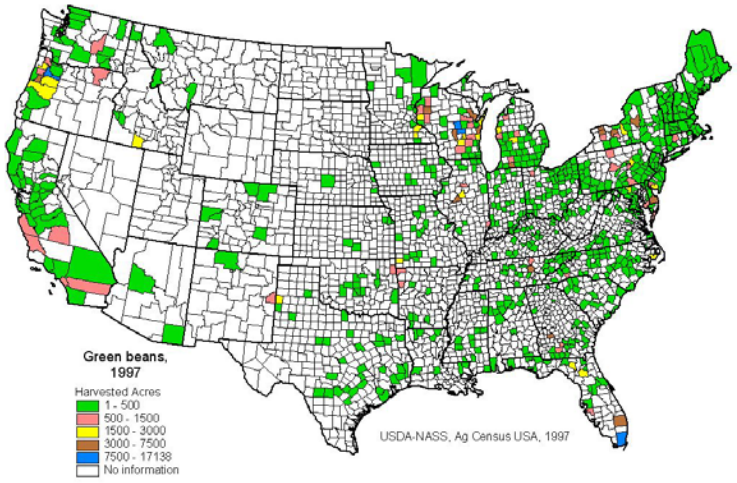
Map 1. Avocado (*Persea americana*)



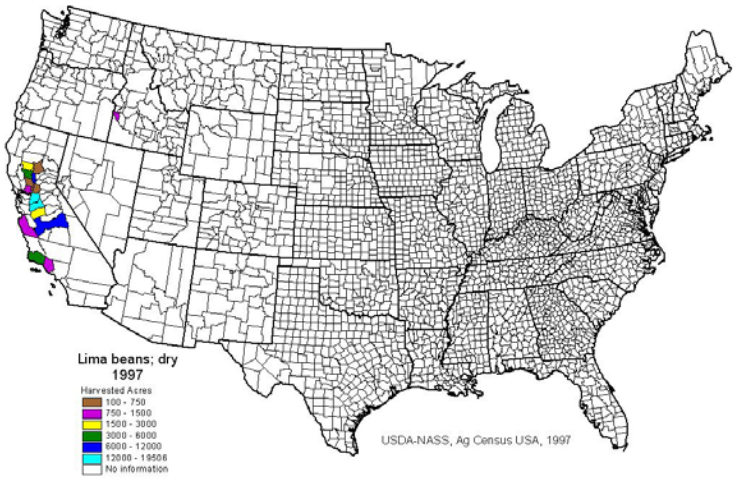
Map 2. Beans; dry edible (*Phaseolus* spp., *P. vulgaris*)



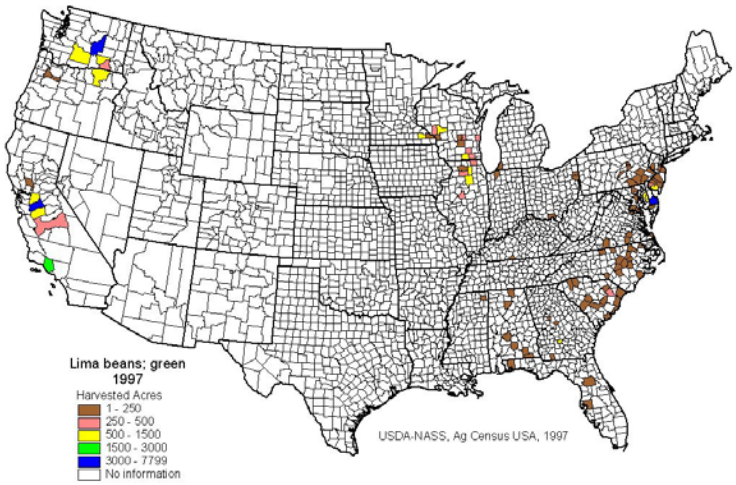
Map 3. Beans; green (*Phaseolus* spp., *P. vulgaris*)



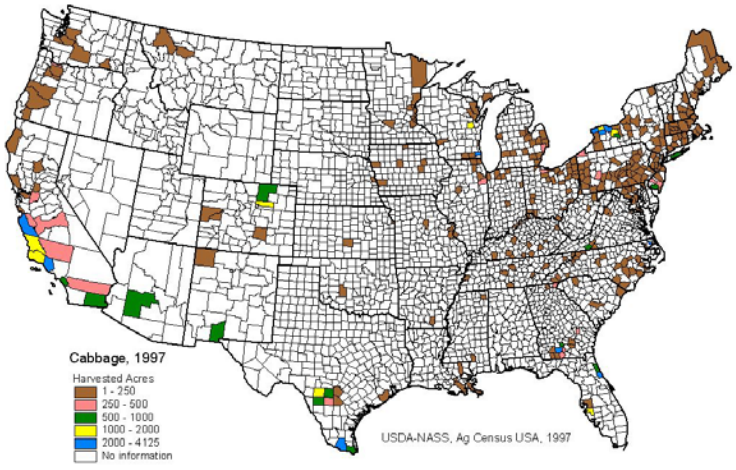
Map 4. Beans; dry lima bean (*Phaseolus lunatus*)



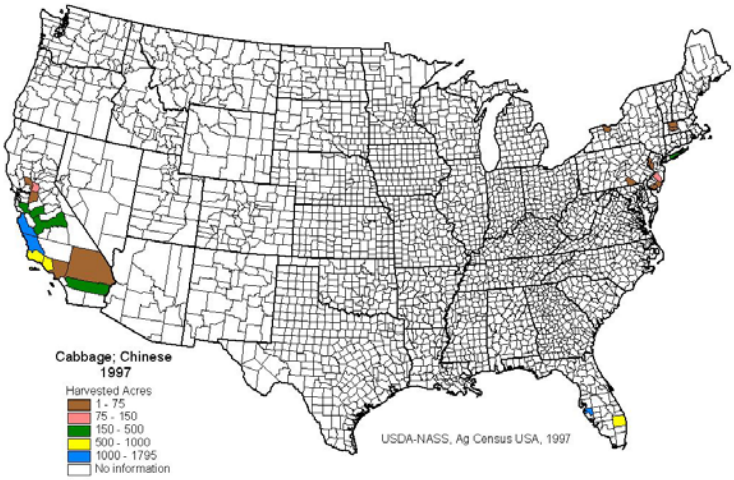
Map 5. Beans; fresh lima bean (*Phaseolus lunatus*)



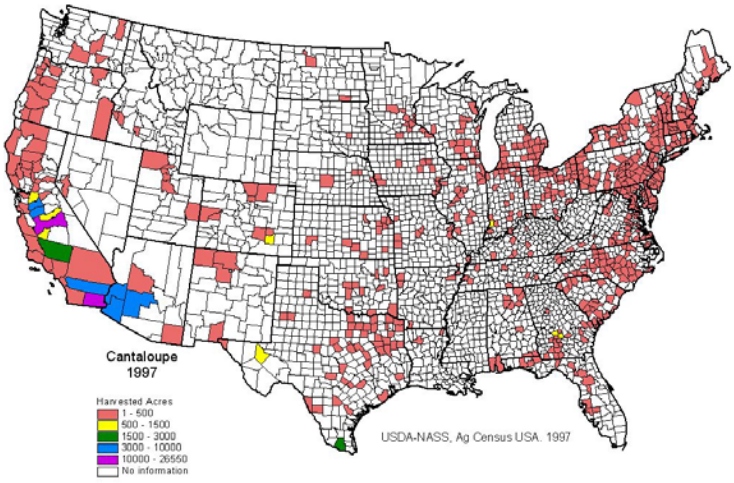
Map 6. Cabbage, head (*Brassica oleracea*)



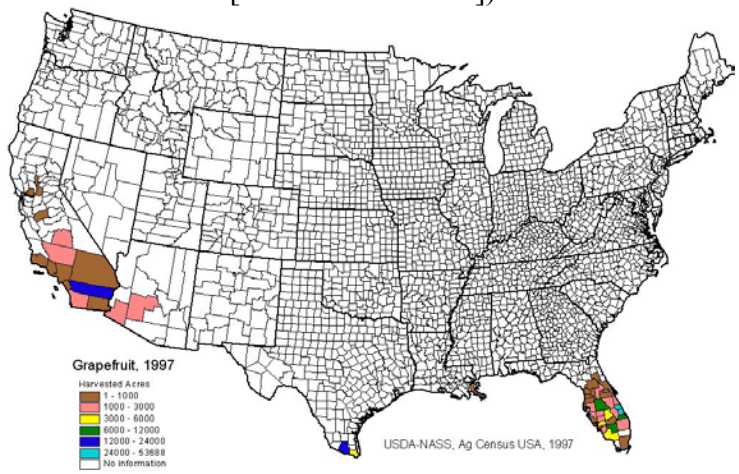
Map 7. Cabbage, Chinese/pak choi (*Brassica chinensis*)



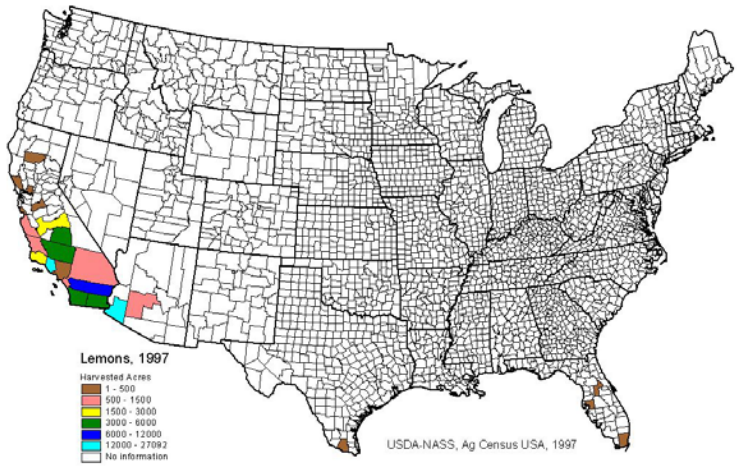
Map 8. Cantaloupe (*Cucumis melo*)



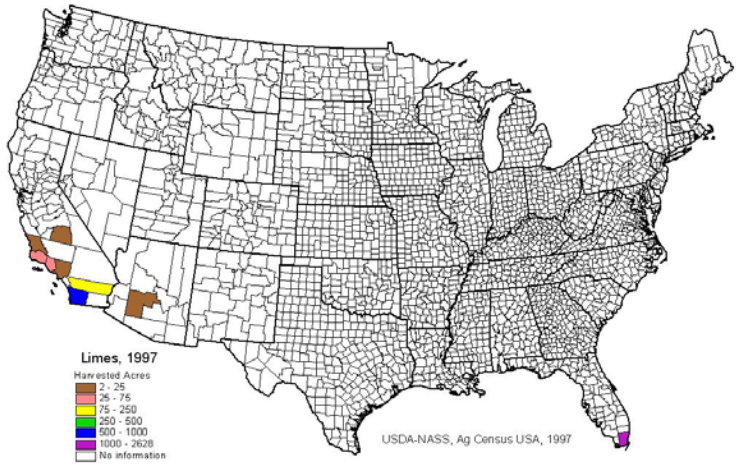
Map 9. Citrus/grapefruit (*Citrus* x*paradisi* (pro.sp.) [*maxima* x *sinensis*])



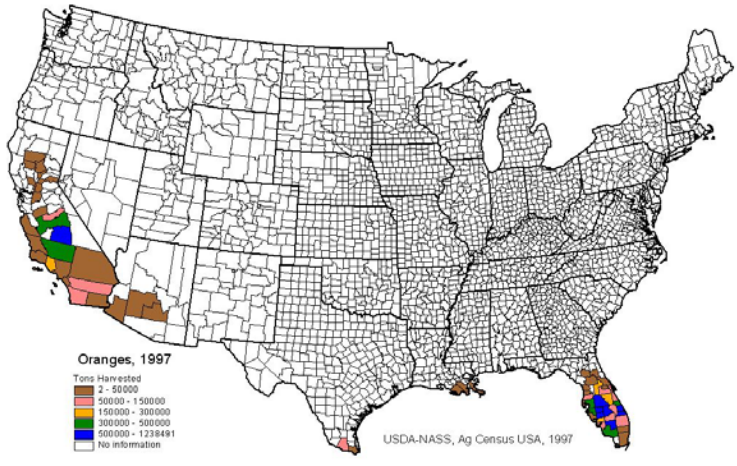
Map 10. Citrus/lemons (*Citrus limon*)



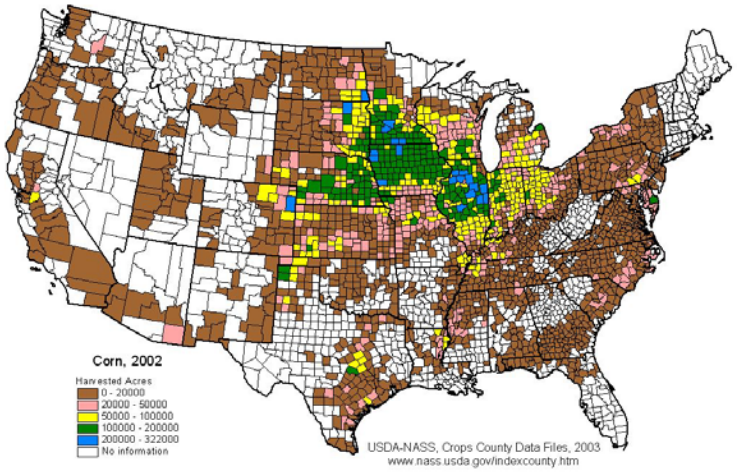
Map 11. Citrus/limes (*Citrus aurantifolia*)



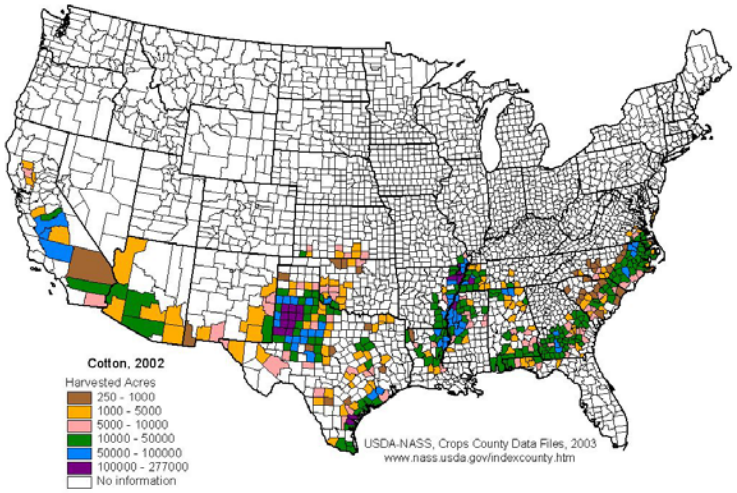
Map 12. Citrus/oranges (*Citrus aurantium*, *C. sinensis*)



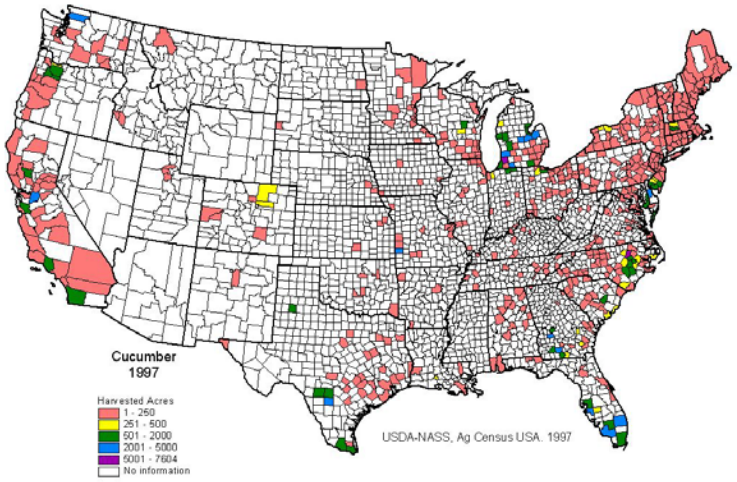
Map 13. Corn (*Zea mays*)



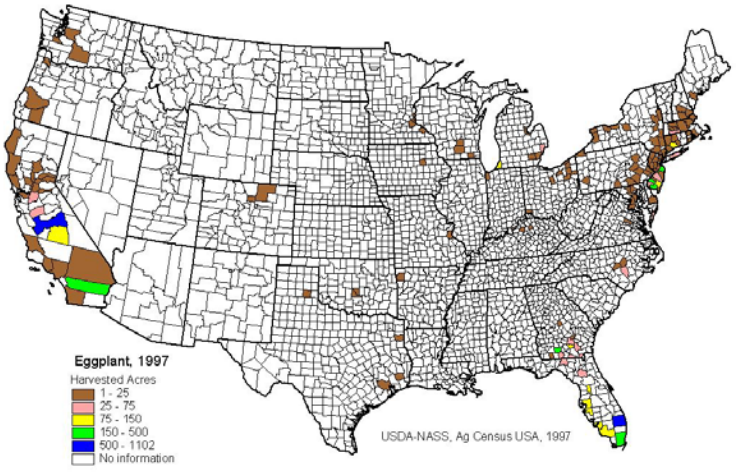
Map 14. Cotton (*Gossypium hirsutum*)



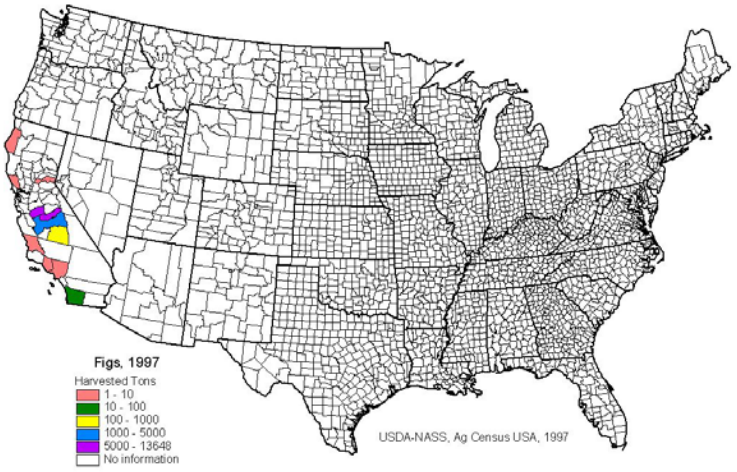
Map 15. Cucumber (*Cucumis sativus*)



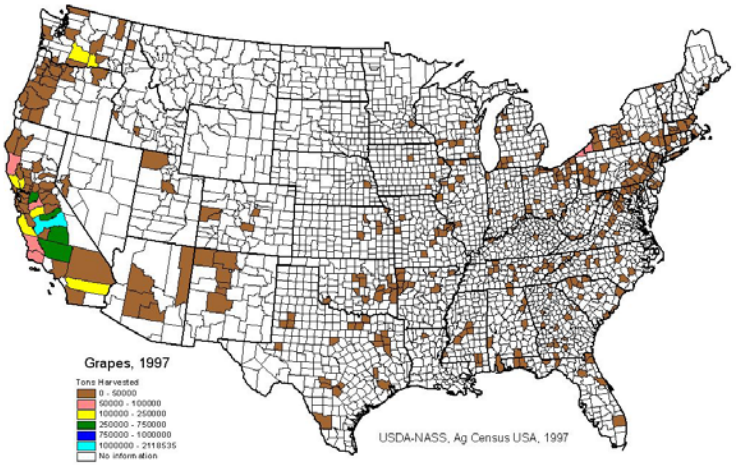
Map 16. Eggplant (*Solanum melongena*)



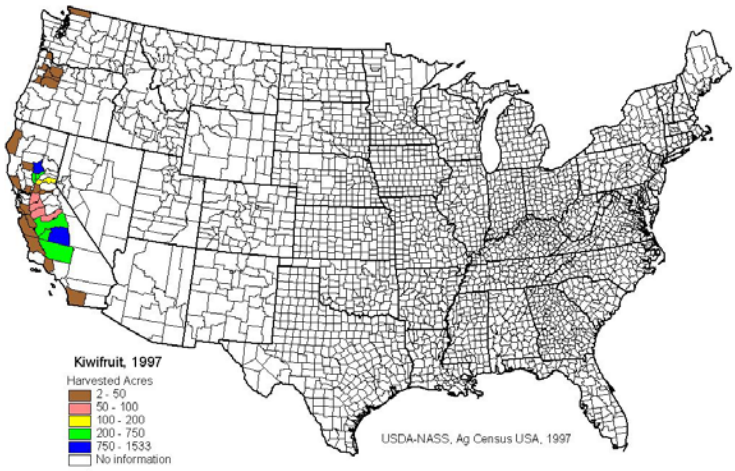
Map 17. Figs, edible (*Ficus carica*)



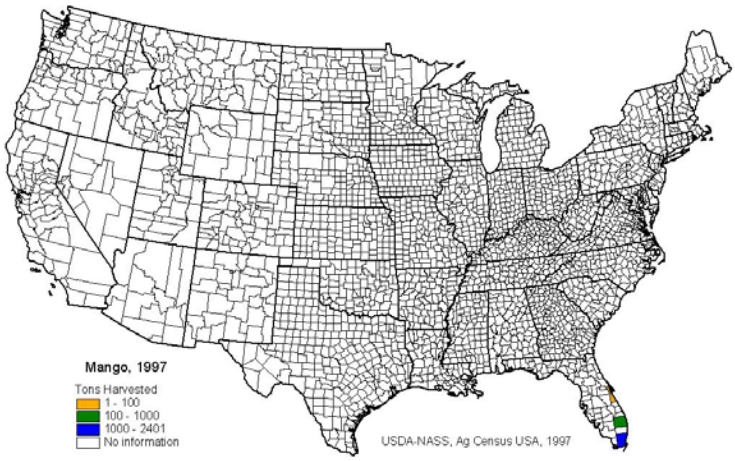
Map 18. Grapes (*Vitis* spp.)



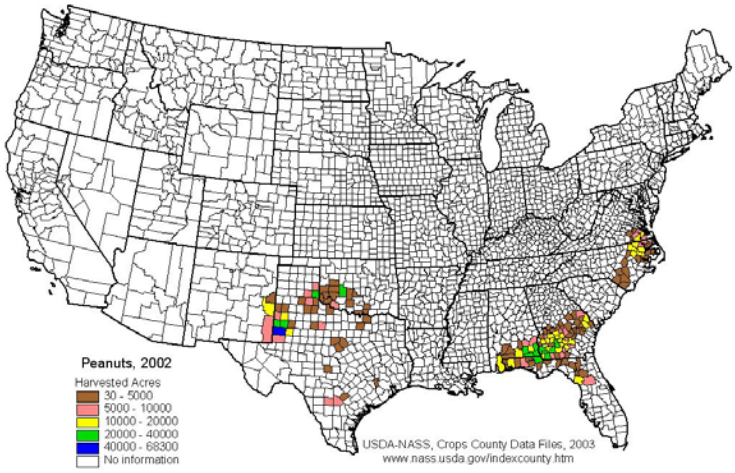
Map 19. Kiwi (*Actinidia chinensis*)



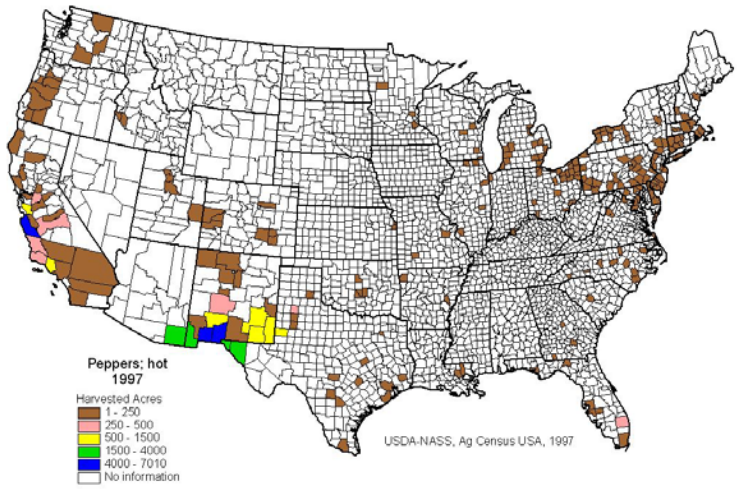
Map 20. Mango (*Mangifera indica*)



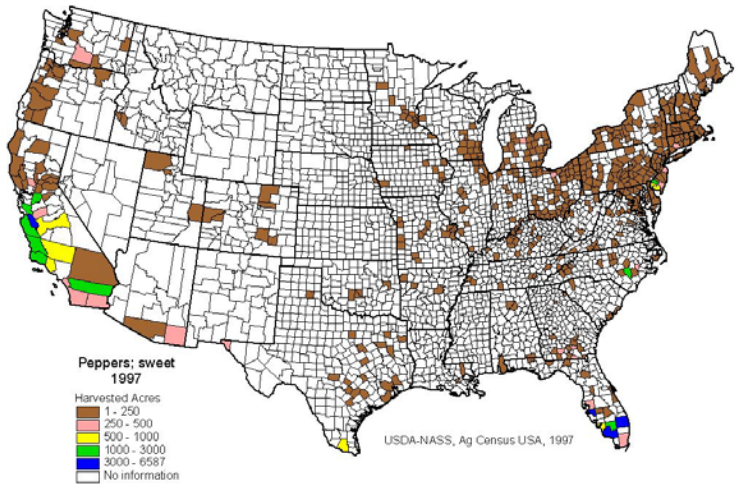
Map 21. Peanut (*Arachis hypogaea*)



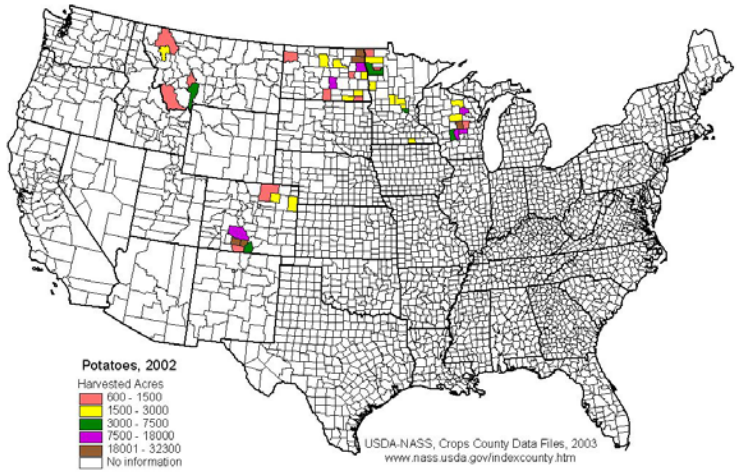
Map 22. Peppers; hot (*Capsicum* spp.)



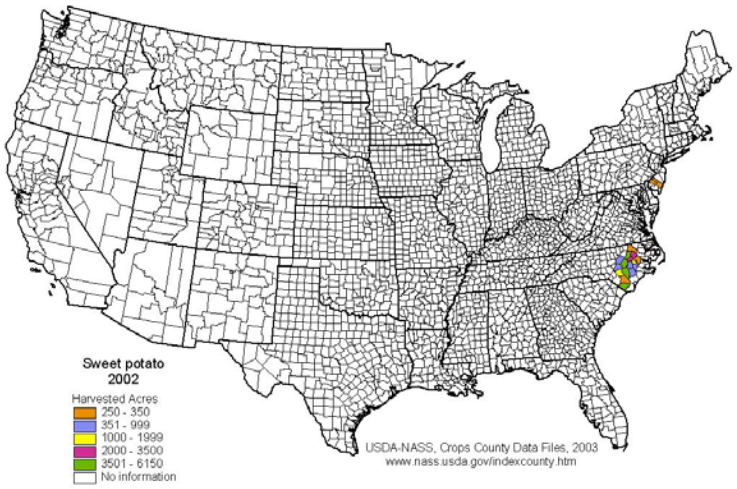
Map 23. Peppers, sweet



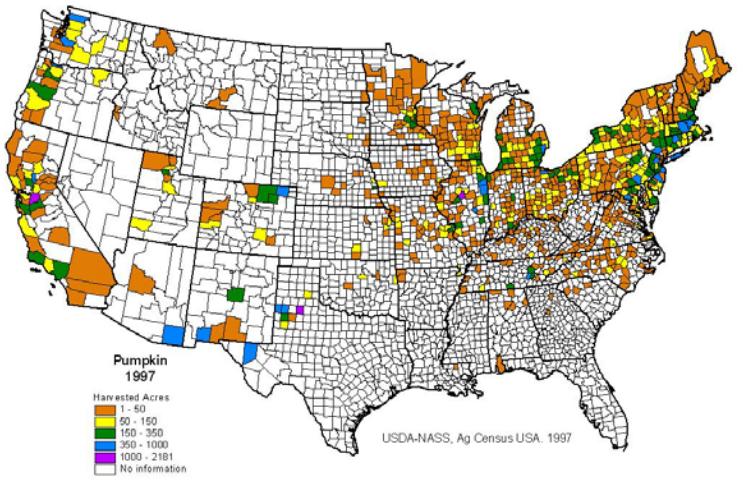
Map 24. Potato (*Solanum tuberosum*)



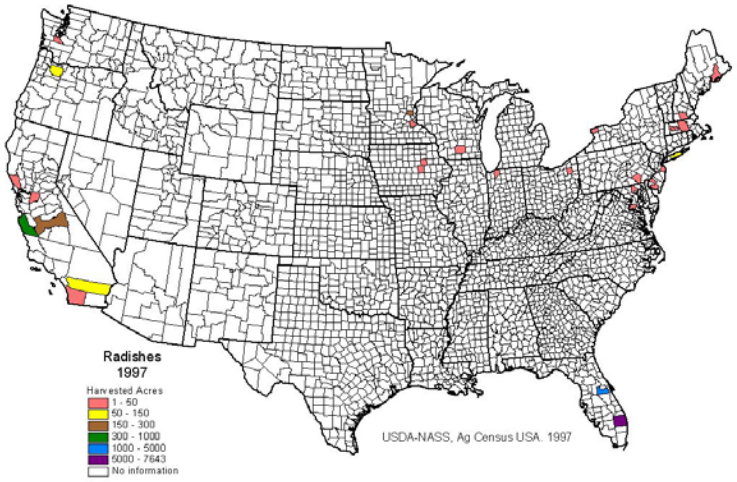
Map 25. Sweet Potato (*Ipomoea batatas*)



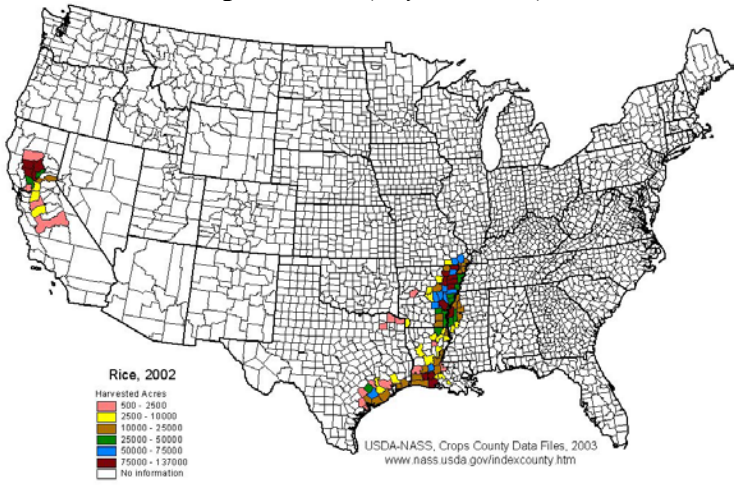
Map 26. Pumpkin (*Cucurbita pepo*)



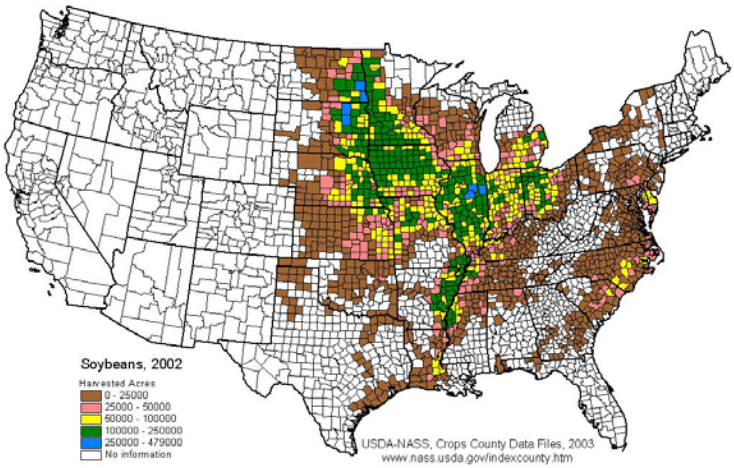
Map 27. Radish (*Raphanus sativus*)



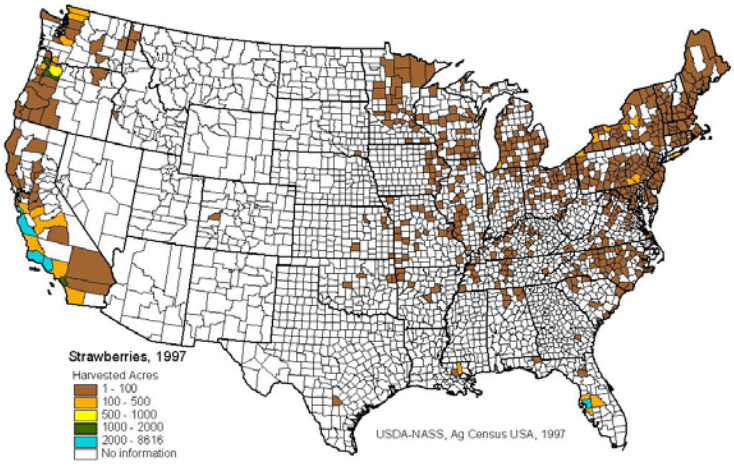
Map 28. Rice (*Oryza sativa*)



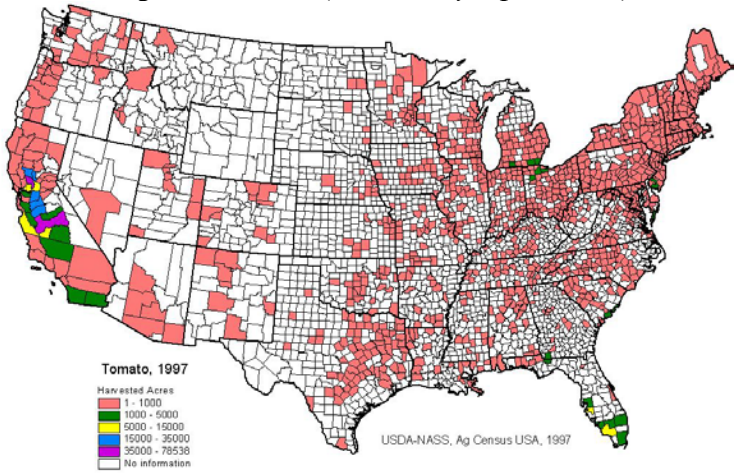
Map 29. Soybean (*Glycine max*)



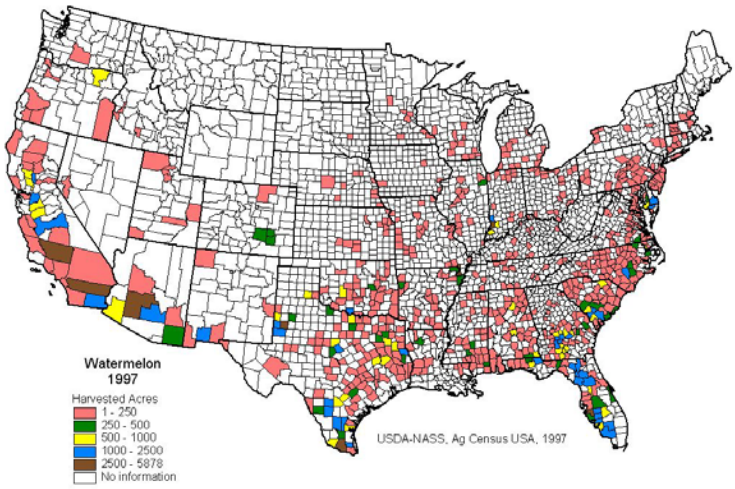
Map 30. Strawberry (*Fragaria* spp., *F. ananassa, F. chiloensis*)



Map 31. Tomato (*Solanum lycopersicum*)



Map 32. Watermelon (*Citrullus lanatus*)



Appendix C. Taxonomy of *Planococcus minor* (Maskell) nom. rev., stat. n., comb. n. [quoted from Cox (1989)]

Pseudococcus calceolariae var. *minor* Maskell, 1897: 322. LECTOTYPE ♀. MAURITIUS: on roots of 'onion grass' (NZAC) here designated [examined].
Planococcus pacificus Cox 1981: 48. Holotype ♀, WESTERN SAMOA (Intercepted in quarantine. Auckland, New Zealand): on croton leaves (BMNH) [examined]. Syn. n.

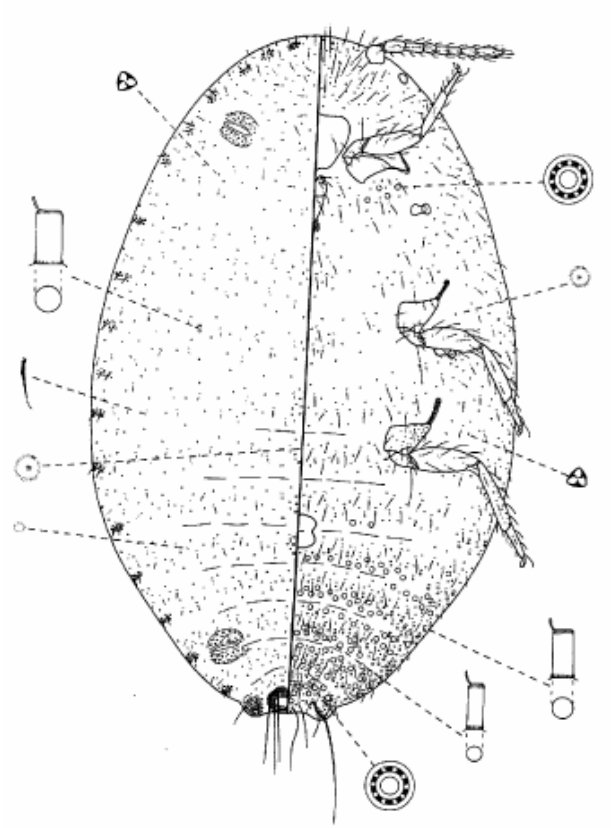


Figure C1. Line drawing of *Planococcus minor* (Maskell) [Reproduced from Cox, 1989]

ADULT FEMALE [Fig C1]. Mounted specimens oval, length 1.3-3.2 mm, width 0.8-1.9 mm. Margin of body with complete series of 18 pairs of cerarii, each cerarius with 2 conical setae, except for preocular cerarii each of which may have 1 or 3 setae. [See Fig. C2 for a general description of the anatomy of *Planococcus* sp.] Legs elongate; hind trochanter + femur 220-360 μm long. hind tibia + tarsus 270-360 μm long, ratio of lengths of hind tibia + tarsus to hind trochanter + femur 1.05-1.15; translucent pores apparent on hind coxae and tibiae. Inner edges of ostioles moderately sclerotized. Circulus quadrate, width 85-160 μm**.** Cisanal setae usually shorter than anal ring setae, occasionally longer. Anal lobe cerarii each situated on a small, moderately sclerotized area.

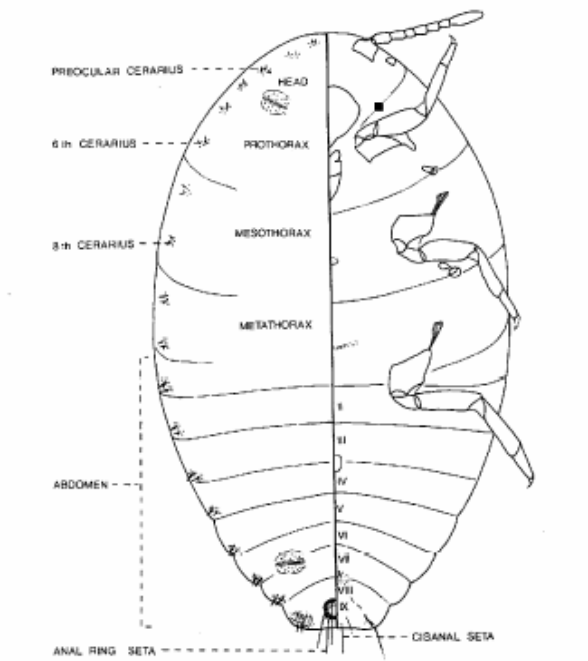


Figure C2. Generalized diagram of *Planococcus* sp. showing numbering of body segments and cerarii
[Reproduced from Cox, 1989]

Venter. Multilocular disc pores present around vulva, in double rows across posterior edges of abdominal segments III-VII (except in very small specimens, hind tibia tarsus less than 250 μm, where these rows may be single), in single rows across anterior edges of segments V-VII or VI-VII, in small groups on margins of abdominal segments IV-VII, sometimes a few pores scattered over median area of the thorax and head, and frequently several pores present behind each front coxa. Trilocular pores moderately numerous and evenly distributed. Oral collar tubular ducts of 2 sizes: smaller ducts present sparsely in rows across median areas of abdominal segments III-VII: larger ducts present in marginal groups on abdominal segments, often present in small numbers on margins of head and thoracic segments (see Table [C1]), and scattered over median area of thorax. Simple pores about the same size as the trilocular pores, sparsely but evenly distributed.

Dorsurm. Multilocular disc pores absent. Tubular ducts, without apparent rims and slightly larger than the larger size on the venter, sometimes present adjacent to some cerarii, 1 or 2 ducts occasionally present on median areas. Trilocular pores as for venter. Simple pores of 2 sizes, smaller pores smaller than those on venter, scattered over dorsum; larger pores about twice the size of the trilocular pores, present in small groups along midline of thoracic and anterior abdominal segments. Setae flagellate and of moderate length, longest seta on abdominal segment VI or VII 23-30 μm long.

... *P. minor* is very similar to *P. citri* [Fig. C3], and the existence of the second species was not established until the variation of individual populations was studied using rearing experiments... . [Morphological characteristics that distinguish *P. citri* from *P. minor* are given in Table C1.]

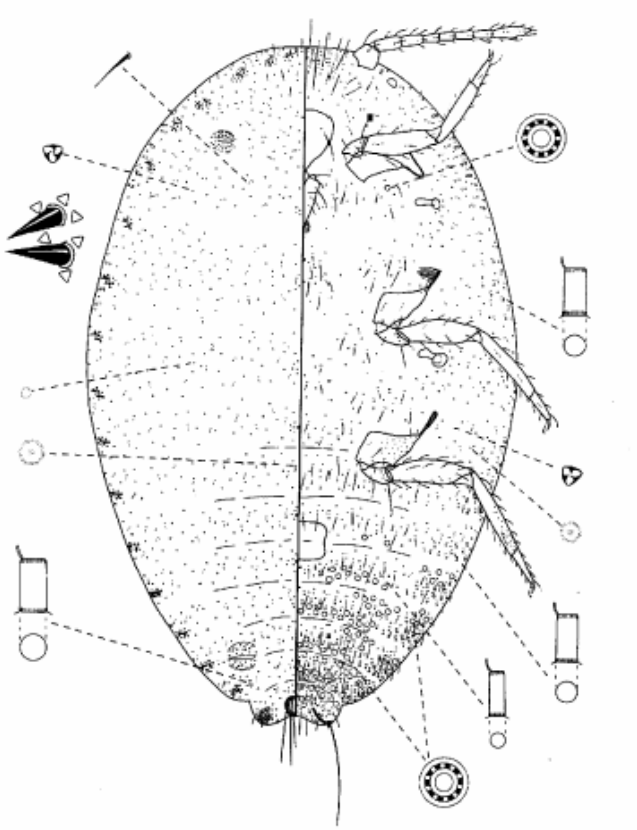


Figure C3. Line drawing of *Planococcus citri* (Risso)
[Reproduced from Cox, 1989]

Table C1. Separation of *P. citri* and *P. minor*

Character		Value	Score
A.	Number of ventral tubular ducts on head	0-3 4-13 14-35	0 10 40
B.	Number of ventral tubular ducts adjacent to 8th pair (numbering from anterior) of cerarii	0-2 3-7 8-30	0 10 40
C.	Tubular ducts present between 2nd and 3rd cerarii on head on at least one side of the body	yes no	10 0
D.	Number of multiocular disc pores behind front coxae	0-6 7-12	5 0
E.	Ratio of length of hind tibia + tarsus to length of trochanter + femur	1.00-1.07 1.08-1.17 1.18-1.30	0 5 10
F.	Width of row of multiocular disc pores on posterior margin of abdominal segment VI	single row intermediate double row	15 5 0

(All numbers are the totals from both sides of the body);
Scores: 0-35 = *minor* (Fig. C1)
35-120 = *citri* (Fig. C3)

Appendix D. Threatened or endangered plants potentially affected by *P. minor*.

Planococcus minor has the potential to adversely affect threatened and endangered plant species. However, because *P. minor* is not known to be established in the US and plant species that are designated threatened or endangered by the US Federal government do not occur outside the US, it is not possible to confirm the host status of these rare plants from the scientific literature. From available host records, *P. minor* is known to be a generalist feeder that affects numerous plant species in over 80 plant families. From these host records, we infer that threatened or endangered plant species which are closely related to known host plants might also be suitable hosts (Table D1). For our purposes closely related plant species belong to the same genus.

Table D1: Threatened and endangered plants in the conterminous U.S. that are potential hosts for *Planococcus minor*.

Documented Host	Threatened and/or Endangered Plant		Protected Status[1]	
	Scientific Name	Common Name	Federal	State
Acacia *sp.,* A. holosericea, *A. spirobis*	*Acacia choriophylla*	cinnecord		FL (E)
Acalypha godseffiana, A. hispida, A. tricolor	*Acalypha deamii*	Deam's threeseed murcury		IN (T)
	A. virginica	Virginia threeseed murcury		NH (T), NY (E)
Amaranthus sp.	*Amaranthus brownii*	Brown's amaranth	E	
	A. pumilus	*seaside amaranth*	T	MD (E), NC (T), NJ (E), NY (E) RI (E)
Bidens pilosa	*Bidens beckii*			IL (E), IN (E), NJ (E)
	B. bidentoides	Delmarva beggarticks		PA (E)
	B. discoidea	small beggarticks		NH (E)
	B. eatonii	Eaton's beggarticks		MA (T), ME (T), NJ (E)
	B. hyperborea	estuary beggarticks		NY (E)
	Bidens hyperborea var. *hyperborea*	estuary beggarticks		MA (E)
	B. laevis	smooth beggarticks		NY (T)
	B. mitis	smallfruit beggarticks		MD (E)
	B. wiebkei	Wiebke's beggarticks	E	
Centrosema pubescens	*Centrosema virginianum*	spurred butterflypea		NJ (E)
Commelina sp.	*Commelina erecta*	whitemouth dayflower		IA (T), NJ (E)

Table D1: Threatened and endangered plants in the conterminous U.S. that are potential hosts for *Planococcus minor*.				
Documented Host	**Threatened and/or Endangered Plant**		**Protected Status**[1]	
	Scientific Name	**Common Name**	**Federal**	**State**
Cordia alliodor, C. myxa	*Cordia bellonis*	serpentine manjack	E	
	C. sebestena	largeleaf geigertree		FL (E)
Croton sp.	*Croton alabamensis*	Alabama croton		TN (E)
	C. glandulosus	vente conmigo		OH (T)
Cucurbita maxima, C. moschata, C. pepo	*Cucurbita okeechobeensis*	Okeechobee gourd	E	FL (E)

Table D1: Threatened and endangered plants in the conterminous U.S. that are potential hosts for *Planococcus minor*.				
Documented Host	**Threatened and/or Endangered Plant**		**Protected Status**[1]	
	Scientific Name	**Common Name**	**Federal**	**State**
Cyperus rotundus	*Cyperus acuminatus*	tapertip flatsedge		IN (E), MN (T), OH (E)
	C. dentatus	toothed flatsedge		IN (E), MD (E)
	C. diandrus	umbrella flatsedge		PA (E), VT (E)
	C. echinatus	globe flatsedge		NY (E)
	C. erythrorhizos	redroot flatsedge		ME (T)
	C. flavescens	yellow flatsedge		NY (E)
	C. grayi	Gray's flatsedge		NH (E)
	C.grayoides	Illinois flatsedge		IL (T)
	C. houghtonii	Houghton's flatsedge		MA (E), NH (T), PA (E), VT (T)
	C. hystricinus	bristly flatsedge		NJ (E)
	C. lancastriensis	manyflower flatsedge		IL (E), NJ (E), OH (E)
	C. lupulinus ssp. *lupulinus*	Great Plains flatsedge		NY (T)
	C. plukenetti	Plukenet's		MD (E), NJ (E)
	C. polystachyos	manyspike flatsedge		NJ (E)
	C. polystachyos var. *texensis*	Texan flatsedge		NY (E)
	C. pseudovegetus	marsh flatsedge		NJ (E)
	C. refractus	feflexed flatsedge		NJ (E), OH (E), PA (E)
	C. retrofractus	rough flatsedge		NJ (E), OH (E),
	C. retrorsus	pine barren flatsedge		NY (E)
	C. squarrosus	bearded flatsedge		RI (E)
	C. trachysanthos	sticky flatsedge	E	
Euphorbia atoto, E. heterophylla, E. pulcherrima	*Euphorbia commutata*	tinted woodland spurge		MI (T)
	E. ipecacuanhae	American ipecac		NY (E), PA (E)
	E. mercurialina	mercury spurge		KY (T)
	E. purpurea	Darlington's glade spurge		MD (E), NJ (E), OH (E), PA (E)

Table D1: Threatened and endangered plants in the conterminous U.S. that are potential hosts for *Planococcus minor*.				
Documented Host	**Threatened and/or Endangered Plant**		**Protected Status**[1]	
	Scientific Name	**Common Name**	**Federal**	**State**
	E. spathulata	warty spurge		IL (E), MD (E), PA (E)
	E. telephioides	telephus spurge	T	FL (E)
Geranium sp.	*Geranium bicknellii*	Bicknell's cranesbill		IL (E), IN (E), OH (E), PA (E)
	G. carolinianum var. *carolinianum*	Carolina geranium		NH (E)
	G. carolinianum var. *sphaerospermum*	Carolina geranium		NY (T)
	G. robertianum	Robert geranium		IN (T), MD (E)
Helianthus sp.	*Helianthus angustifolius*	swamp sunflower		IL (T), NY (T)
	H. carnosus	lakeside sunflower		FL (E)
	H. eggertii	Eggert's sunflower	T	KY (T), TN (T)
	H. giganteus	giant sunflower		IL (E)
	H. glaucophyllus	whiteleaf sunflower		TN (T)
	H. laevigatus	smooth sunflower		MD (E)
	H. micrecephalus	small woodland sunflower		MD (E)
	H. mollis	ashy sunflower		MI (T), OH (T)
	H. niveus ssp. *tephrodes*	Algodones sunflower		CE (E)
	H. occidentalis	fewleaf sunflower		MD (T)
	H. paradoxus	paradox sunflower		NM (E), TX (T)
	H. schweinitzii	Schweinitz's sunflower	E	NC (E)
	H. silphioides	rosinweed sunflower		KY (E)
	H. strumosus	paleleaf woodland sunflower		VT (T)
	Helianthus W *verticillatus* (pro sp.) [*angustifolius* W *grosseserratus*]			TN (E)
Hibiscus manihot	*Hibiscus moscheutos* ssp. *lasiocarpos*	crimsoneyed rosemallow		IN (E)
Ipomoea batatas, *I. pes-caprae*	*Ipomoea microdactyla*	calcareous morning-glory		FL (E)
	I. pandurata	man of the earth		MI (T), NY (E)
	I. tenuissima	rockland morning-glory		FL (E)
Ludwigia octovalis	*Ludwigia decurrens*	wingleaf primrose-willow		PA (E)

Table D1: Threatened and endangered plants in the conterminous U.S. that are potential hosts for *Planococcus minor*.				
Documented Host	**Threatened and/or Endangered Plant**		**Protected Status**[1]	
	Scientific Name	**Common Name**	**Federal**	**State**
	L. glandulosa	cylindric fruit primrose-willow		IN (T), MD (E)
	L. hirtella	spindleroot		KY (E), MD (E)
	L. polycarpa	manyfruit primrose-willow		MA (T), PA (E), VT (E)
	L. sphaerocarpa	globefruit primrose-willow		CT (E), IN (E), MA (T), MI (T), NY (T), RI (E), TN (T)
Manihot esculenta	*Manihot walkerae*	Walker's manihot	E	TX (E)
Mikania scandens	*Mikania scandens*	climbing hempvine		IN (E), NH (T)
Morus sp.	*Morus rubra*	red mulberry		CT (E), MA (E), MI (T), VT (T)
Passiflora edulis	*Passiflora incarnata*	purple passionflower		OH (T)
	P. lutea	yellow passionflower		PA (E)
Persea americana	*Persea borbonia*	red bay		MD (E)
	P. palustris	swamp bay		AR (E)
Phyllanthus niruri	*Phyllanthus caroliniensis*	Carolina leaf-flower		OH (E), PA (E)
	P. liebmannianus	Florida leaf-flower		FL (E)
Pluchea odorata	*Pluchea camphorata*	camphor pluchea		MD (E), OH (E)
	P. foetida	stinking camphorweed		NJ (E)
	P. odorata	sweetscent		PA (E)
Rhus sp.	*Rhus aromatica* var.*arenaria*	fragrant sumac		IN (T)
	R. michauxii	false poison sumac	E	FL (E), GA (E), NC (E)
Rosa chinensis	*Rosa acicularis*	prickly rose		IA (E), IL (E), MA (E), NH (E), VT (E)
	R. acicularis ssp. *sayi*	prickly rose		NY (E)
	R. blanda	smooth rose		MD (E), OH (T)
	R. minutifolia	Baja rose		CA (E)

Table D1: Threatened and endangered plants in the conterminous U.S. that are potential hosts for *Planococcus minor*.				
Documented Host	**Threatened and/or Endangered Plant**		**Protected Status**[1]	
	Scientific Name	**Common Name**	**Federal**	**State**
	R, nitida	shining rose		NY (E)
Rumex sp.	*Rumex altissimus*	pale dock		MD (E)
	Rumex aquaticus var. *fenestratus*	western dock		MI (E)
	R. hastatulus	heartwing sorrel		NY (E)
	R. maritimus	golden dock		NY (E)
	R. pallidus	seaside dock		MA (T), NH (E)
	R. verticillatus	swamp dock		MA (T), MD (E)
Senna alata	*Senna hebecarpa*	American senna		MA (E), VT (T)
Spermacoce assurgens	*Spermacoce glabra*	smooth false buttonweed		MD (E)
Tournefortia argentata	*Tournefortia gnaphalodes*			FL (E)
Tradescantia sp.	*Tradescantia bracteata*	longbract spiderwort		IL (T)
	T. ohiensis	bluejacket		PA (E)
Verbena sp. [2]	*Glandularia maritima*	coastal mock vervain		FL (E)
	G. tampensis	Tampa mock vervain		FL (E)
	Verbena californica	Red Hills vervain	T	CA (T)
	V. simplex	narrowleaf vervain		MA (E), NJ (E)
Vernonia sp.	*Vernonia gigantea*	giant ironweed		NY (E)
	V. glauca	broadleaf ironweed		NJ (E), PA (E)
	V. missurica	Missouri ironweed		OH (E)
Vitis vinifera	*V. aestivalis*	summer grape		ME (E)
	V. cinerea var. *baileyana*	graybark grape		PA (E)
	V. rupestris	sand grape		IN (E), KY (T), PA (E)
	V. vulpina	frost grape		MI (T), NY (E)
	Vitis W *novae-angliae* (pro sp.) [*labrusca* W *riparia*]	pilgrim grape		MD (E), PA (E)

1. E= Endangered; T=Threatened
2. Documented host, *Verbena* sp., may have been synonymized with *Glandularia*

Appendix E. Biology of *Planococcus minor*

Population phenology

With the exception of a few species such as *Planococcus citri*, details about life stages of many mealybugs, particularly *P. minor*, are not well known. *Planococcus citri* has 4-8 generations annually, and within *Planococcus* species, there are typically 4 instars for females and 5 for males (McKenzie 1967, Williams 1985). In Israel, generation time ranges from 4-6 weeks during summer months and approximately 3 months in winter (Mendel and Blumberg 2004). Development rate and the number of generations is highly variable and determined by several factors including plant host selection and feeding site as these relate to nutrition, temperature, population density of the mealybug complex, and the presence of predators (McKenzie 1967, Miller and Kosztarab 1979, Williams 1985). Population density may also vary depending on the presence of ants (several genera) that are known to have an association with *Planococcus* species. Ants have been observed feeding on the honeydew excretions of mealybugs and protecting this important food source from predators. Ants may also play a role in mealybug dispersal. Other ants may be predaceous. Ants may also be selective of the mealybug species they tend, when multiple species are present. Mealybug populations closely associated with ants tend to be larger than non-tended populations of the same species(McKenzie 1967, Lamb 1974, Youdeowei and Service 1983, Buckley and Gullan 1991).

Stage specific biology

Most species are thought to reproduce sexually, though some parthenogenesis may occur. To further add to the complexity, hybrid crosses of *P. citri* and *P. ficus* have been observed under laboratory conditions, which suggests that similar hybridization may occur among closely related species in a mealybug complex under natural conditions (Williams 1985).

In laboratory studies, *P. minor* females produced between 65-425 eggs on varying hosts (Maity et al. 1998, Martinez and Suris 1998, Biswas and Ghosh 2000). Preoviposition period ranged from 8-12 days, incubation period lasted approximately 3 days. The time to complete 1 generation ranged from 31-50 days. The median development time for males was slighlty longer in duration than for females (Table E1).

Table E1. Median development time (days) for male and female instars on various hosts in the laboratory.

Larval instar	Male	Female
First	8.22	8.01
Second	15.18	13.29
Third	17.67	17.49
Fourth	21.36	NA
Total median duration (days)		