Mini Risk Assessment
Egyptian cotton leafworm, *Spodoptera littoralis* Boisduval
[Lepidoptera: Noctuidae]

Robert C. Venette, Erica E. Davis, Jennifer Zaspel, Holly Heisler, & Margaret Larson
Department of Entomology, University of Minnesota
St. Paul, MN 55108
September 27, 2003

Introduction

Spodoptera littoralis is a polyphagous pest that poses a high degree of risk to US agriculture and ecosystems. In a pathway-initiated risk assessment, this insect was judged highly likely of establishing in the US should it be introduced; the consequences of its establishment were considered severe (Lightfield 1997). In a pest-specific risk assessment, Fowler and Lakin (2001) concluded that if this pest if it were introduced it would be highly likely of encountering a suitable climate and hosts in much of the US and causing severe economic and environmental consequences.

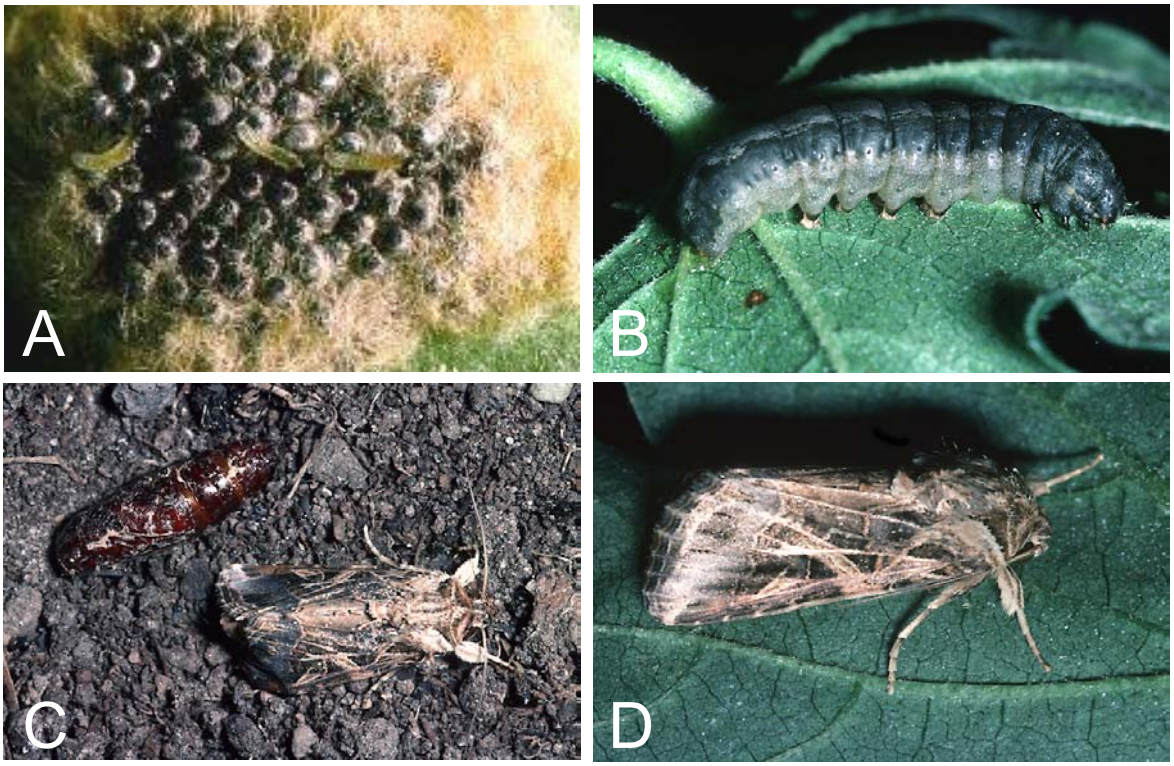


Figure 1. Life stages of *Spodoptera littoralis*, images not to scale: (A) neonates and egg mass covered in scales from female; (B) late instar larva; (C) pupa and adult on soil; (D), adult on leaf [Image A from http://www.defra.gov.uk/planth/pestnote/spod.htm; B-D from Entopix]

1. **Ecological Suitability. Rating: High.** *Spodoptera littoralis* can be found in the Mediterranean, the Middle East, and in most of Africa (CIE 1967, Zhang 1994). The climates within its range can be characterized as dry, tropical, and temperate climates (CAB 2003). Available geographic records of the distribution of

S. littoralis, suggest the species may be most closely associated with deserts and xeric shrublands; Mediterranean scrub; temperate broadleaf and mixed forests; tropical and subtropical grasslands, savannas, and shrublands; and tropical and subtropical moist broadleaf forests. Based on the distribution of climate zones in the US, we estimate that approximately 49% of the continental US would be suitable for *S. littoralis* (Fig. 2). See Appendix A for a more detailed description of this analysis.

Our analysis generally concurs with the findings of Fowler and Lakin (2001) but suggests that the southeastern US would be less favorable, and the upper Midwest, more favorable, than they had predicted.

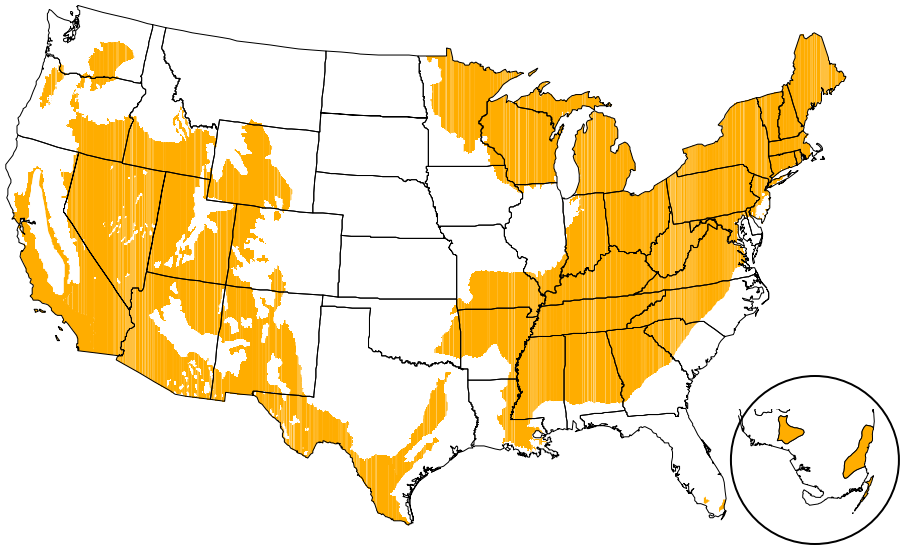


Figure 2. Predicted distribution of *Spodoptera littoralis* in the continental US. Southern Florida is enlarged for detail.

2. **Host Specificity/Availability. Rating Low/High** *Spodoptera littoralis* is highly polyphagous and has hosts in 40 plant families (Salama et al. 1970, Brown and Dewhurst 1975, Zhang 1994, CAB 2000, Pogue 2003). Host plants include: alfalfa/lucerne (*Medicago sativa*), anemone (*Anemone* sp.), apple (*Malus domestica*), apple of Peru (*Nicandra physaloides*), artichoke (*Cynara scolymus*), arum (*Arum* sp.), aubergine/eggplant (*Solanum melongena*), avocado (*Persea americana*), banana (*Musa x paradisiaca*), beach sheoak (*Casuarina equisetifolia*), bean/green bean/kidney bean/dry edible bean (*Phaseolus vulgaris*), beet (*Beta vulgaris*), bindweed/field bindweed (*Convolvulus* sp., *C. arvensis*), black gram (*Vigna mungo*), blackeyed pea (*Vigna unguiculata*), broad bean/horsebean (*Vicia faba*), brown indianhemp (*Hibiscus cannabinus*), brussels sprouts (*Brassica oleracea* var. *gemmifera*), butterfly pea (*Centrosema* sp.), caladium (*Caladium* sp.), canna (*Canna* sp.), cardoon (*Cynara cardunculus*), carnation (*Dianthus caryophyllus*), carrot (*Daucus carota* ssp. *sativus*), castor bean (*Ricinus communis*), cheeseweed mallow (*Malva parviflora*), chickory

(*Cichorium intybus*), China aster (*Callistephus chinensis*), chrysanthemum (*Chrysanthemum* sp.), chulta (*Dillenia indica*), citrus/sour orange (*Citrus* spp., *C. aurantium*), clover/Egyptian clover (*Trifolium* sp., *T. alexandrinum*), coco yam (*Colocasia esculenta*), cocoa/cacao (*Theobroma cacao*), coffee (*Coffea arabica*), corn (*Zea mays*), cotton (*Gossypium hirsutum*, *G. barbadense*), cowpea (*Vigna unguiculata*), cruciferous crops (*Brassica* spp.), cypress (*Cupressus* sp., *C. lusitanica* var. *lusitanica*), daisy (*Dendranthema* sp., *D. indicum*), date palm (*Phoenix dactylifera*), datura (*Datura* sp.), Dixie rosemallow (*Hibiscus mutabilis*), eggplant/aubergine (*Solanum melongena*), Egyptian riverhemp (*Sesbania sesban*), elegant zinnia (*Zinnia violacea*), erect spiderling (*Boerhavia erecta*), European heliotrope (*Heliotropium europaeum*), fig (*Ficus* spp., *F. variegata*), fig/edible (*Ficus carica*), finger millet (*Eleusine coracana*), fire on the mountain (*Euphorbia cyathophora*), flax (*Linum usitatissimum*), florist's cineraria (*Pericallis x hybrida*), garden pepper (*Capsicum* sp., *C. annuum*), gerbera daisy (*Gerbera* sp.), giant golden taro (*Xanthosoma mafaffa*), gladiolus (*Gladiolus* sp.), Gnaphalium (*Gnaphalium* sp., *G. luteo-album*), gourd/pumpkin (*Cucurbita pepo*), grain amaranth (*Amaranthus* spp.), grape (*Vitis vinifera*), grasses (Poaceae), guava (*Psidium guajava*), gum arabic tree (*Acacia nilotica*), high mallow (*Malva sylvestris*), hollyhock (*Alcea rosea*), Indian rosewood (*Dalbergia sissoo*), Japanese cedar (*Cryptomeria* sp.), Jerusalem artichoke (*Helianthus tuberosus*), jute/nalta jute (*Corchorus capsularis*, *C. olitorius*), lantana (*Lantana* sp.), lettuce (*Lactuca sativa*), little hogweed (*Portulaca oleracea*), macadamia nut (*Macadamia ternifolia*), melons (*Cucumis melo*, *Citrullus lanatus*), Mexican fireplant (*Euphorbia heterophylla*), mulberry (*Morus* sp), mung bean (*Vigna radiata*), nettleleaf goosefoot (*Chenopodium murale*), nightshade (*Solanum* sp., *S. anguivi*, *S. grandiflorum*, *S. villosum*), okra (*Abelmoschus esculentus*), onion (*Allium cepa*), oranges/other citrus (*Citrus* spp.), parsley (*Petroselinum crispum*), pea (*Pisum sativum*), peanut/groundnut (*Arachis hypogaea*), pear (*Pyrus communis*), pepper (*Capsicum* spp.), pepper (*Piper* sp.), philodendron (*Philodendron* sp., *P. domesticum*), pine (*Pinus* sp., *P. kesiya*), plantain (*Musa paradisiaca*), plum (*Prunus domestica*), pokeweed (*Phytolacca dodecandra*), pomegranate (*Punica granatum*), potato (*Solanum tuberosum*), pricklypear (*Optunia* sp., *Cactus optunia*), prostrate pigweed (*Amaranthus albus*), radish (*Raphanus sativus*), rape mustard (*Brassica rapa* ssp. *rapa*), redroot amaranth (*Amaranthus retroflexus*), rhubarb (*Rheum rhabarbarum*, *R. rhaponticum*), ribbon bush (*Muehlenbeckia platycladum*), rice (*Oryza sativa*), roses (*Rosa* spp.), sage (*Salvia officinalis*), sesame (*Sesamum orientale*), sicklefruit fenugreek (*Trigonella foenum-graecum*), sorghum (*Sorghum bicolor*), sorrel (*Rumex acetosa*), soybean (*Glycine max*), spearmint (*Mentha spicata*), spinach (*Spinacia oleracea*), sponge gourd (*Luffa aegyptiaca*), sugarbeet (*Beta vulgaris*), sugarcane (*Saccharum officinarum*), sunflower (*Helianthus annuus*), swallow-wort (*Cyanchum* sp., *C. acutum*), sweet basil (*Ocimum basilicum*), sweet potato (*Ipomoea batatas*), sweet violet (*Viola odorata*), sweetwilliam (*Dianthus barbatus*), Sydney bluegum (*Eucalyptus saligna*), tapioca (*Manihot esculenta*), tarovine (*Monstera deliciosa*), Tasmanian bluegum (*Eucalyptus globulus*), tea (*Camellia sinensis*), tobacco (*Nicotiana tabacum*), tomato (*Lycopersicon esculentum*), tree tobacco (*Nicotiana*

glauca), true indigo (*Indigofera tinctoria*), turkey berry (*Solanum torvum*), umbrella-tree (*Maesopsis eminii*), verbena/vervain (*Verbena* sp.), water hyacinth (*Eichhornia crassipes*), water lettuce (*Pistia stratiotes*), wheat (*Triticum aestivum*), white poplar (*Populus alba*), wild celery (*Apium graveolens*), wild coffee (*Psychotria* sp., *P. capensis*), and woodland strawberry (*Fragaria vesca*).

See Appendix B for detailed maps of where hosts plants for *S. littoralis* are grown commercially in the US.

3. **Survey Methodology. Rating: Medium** A number of sampling considerations for *S. littoralis* have been proposed: Surveys for this pest can take place any time during the growing season while plants are actively growing; early instars (<3rd) are likely to be on lower leaf surfaces during the day; larvae will skeletonize leaves by feeding on this surface and such damage to the leaf provides evidence of the presence of larvae; sweep net sampling may be effective at dawn or dusk; specimen identification should be confirmed by a trained taxonomist (USDA 1982). However, not all sampling methods are equally effective for all life-stages of the insect. Eggs are only likely to be found by visual inspection of leaves. First through third instars may be detected by sweep net sampling; nearly all instars can be detected by visual inspection of plants; and, later instars (4th-6th) and pupae may be found by sieving soil samples (Abul-Nasr and Naguib 1968, Abul-Nasr et al. 1971).

   Active traps (either light- or pheromone-based) have been recommended for monitoring relative densities of adults (DEFRA 1999). The synthetic sex pheromone (*Z*,*E*)-(9,11)-tetradecadienyl acetate has proven highly effective at trapping male moths of *S. littoralis* (Salem and Salama 1985). Sex-pheromone baited delta traps remained attractive for approximately 2 weeks, but effectiveness declined after 3 to 4 weeks of use (Ahmad 1988). To monitor male flight activity in vegetable production areas, delta traps were placed 1.7 m above the ground at a rate of 2 traps/ha (approximately 1 trap/acre) (Ahmad 1988). Pheromone lures impregnated with 2 mg of the pheromone blend (blend not specified) were replaced after 4 weeks of use (Ahmad 1988). Traps are deployed at a similar height (1.5 m) to monitor male flight in cotton (Salem and Salama 1985). Catches in pheromone traps did not correlate as well with densities of egg-masses in cotton fields as did catches in a black-light trap (Rizk et al. 1990b). The attractiveness of traps baited with (*Z*,*E*)-(9,11)-tetradecadienyl acetate is governed primarily by minimum air temperature; relative humidity, adult abundance, wind velocity, densities of female *S. littoralis* also affect the number of males that are captures at different times of the year (Rizk et al. 1990a).

   Lures for *S. littoralis* can be used in the same traps with lures for *S. litura*, *Helicoverpa armigera*, *Pectinophora scutigera* (all not known to occur in the US), and *P. gossypiella* (exotic established in US). Lures for *S. littoralis* may also attract *Erastria* sp. (established in US) (PPQ 1993).

Light traps using a 125 W mercury-vapor bulb have been used to non-discriminately capture multiple *Spodoptera* spp. (Blair 1974) and most assuredly other insects as well. A modified light trap using six 20-W fluorescent lights also proved an effective for monitoring flight activity of *S. littoralis* (El-Mezayyen et al. 1997).

4. **Taxonomic Recognition**. **Rating: Low.** *Spodoptera littoralis* and *S. litura*, another exotic lepidopteran pest, have long been "taxonomically confused" (Mochida 1973). Because of their morphological similarities, the two species were erroneously considered as a single species in historical literature (Hafez and Hassan 1969, CABI/EPPO 1997). Both species are difficult to distinguish without close examination of the genitalia (Mochida 1973, Brown and Dewhurst 1975, DEFRA 1999). With regard to geographical distribution, "the ranges of the two species do not currently overlap and neither has extended its range (except in the special case of glasshouses in Europe)" (CABI/EPPO 1997). Unlike *S. littoralis*, *S. litura* is found in much of southeastern Asia and Oceania (IIE 1993).

   See Appendix C for a more detailed description of the taxonomy and morphology of *S. littoralis*.

5. **Entry Potential. Rating: High.** Interceptions of *S. littoralis* or "*Spodoptera* sp." have been reported 1,460 times since 1985 on fruits, vegetables, ornamentals, and other miscellaneous plants (USDA 2003). Each year approximately 77 (±7.6 standard error of the mean) interceptions of *S. littoralis* or "*Spodoptera* sp." have been reported (USDA 2003). The majority of interceptions have been associated with permit cargo (59%), general cargo (24%), and international airline passengers (16%).

   The pest has been intercepted at 49 international ports of entry, including ports in Hawaii. The majority of interceptions have been reported from JFK International Airport (52%), Honolulu (17%), Miami (8%), Los Angeles (5%), Houston (2%), Atlanta (2%), and San Francisco (2%). These ports are the first points of entry for cargo or international airline passengers coming into the US and do not necessarily represent the intended final destination of infested material. Movement of potentially infested material within the US is more fully characterized later in this document. *Spodoptera littoralis* or "*Spodoptera* sp." have been intercepted in association with nearly 230 plant taxa.

6. **Destination of Infested Material. Rating: High.** When an actionable pest is intercepted, officers ask for the intended final destination of the conveyance. Cargo or passengers were destined for 32 states, including the District of Columbia. The most commonly reported destinations were New York (48%), California (18%), Florida (10%), Hawaii (4%), Texas (4%), New Jersey (3%), Pennsylvania (2%), Washington (2%), and Georgia (2%). We note that some portion of each of these states has a climate and hosts that would be suitable for establishment by *S. littoralis*.

7. **Potential Economic Impact. Rating: High.** A brief history of the direct effects of *S. littoralis* on the quantity and quality of food and fiber crops is provided by (USDA 1982), and this history suggests that the pest can have devastating consequences. In the late 1930's, *S. littoralis* lowered cotton yields by as much as 75% (USDA 1982). Currently, this pest remains "one of the most destructive agricultural lepidopterous pests within its subtropical and tropical range. It can attack numerous economically important crops all the year round" (CABI/EPPO 1997). The pest is particularly problematic on vegetables, ornamentals, and leguminous forage in the Mediterranean (Inserra and Calabretta 1985, CABI/EPPO 1997) and on cotton in Egypt (Inserra and Calabretta 1985, CABI/EPPO 1997).

   The economic consequences of establishment by *S. littoralis* would not be limited to its direct effects on production agriculture; *S. littoralis* could also adversely affect access to foreign markets. The European and Mediterranean Plant Protection Organization (EPPO) considers *S. littoralis* an A2 quarantine pest; the pest also has quarantine status with the Caribbean Plant Protection Commission (CPPC), the Organismo Internacional Regional de Sanidad Agropecuaria (OIRSA), the North American Plant Protection Organization (NAPPO), Belarus, Russia, Ukraine, and Turkey (CABI/EPPO 1997, EPPO 1999).

8. **Establishment Potential. Rating: Medium-High.** No infestations of *S. littoralis* have been reported in the wild in the United States. Thus, the potential for establishment remains speculative. This insect is intercepted regularly from cargo and international airline passengers that are destined for much of the US. Many of these areas are likely to provide a suitable climate, in terms of temperature and moisture. Because of the very broad host range of the species, this insect is very likely to find a suitable host. In fact, larvae of *S. littoralis* have been successfully reared on lawn grass (Blair 1974). Thus, the possibility exists for this species to be an urban pest as well.

   For a detailed description of the biology of *S. littoralis*, see Ellis (2003).

References:

Abul-Nasr, S., and M. A. Naguib. 1968. The population density of larvae and pupae of *Spodoptera littoralis* (Boisd.) in clover fields in Egypt (Lepid.: Agrotidae). Bulletin De La Societe Entomologique D'Egypte 52: 297-312.

Abul-Nasr, S., S. I. El-Sherif, and M. A. Naguib. 1971. Relative efficiency of certain sampling methods for the assesment of the larval and pupal populations of the cotton leafworm *Spodoptera littoralis* (Boisd.) (Lepid.: Agrotidae) in clover fields. Journal of Applied Entomology/Zeitschrift für Angewandte Entomologie 69: 98-101. PDF

Ahmad, T. R. 1988. Field studies on sex pheromone trapping of cotton leafworm *Spodoptera littoralis* (Boisd.) (Lep.: Noctuidae). Journal of Applied Entomology/Zeitschrift für Angewandte Entomologie 105: 212-215. PDF

Blair, B. W. 1974. Identification of economically important *Spodoptera* larvae (Lepidoptera: Noctuidae). In: Scientific Note. Journal of the Entomological Society of Southern Africa 37: 195-196. PDF

Brown, E. S., and C. F. Dewhurst. 1975. The Genus *Spodoptera* (Lepidoptera: Noctuidae) in Africa and the Near East. Bulletin of Entomological Research 65: 221-262. PDF

CAB. 2000. Crop protection compendium:global module. Commonwealth Agricultural Bureau International, Wallingford, UK.

CAB. 2003. Crop protection compendium: global module. Commonwealth Agricultural Bureau International, Wallingford, UK.

CABI/EPPO. 1997. Quarantine pests for Europe, 2nd Ed. CAB International, Wallingford, UK. PDF

CIE. 1967. *Spodoptera littoralis* (Boisd.). Distribution Maps of Pests, Series A, Map No. 232. Commonwealth Institute of Entomology/Commonwealth Agricultural Bureau, Wallingford, UK. PDF

DEFRA. 1999. *Spodoptera* species, PB 4641(a), 1999. Department for Environment, Food and Rural Affairs. Central Science Laboratory. www.defra.gov.uk/planth/pestnote/spod.htm.

Ellis, S. D. [ed.] 2003. New pest response guidelines: genus *Spodoptera*. US Department of Agriculture, Marketing and Regulatory Programs, Riverdale, MD.

El-Mezayyen, G. A., A. A. El-Dahan, G. M. Moawad, and M. S. Tadros. 1997. A modified light trap as a tool for insects survey in relation to the main weather factors. Egyptian Journal of Agricultural Research 75: 995-1005. PDF

EPPO. 1999. EPPO PQR (Plant Quarantine Report) database (version 3.8). European Plant Protection Organization, Paris.

Fowler, G., and K. Lakin. 2001. Risk Assessment: The cotton leafworm, *Spodoptera littoralis* (Boisduval), (Lepidoptera: Noctuidae), pp. 1-17. USDA-APHIS, Center for Plant Health Science and Technology (Internal Report), Raleigh, NC.

Hafez, M., and S. M. Hassan. 1969. On the correct identity of the Egyptian cotton leafworm (Lepidoptera: Noctuidae). Bulletin de la Societe Entomologique d'Egypte 53: 63-68. PDF

IIE. 1993. *Spodoptera litura* (Fabricius). Distribution Maps of Pests, Series A, Map No.61. Commonwealth Institute of Entomology/Commonwealth Agricultural Bureau, Wallingford, UK. PDF

Inserra, S., and C. Calabretta. 1985. Attack by noctuids: a recurring problem in greenhouse crops of the Ragusa coast. Tecnica Agricola 37: 283-297. PDF

Lightfield, J. 1997. Importation of tomato fruit, *Lycopersicon esculentum* from France into the United States: qualitative, pathway-initiated pest risk assessment. Animal and Plant Health Inspection Service, US Department of Agriculture, Riverdale, MD.

Mochida, O. 1973. Two important insect pests, *Spodoptera litura* (F.) and *S. littoralis* (Boisd.) (Lepidoptera: Noctuidae), on various crops --Morphological discrimination of the adult, pupal, and larval stages. Applied Entomology and Zoology 8: 205-214. PDF

Olson, D. M., E. Dinerstein, E. D. Wikramanayake, N. D. Burgess, G. V. N. Powell, E. C. Underwood, J. A. D'Amico, I. Itoua, H. E. Strand, J. C. Morrison, C. J.

Loucks, T. F. Allnutt, T. H. Ricketts, Y. Kura, J. F. Lamoreux, W. W. Wettengel, P. Hedao, and K. R. Kassem. 2001. Terrestrial ecoregions of the world: a new map of life on earth. BioScience 51: 933-938.

Pogue, M. G. 2002. A world revision of the genus *Spodoptera* Guenée (Lepidoptera: Noctuidae). Memoirs of the American Entomological Society 43.

Pogue, M. G. 2003. World *Spodoptera* database (Lepidoptera: Noctuidae). US Department of Agriculture, Systematics and Entomology Laboratory, Beltsville, MD. http://www.sel.barc.usda.gov/lep/spodoptera/spodoptera.html.

PPQ. 1993. Fact sheet for exotic pest detection survey recommendations. Cooperative Agricultural Pest Survey (CAPS) and Plant Protection and Quarantine, US Department of Agriculture. http://www.ceris.purdue.edu/napis/pests/misc/fexotic.txt.

Rizk, G. A., M. A. Sliman, and H. M. Ismael. 1990a. Factors affecting the attraction of male moths of the cotton leafworm, *Spodoptera littoralis* (Boisd.) to sex pheromone traps. Assuit Journal of Agricultural Sciences 21: 72-84. PDF

Rizk, G. A., M. A. Soliman, and H. M. Ismael. 1990b. Efficiency of sex pheromone and U.V. light traps in attracting male moths of the cotton leafworm, *Spodoptera littoralis* (Boisd.). Assuit Journal of Agricultural Sciences 21: 86-102. PDF

Salama, H. S., N. Z. Dimetry, and S. A. Salem. 1970. On the host preference and biology of the cotton leaf worm *Spodoptera littoralis*. Zeitung für Angewandte Entomologie 67: 261-266. PDF

Salem, S., and H. S. Salama. 1985. Sex pheromones for mass trapping of *Spodoptera littoralis* (Boisd.) in Egypt. Journal of Applied Entomology/Zeitschrift für Angewandte Entomologie 100: 316-319. PDF

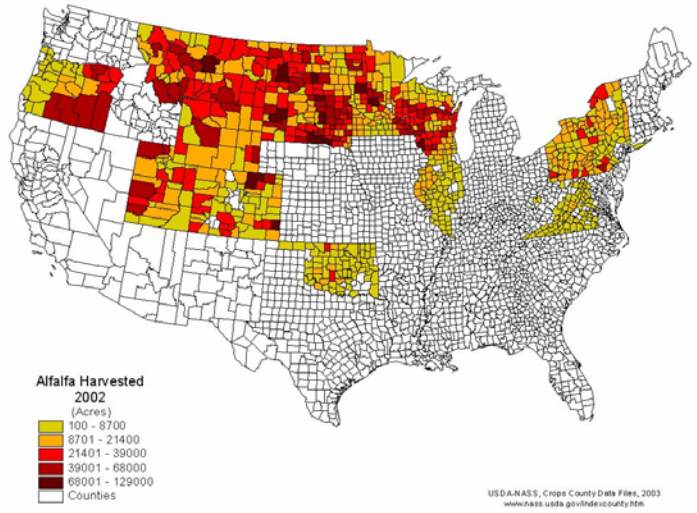
USDA. 1982. Pests not known to occur in the United States or of limited distribution, No. 25: Egyptian cottonworm., pp. 1-14. APHIS-PPQ, Hyattsville, MD. PDF

USDA. 2003. Port Information Network (PIN-309): quarantine status database. US Department of Agriculture, Animal and Plant Health Inspection Service, Plant Protection and Quarantine, Riverdale, MD. restricted access database.

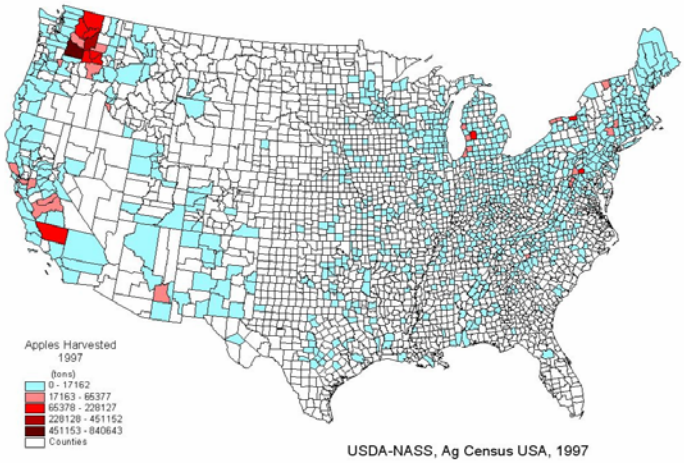
Zhang, B. C. 1994. Index of economically important Lepidoptera. CAB International, Wallingford, UK. PDF

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 (CAB 2000). 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.

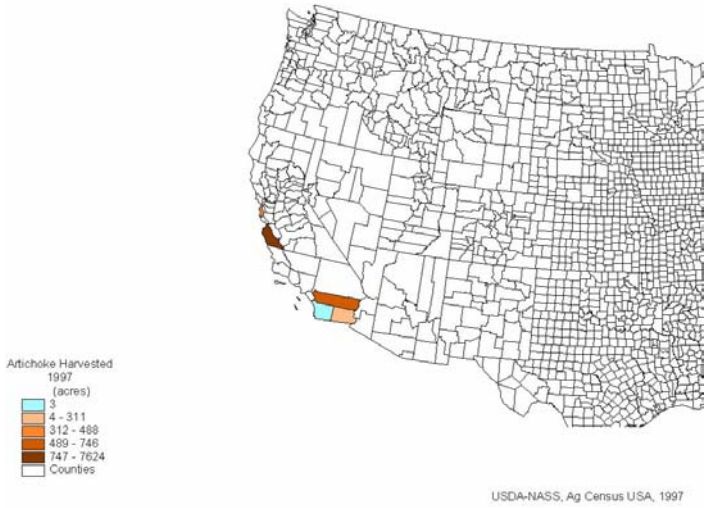
Appendix B. Commercial production of hosts of *Spodoptera littoralis* in the continental US.



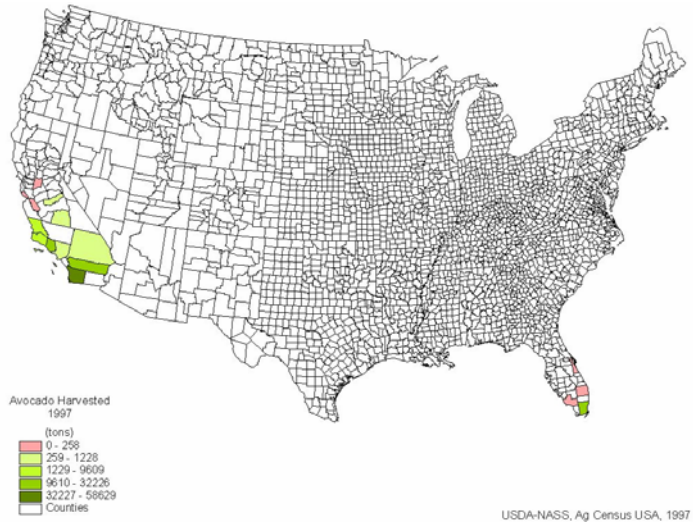
Map 1. Alfalfa (*Medicago sativa*)



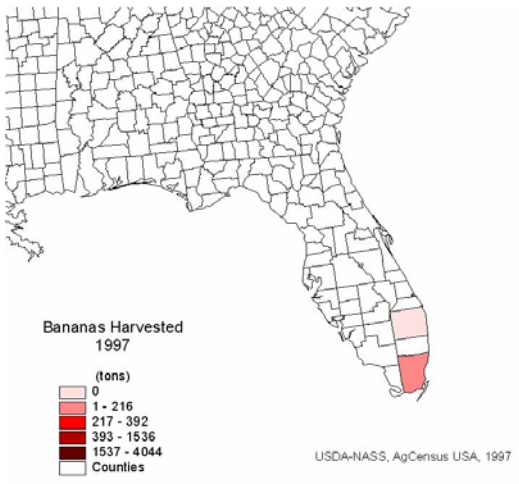
Map 2. Apple (*Malus domestica*)



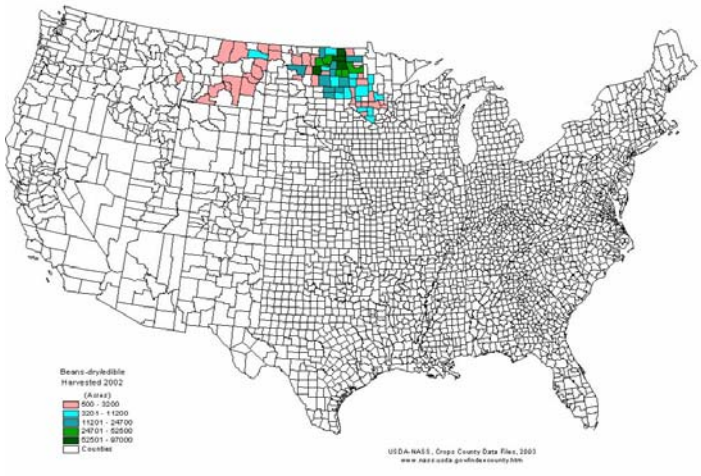
Map 3. Artichoke (*Cynara scolymus*)



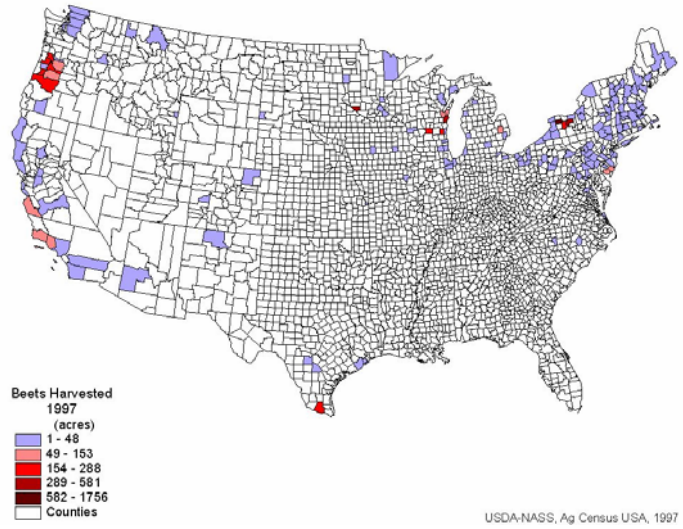
Map 4. Avocado (*Persea americana*)



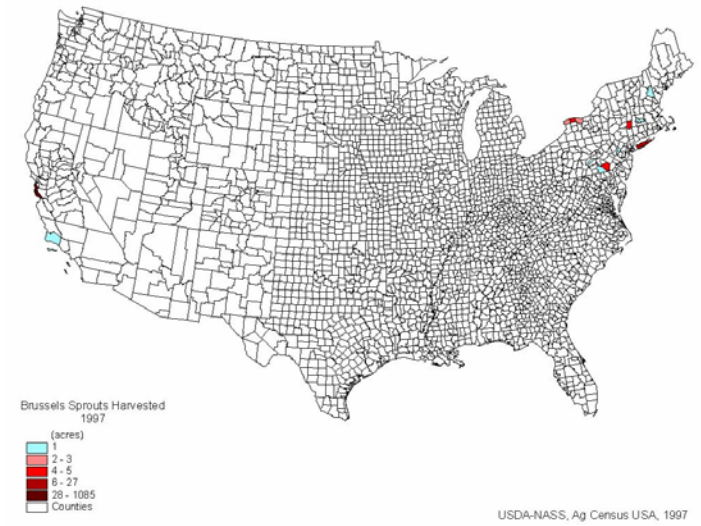
Map 5. Banana (*Musa x paradisiaca*)



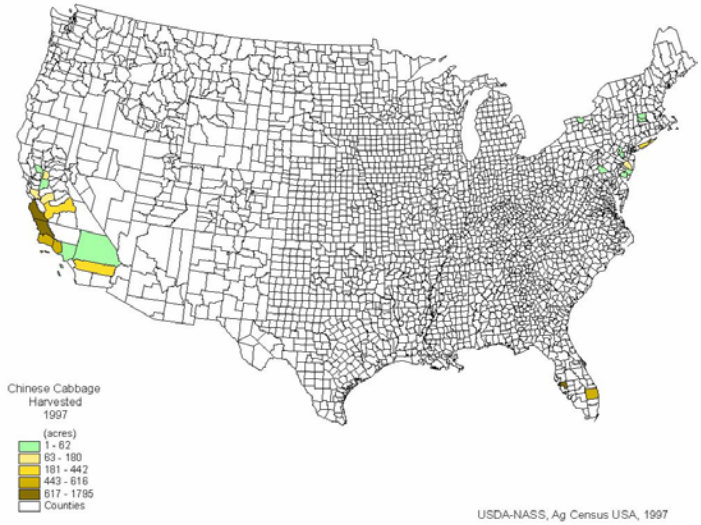
Map 6. Beans; dry edible (*Phaseolus vulgaris*)



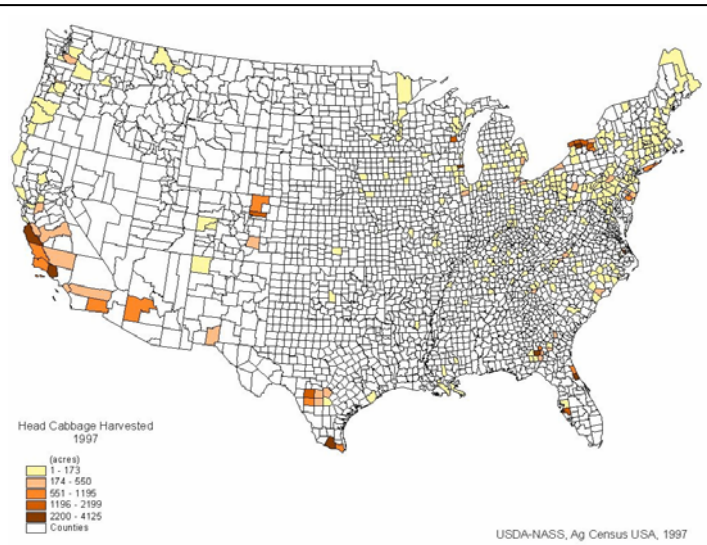
Map 7. Beet (*Beta vulgaris*)



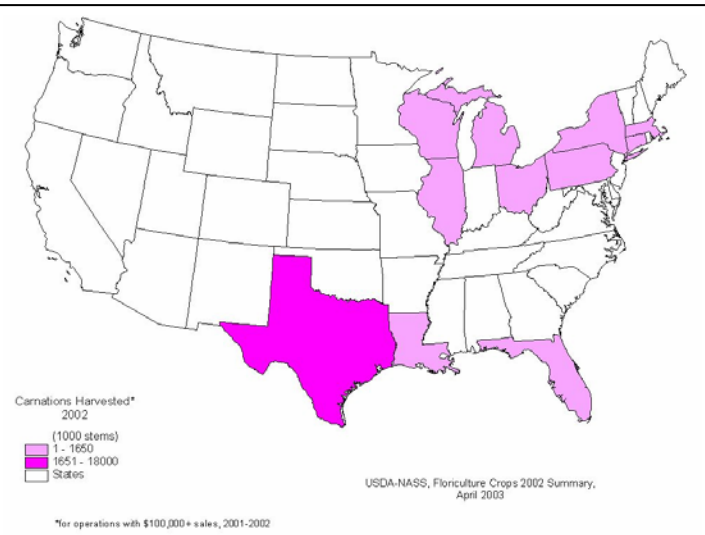
Map 8. Brussels sprouts (*Brassica oleracea* ssp. *gemmifera*)



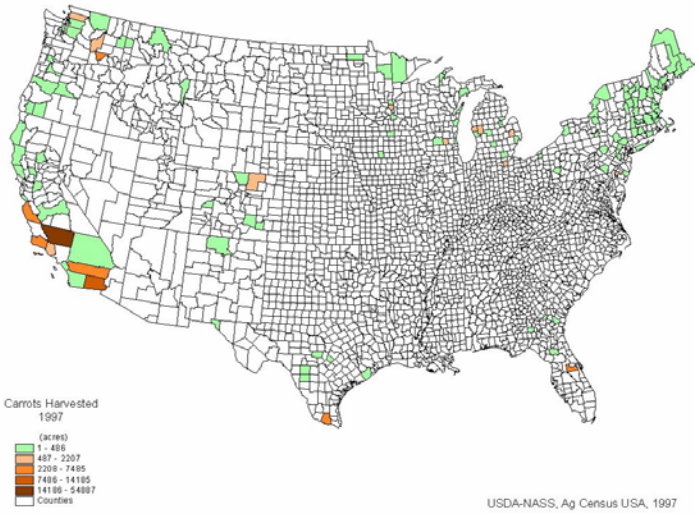
Map 9. Cabbage; Chinese (*Brassica oleracea* spp.)



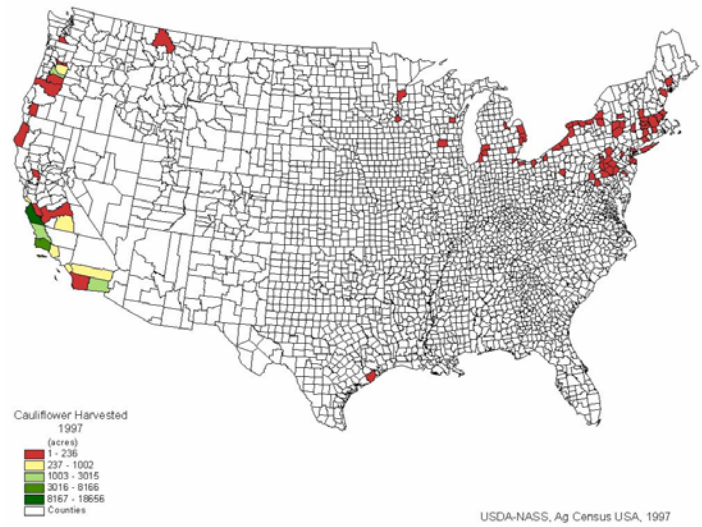
Map 10. Cabbage; head (*Brassica oleracea* spp.)



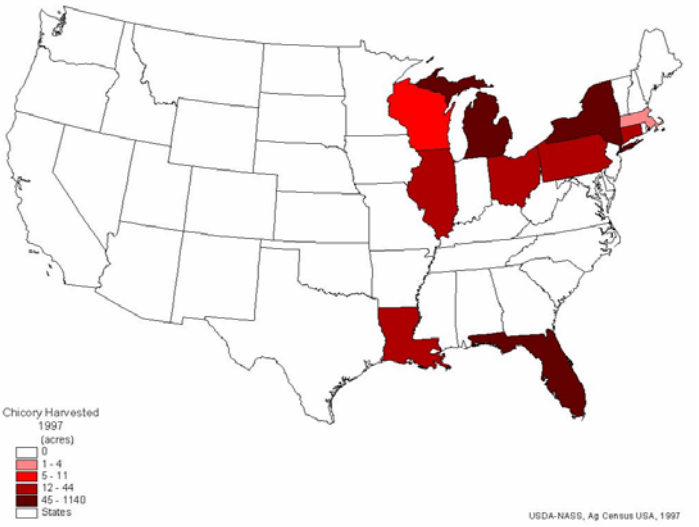
Map 11. Carnation (*Dianthus caryophyllus*)



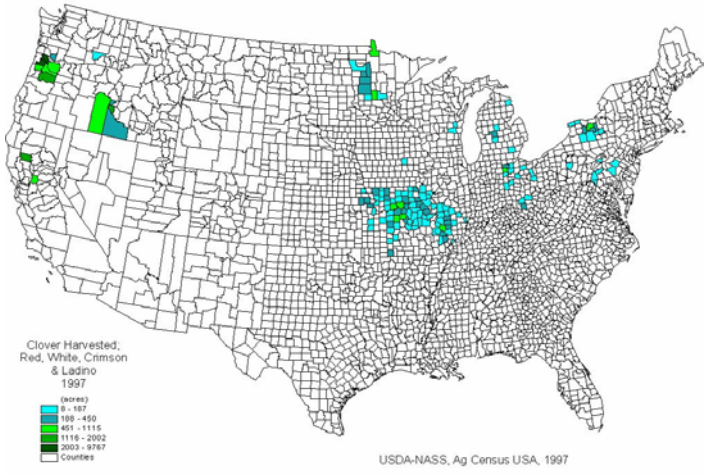
Map 12. Carrot (*Dacus carota* ssp. *sativus*)



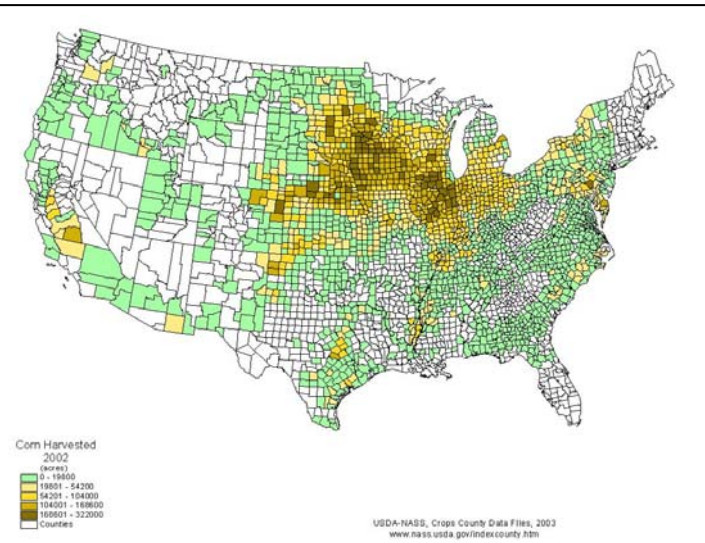
Map 13. Cauliflower (*Brassica oleracea* ssp. *botrytis*)



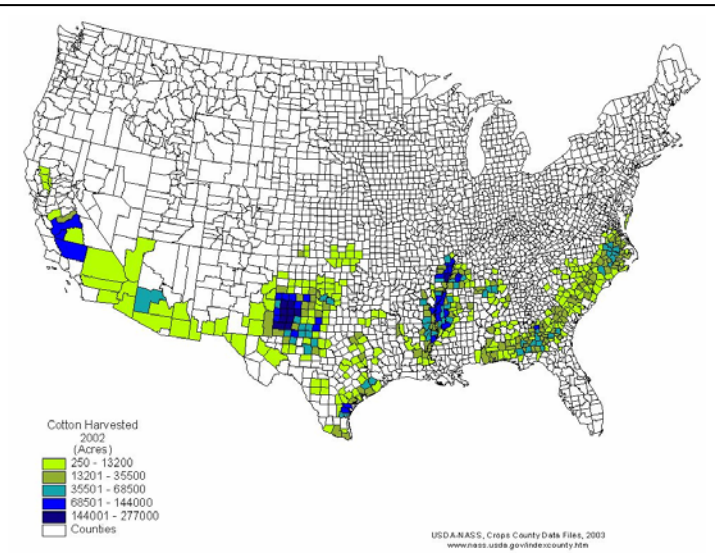
Map 14. Chicory (*Cichorium intybus*)



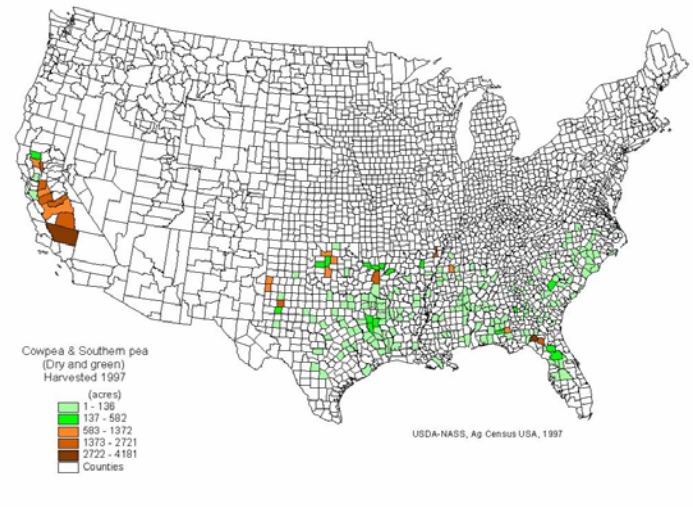
Map 15. Clover (*Trifoloim sp.*)



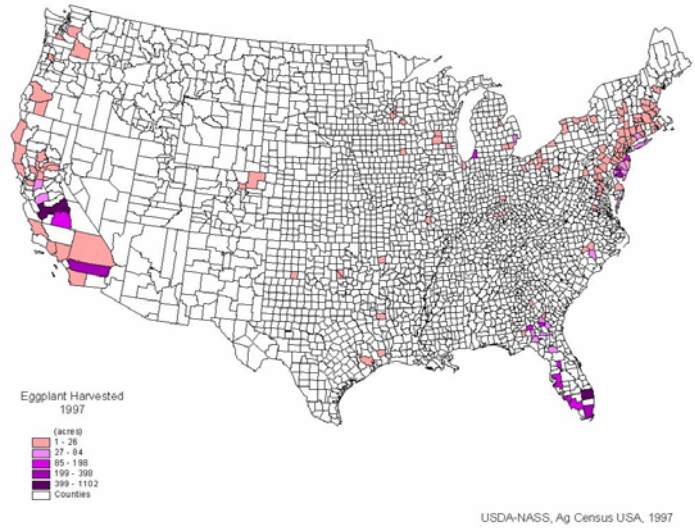
Map 16. Corn (*Zea mays*)



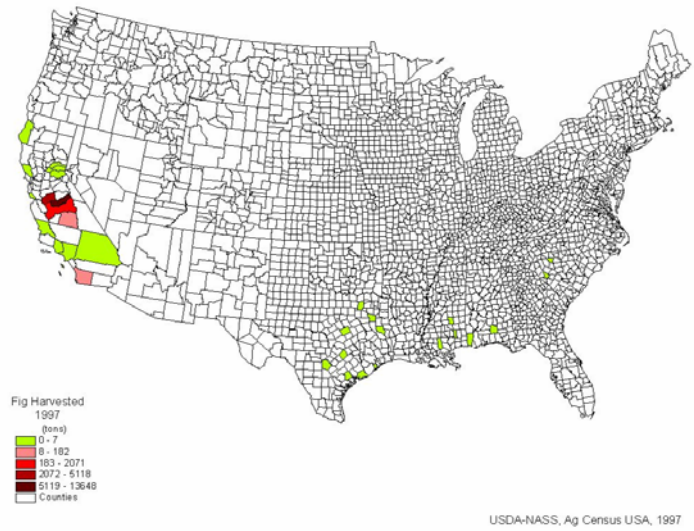
Map 17. Cotton (*Gossypium hirsutum*)



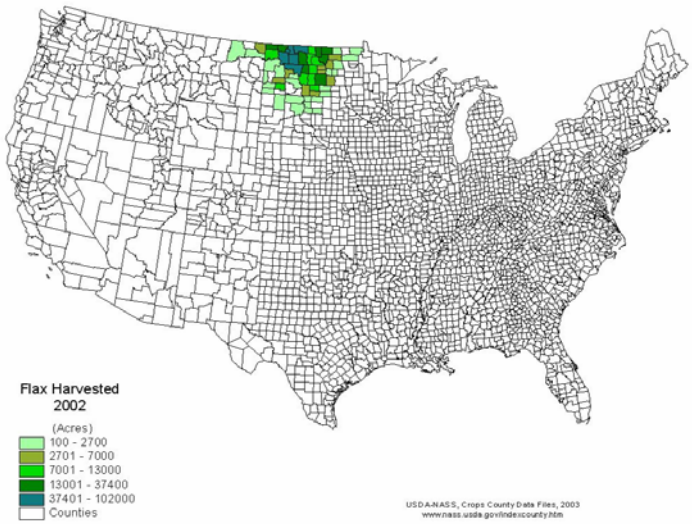
Map 18. Cowpea (*Vigna unguiculata*)



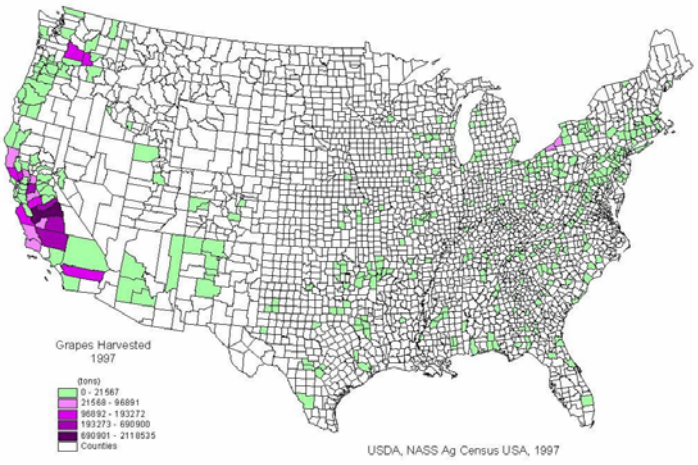
Map 19. Eggplant (*Solanum melongena*)



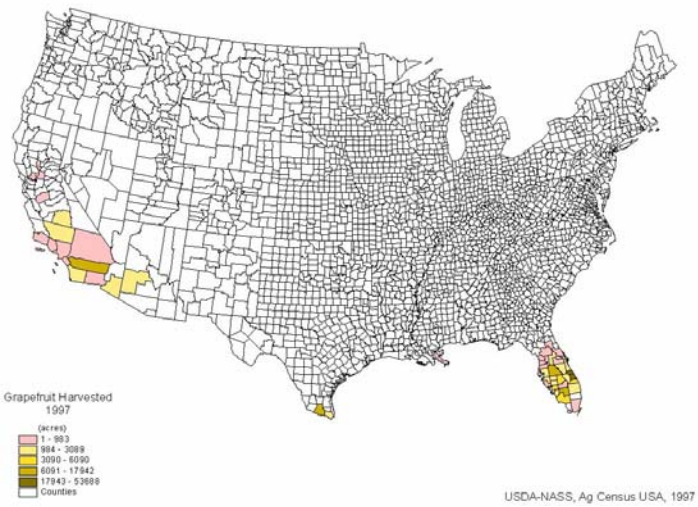
Map 20. Fig (*Ficus carica*)



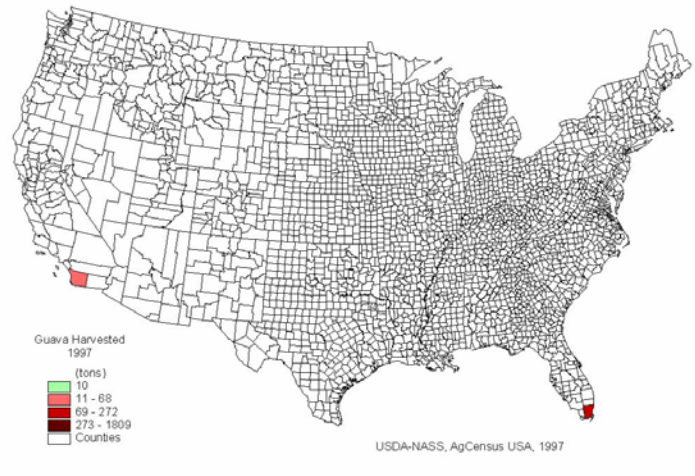
Map 21. Flax (*Linum usitatissimum*)



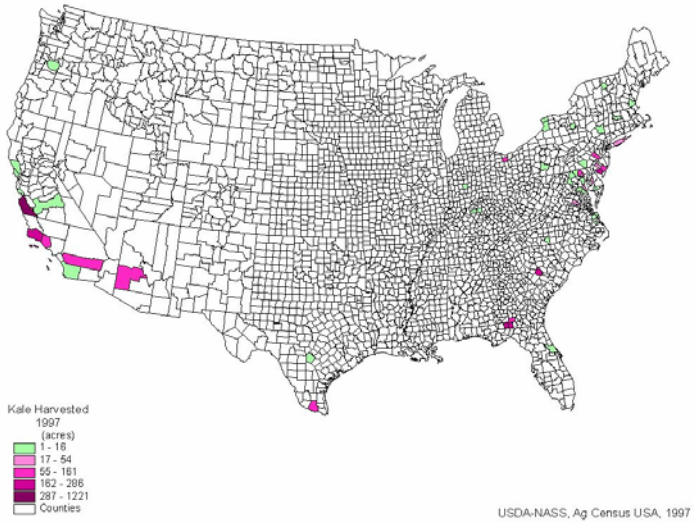
Map 22. Grape (*Vitis vinifera*)



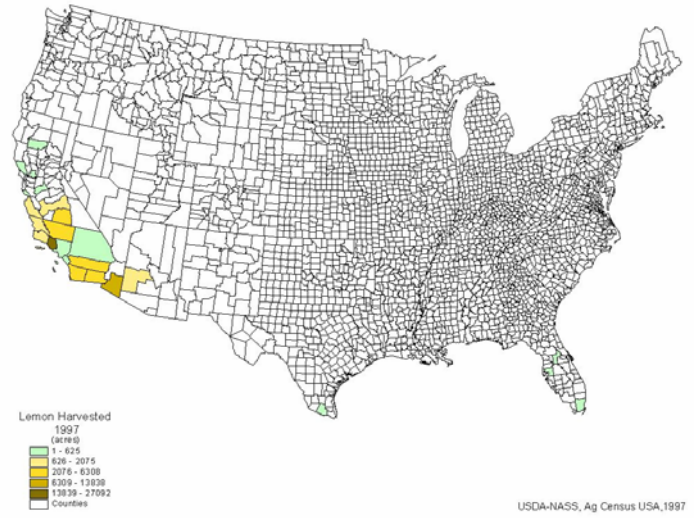
Map 23. Grapefruit (*Citrus paradisi*)



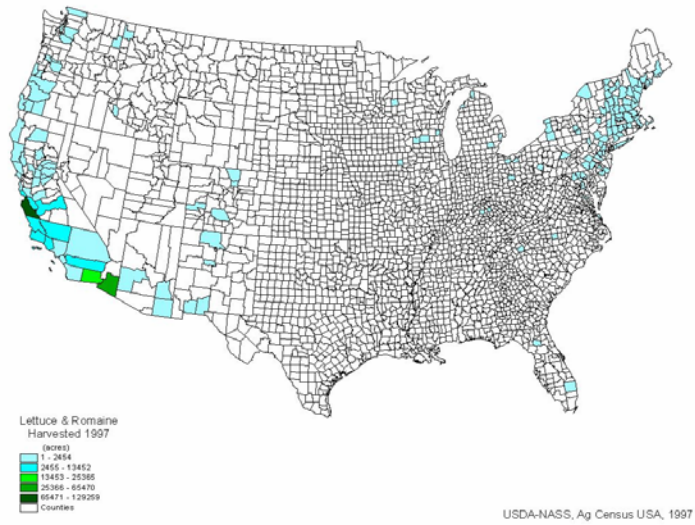
Map 24. Guava (*Psidium guajava*)



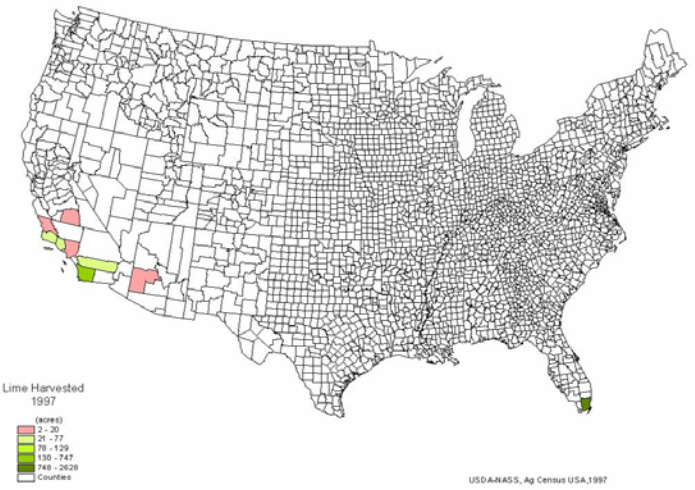
Map 25. Kale (*Brassica alboglabra*)



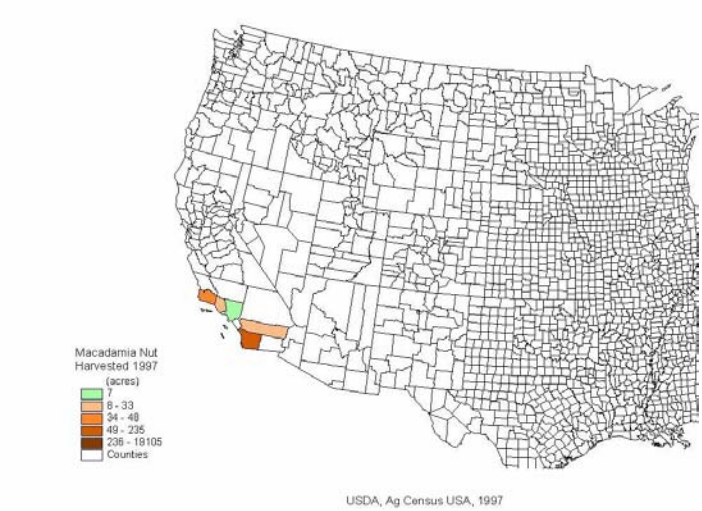
Map 26. Lemon (*Citrus limon*)



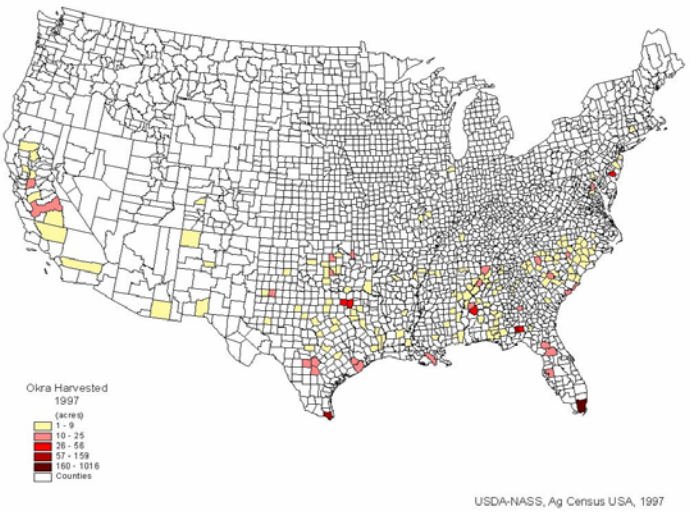
Map 27. Lettuce (*Lactuca sativa*)



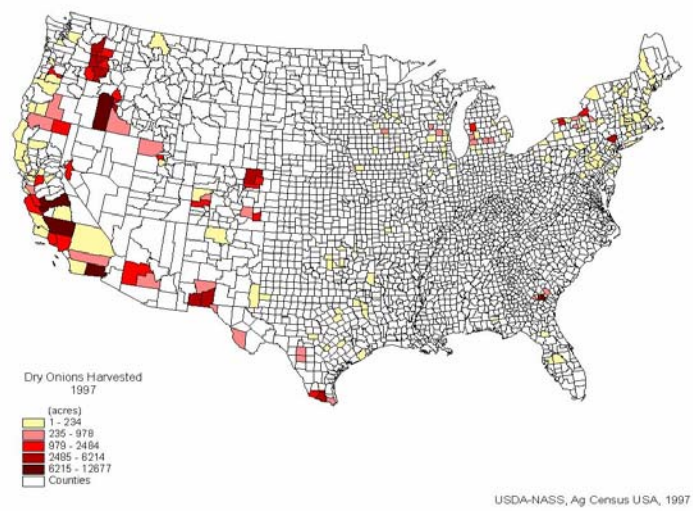
Map 28. Lime (*Citrus aurantifolia*)



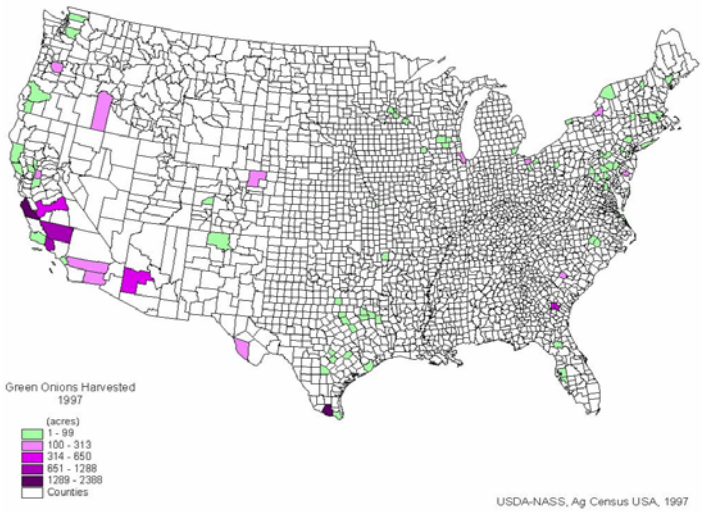
Map 29. Macadamia nut (*Macadamia ternifolia*)



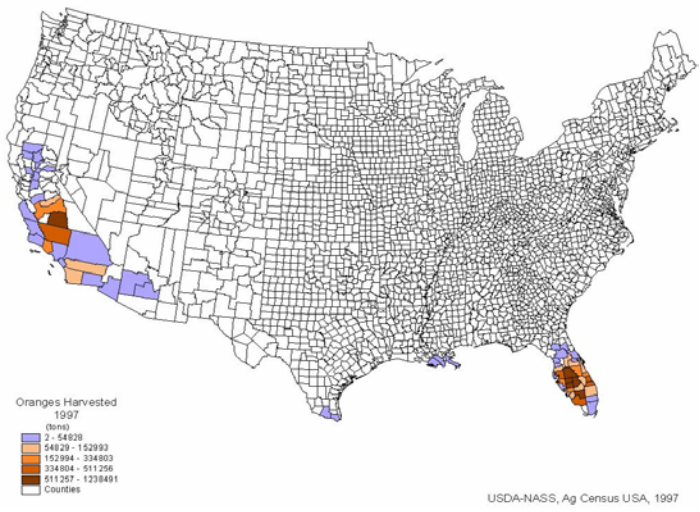
Map 30. Okra (*Abelmoschus esculentus*)



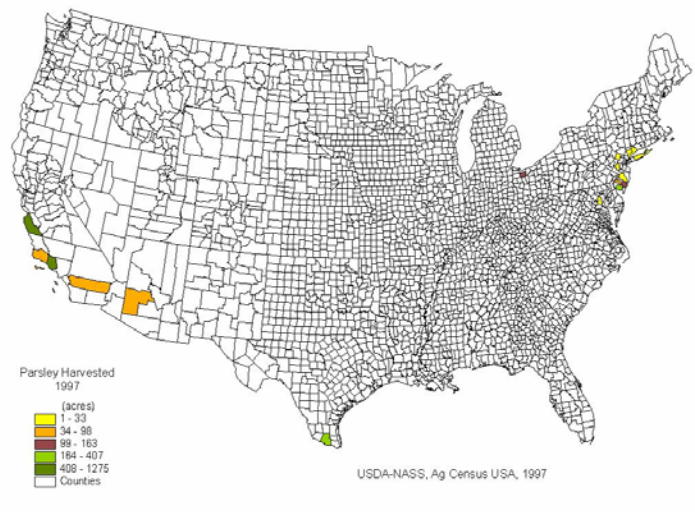
Map 31. Onion; dry (*Allium cepa*)



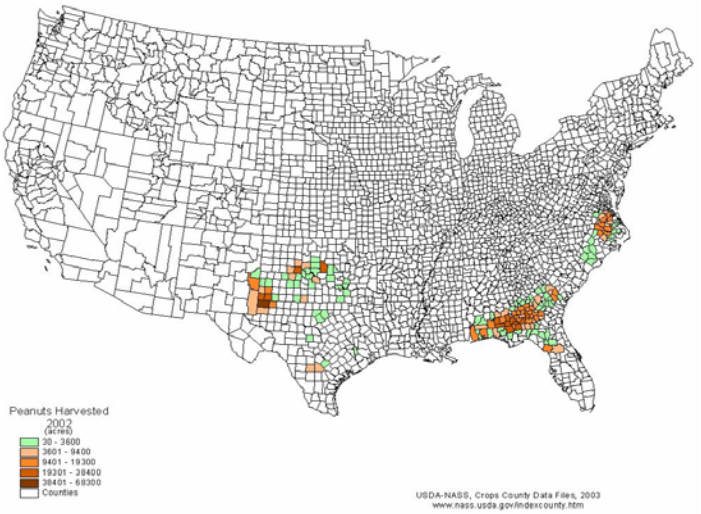
Map 32. Onion; green (*Allium cepa*.)



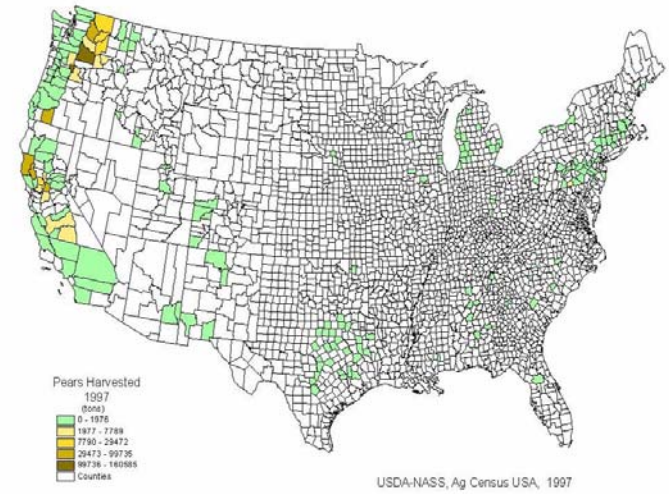
Map 33. Oranges (*Citrus* spp.)



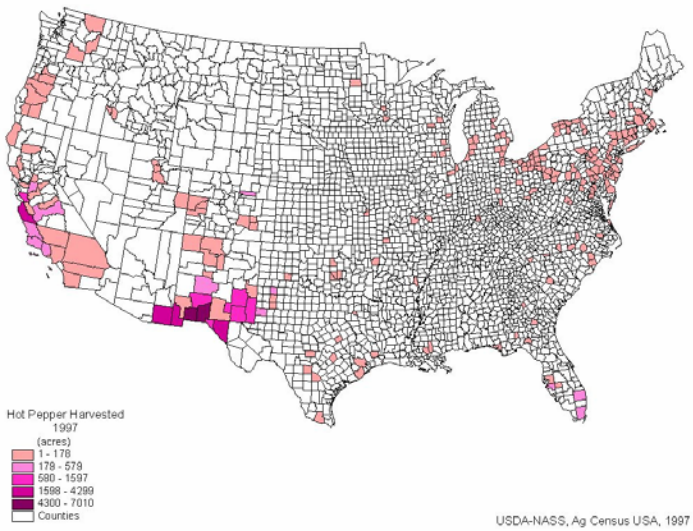
Map 34. Parsley (*Petroselinum crispum*)



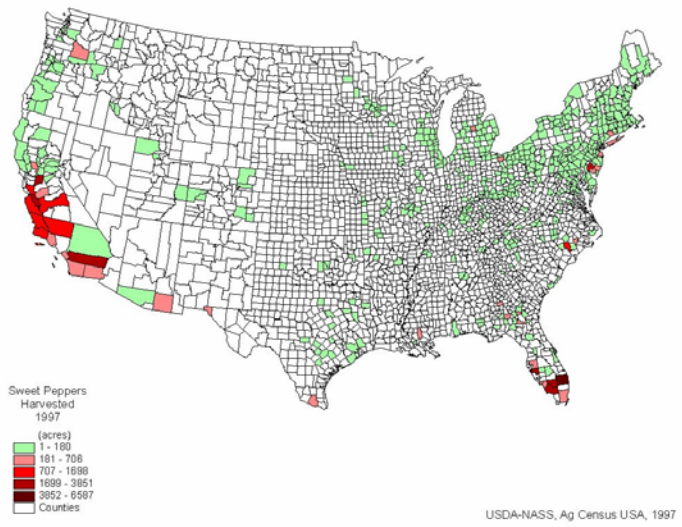
Map 35. Peanut (*Arachis hypogaea*)



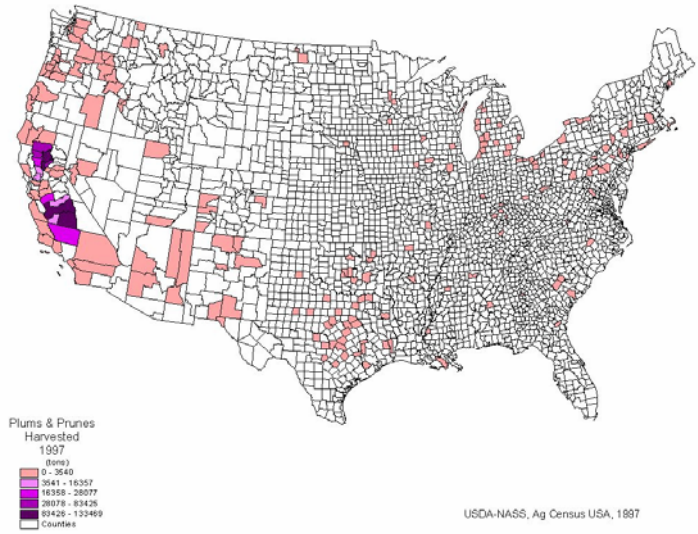
Map 36. Pear (*Pyrus commnis*)



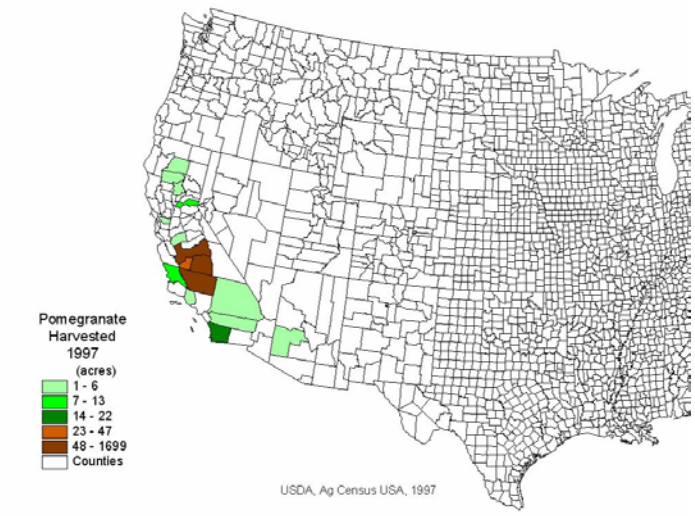
Map 37. Pepper; hot (*Capsicum* spp.)



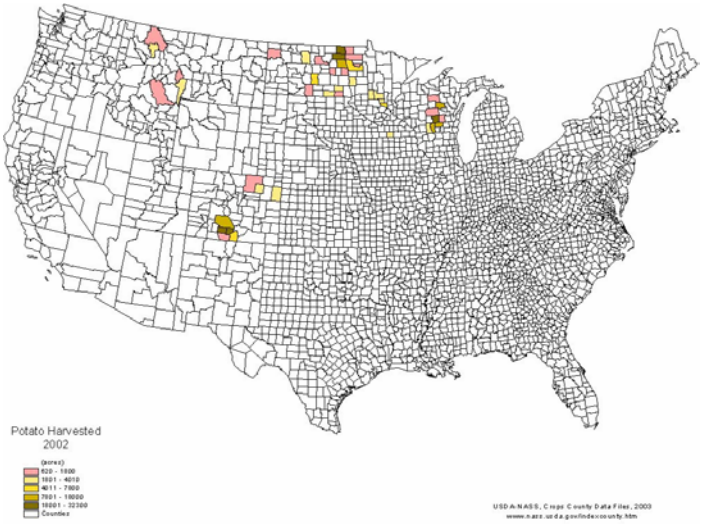
Map 38. Pepper; sweet (*Capsicum* spp.)



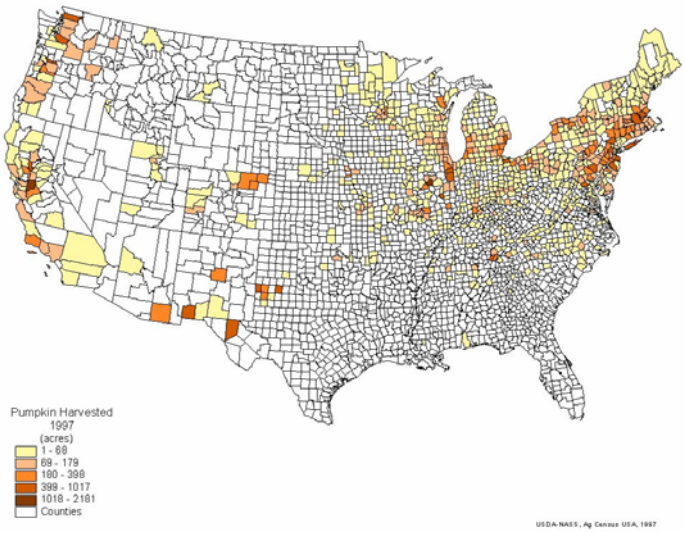
Map 39. Plum & Prune (*Prunus domestica*)



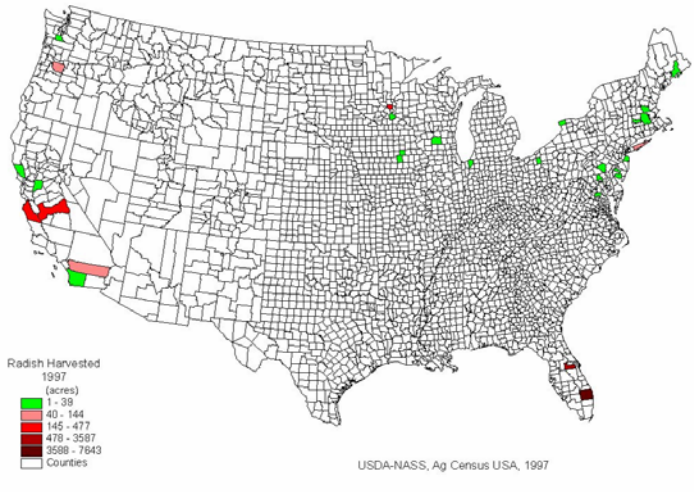
Map 40. Pomegranate (*Punica granatum*)



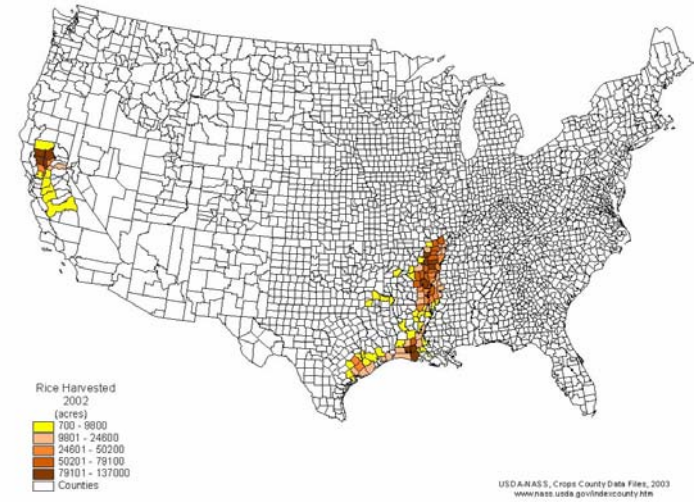
Map 41. Potato (*Solanum tuberosum*)



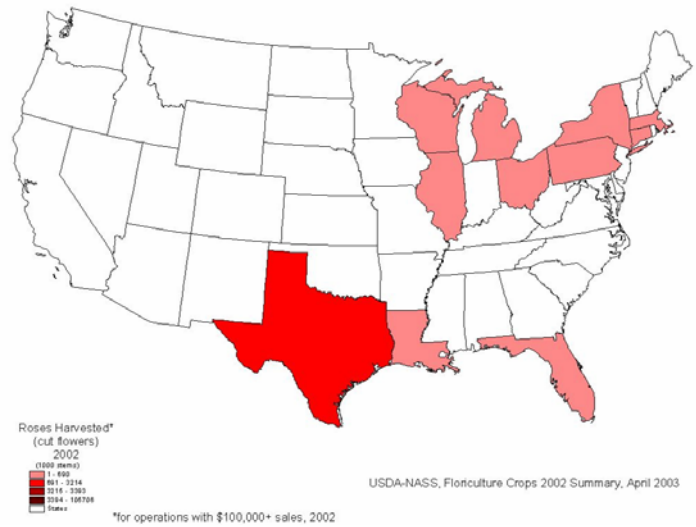
Map 42. Pumpkin (*Cucurbita pepo*)



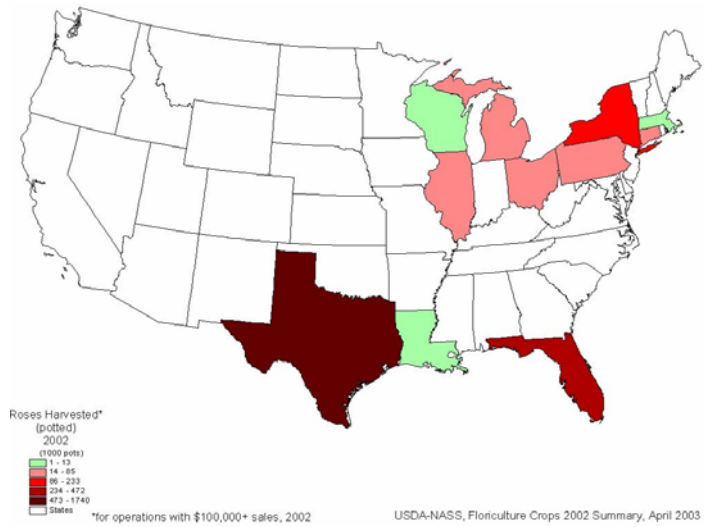
Map 43. Radish (*Raphanus sativus*)



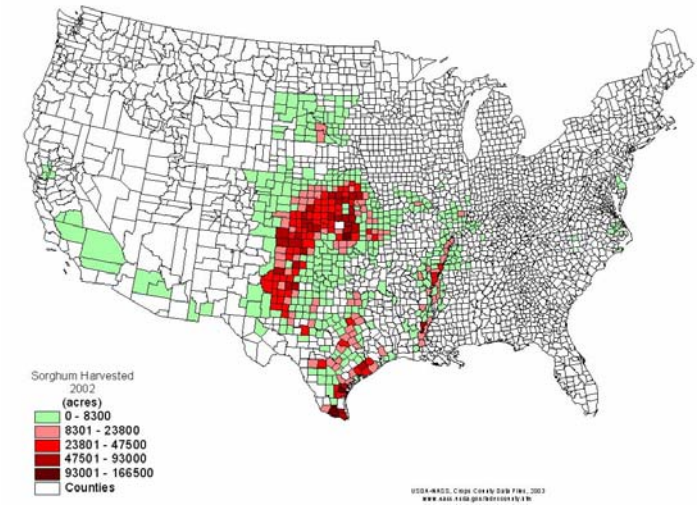
Map 44. Rice (*Oryza sativa*)



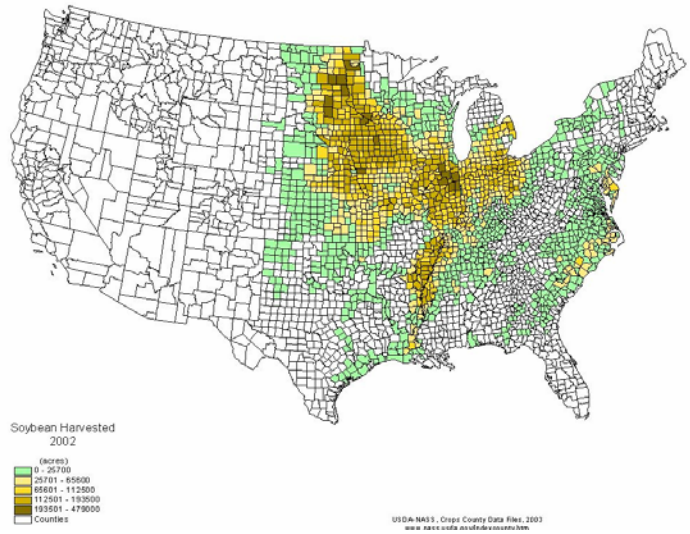
Map 45. Roses; cut (*Rosa* spp.)



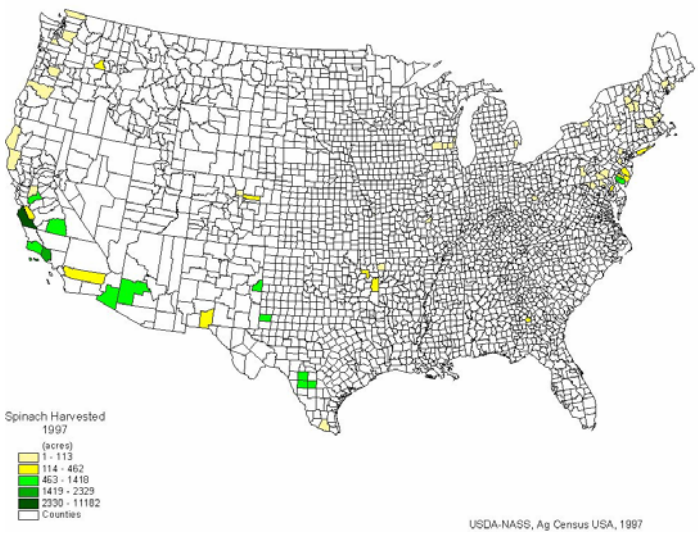
Map 46. Roses; potted (*Rosa* spp.)



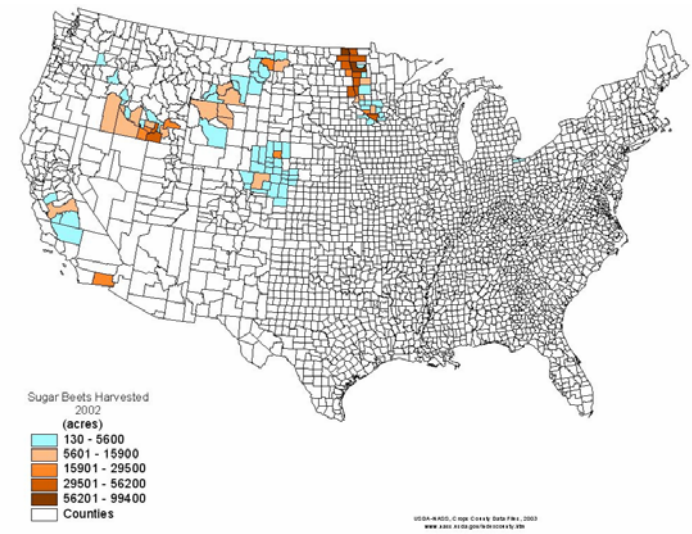
Map 47. Sorghum (*Sorghum bicolor*)



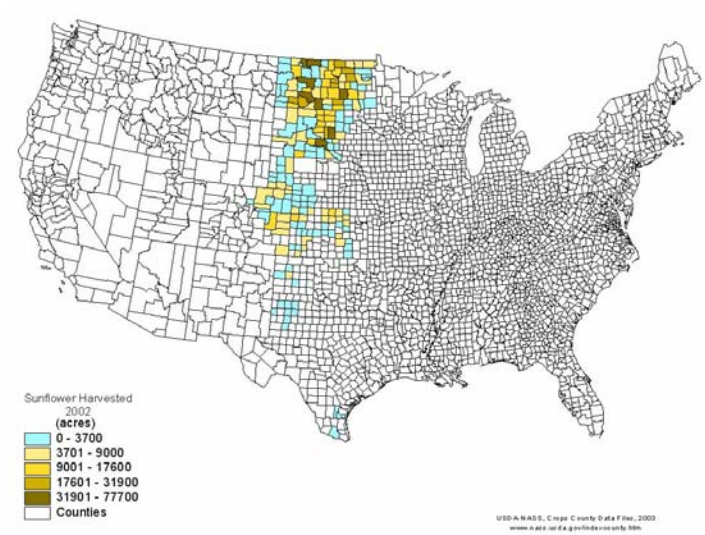
Map 48. Soybean (*Glycine max*)



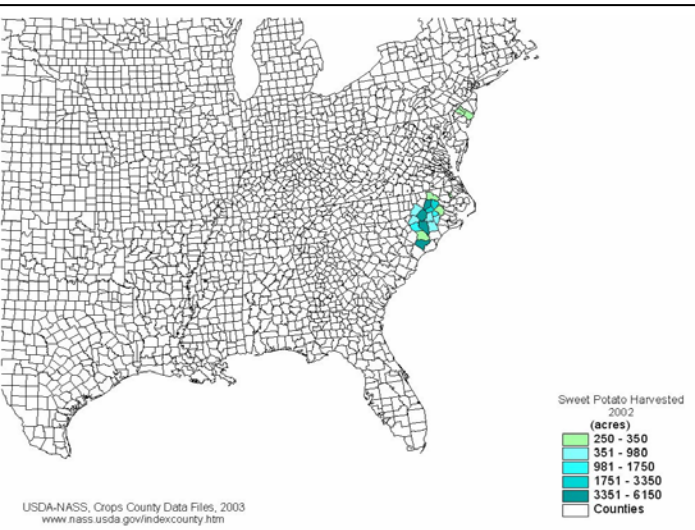
Map 49. Spinach (*Spinacia oleracea*)



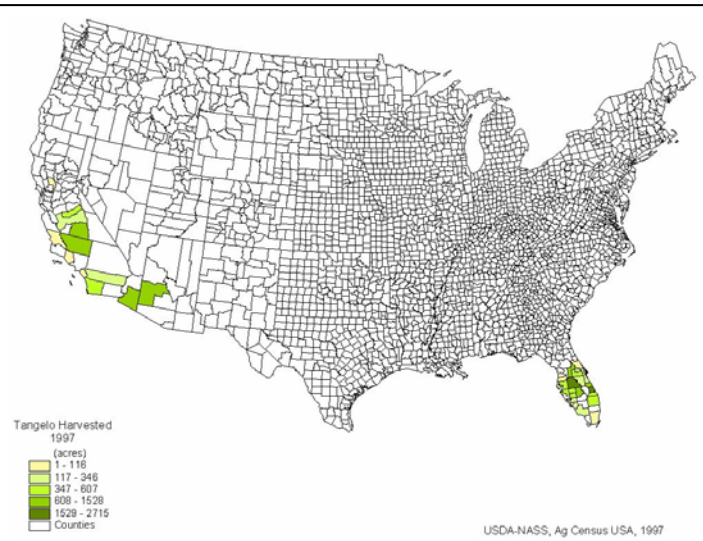
Map 50. Sugarbeet (*Beta vulagris*)



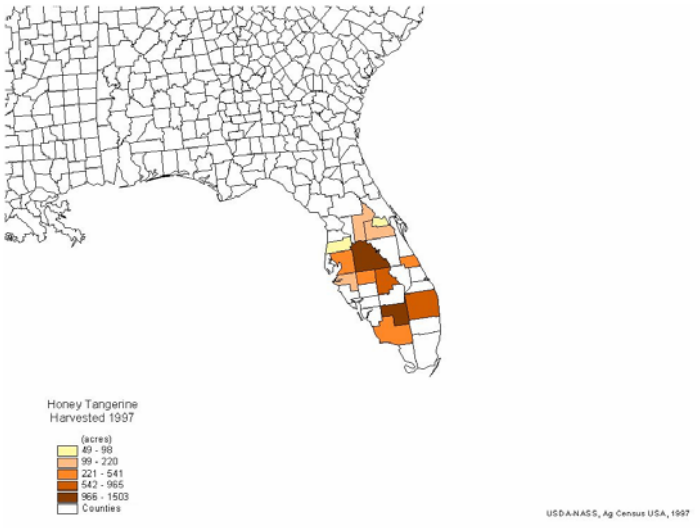
Map 51. Sunflower (*Helianthus annuus*)



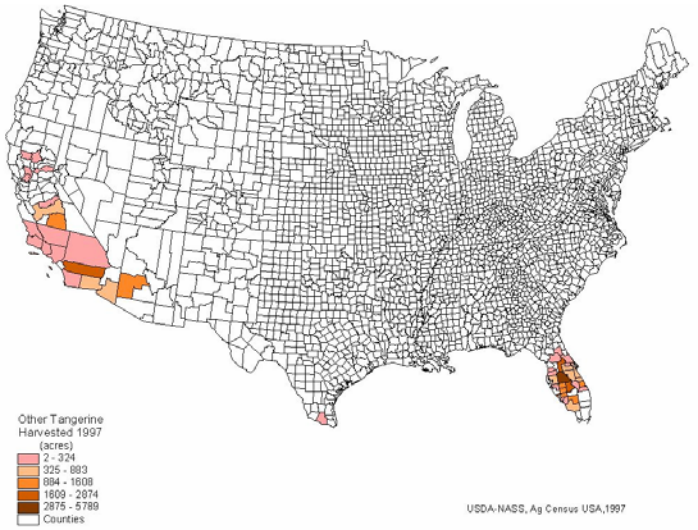
Map 52. Sweet potato (*Ipomoea batatas*)



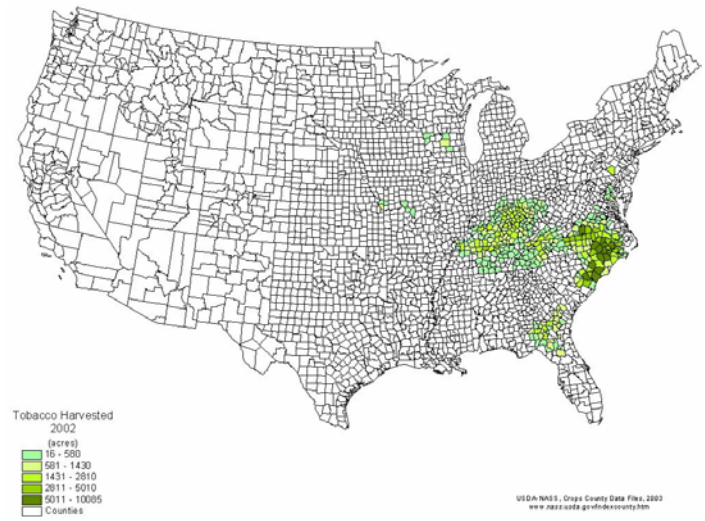
Map 53. Tangelo (*Citrus tangelo*)



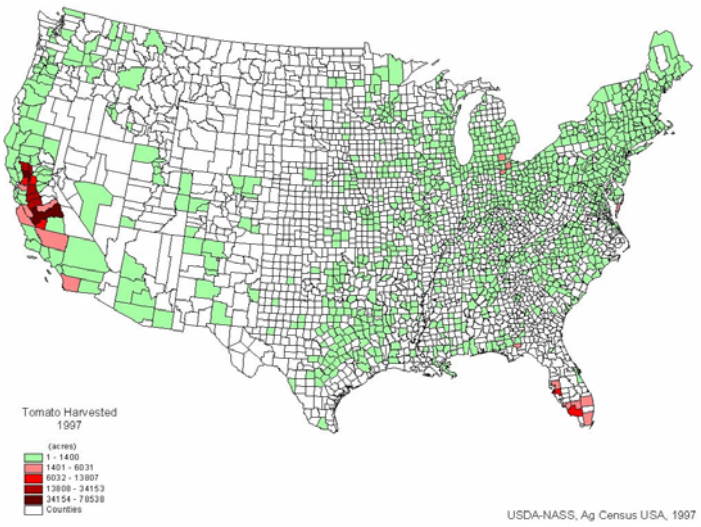
Map 54. Tangerine; honey (*Citrus reticulata*)



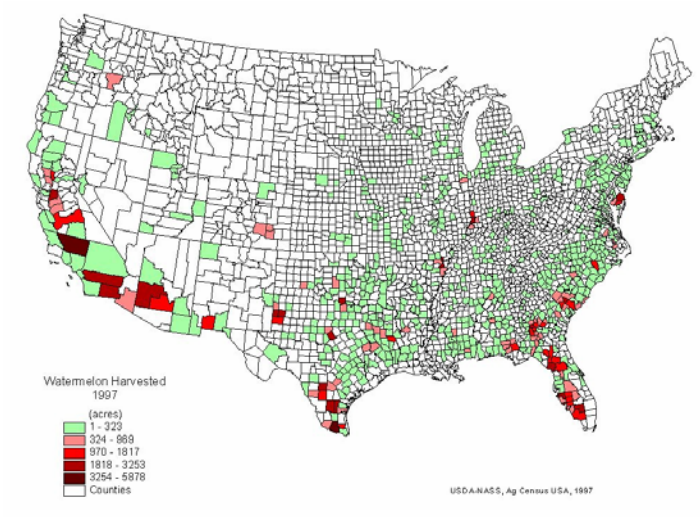
Map 55. Tangerine; other (*Citrus reticulata*)



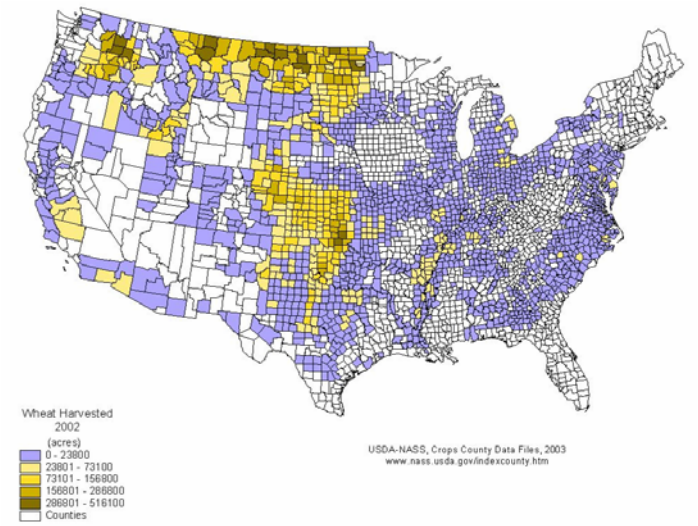
Map 56. Tobacco (*Nicotiana tabacum*)



Map 57. Tomato (*Lycopersicon esculentum*)



Map 58. Watermelon (*Citrullus lanatus*)



Map 59. Wheat (*Triticum aestivum*)

Appendix C. Taxonomy of *Spodoptera littoralis* (Boisduval) and related Noctuidae (prepared by J. Zaspel).

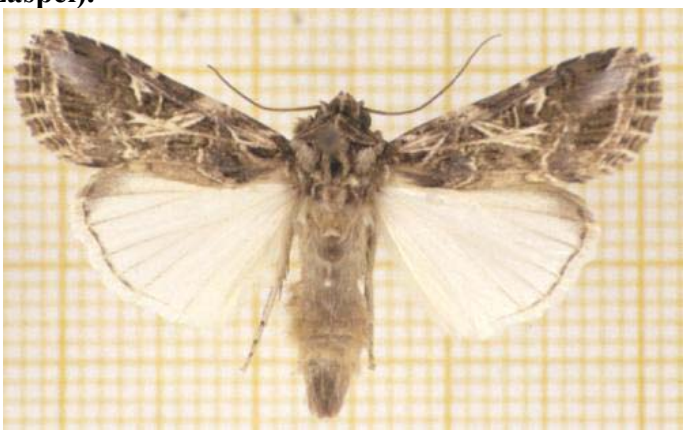


Figure C1. *Spodoptera littoralis* (Boisduval)
[Image from http://www.funet.fi/pub/sci/bio/life/insecta/lepidoptera/ditrysia/noctuoidea/noctuidae/ipimorphinae/spodoptera/littoralis.jpg]

Synonyms

At the generic level:
Spodoptera Guenée 1852; (Viette 1863)

- *Prodenia* Guenée 1852a; (Hampson 1894)
- *Hadena* Boisduval (1833)

At the species level:
littoralis Boisduval 1833

- *testaceoides* Guenée 1852
- *retina* Guenée 1852

Diagnosis of the genus *Spodoptera*

[Description from Pogue (2002)] *Spodoptera* species can be recognized by the gray to brown forewing ground color and white hindwing. Several forewing patterns exist and once recognized can distinguish *Spodoptera* from other genera. In most male genitalia, the valvula is separate from the valve apically (Fig C2). Females have a large tuft of dense scales encircling the eighth abdominal segment.

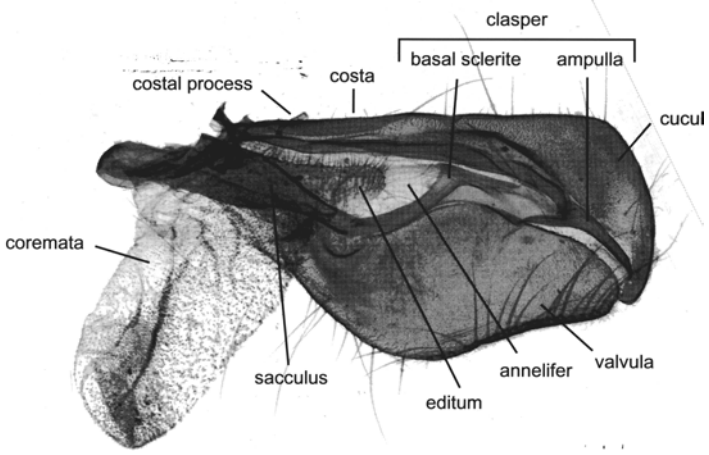


Figure C2 Generalized description of *Spodoptera* valve with structures labeled**.**

Diagnosis of *Spodoptera littoralis*

[Description from Pogue (2002)] External color and pattern are almost indistinguishable from *S. litura*. Forewings (length=12-16 mm) are brownish with a pale yellow along the median vein and the hindwing vein tips of *S. littoralis* are white (see description for wing color and pattern information in great detail). The ochreous median area of the forewing is between the antemedial and postmedial lines, and below vein M (see description below). Male genitalia with juxta quadrate (Fig. C3); base of ampulla, robust; dorsal lobes of coremata shorter than ventral lobes (see description below). Female genitalia with distal margin of ventral plate of ostium bursa straight; ductus bursae shorter than *S. litura*.

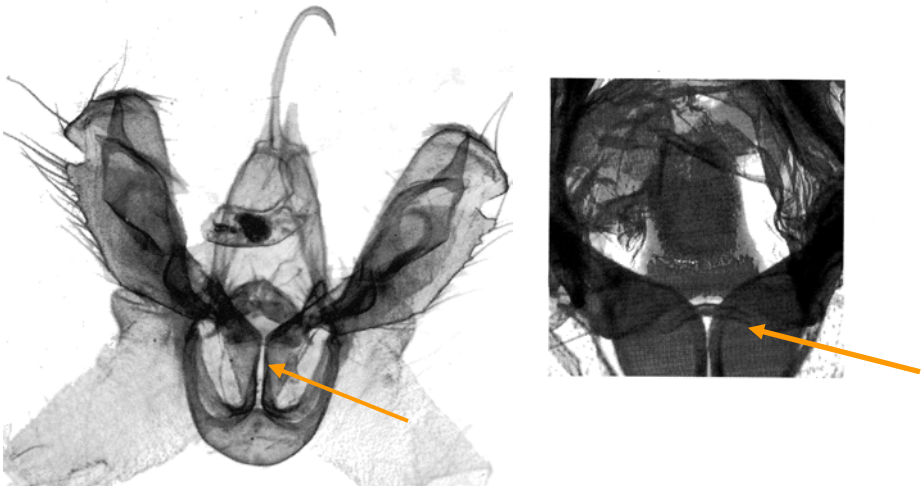


Figure C3. Male genitalia of *Spodoptera littoralis*; arrows indicate position of juxta; image on right is an enlargement of the image on the left
[Reproduced from Pogue (2002)]

Description [from Pogue (2002)]

***Adult Male Head*:** Basal segment of labial palpus cream with median patch variably mixed with black and rufous scales; median segment cream with black median band variably mixed with rufous scales; apical segment black, apex cream. Frons with short scales cream; long scales brown and cream; lateral spots at eye margin brown to black; vertex cream and brown; flagellum cream.

***Thorax*:** Patagium light brown to brown flecked with black, median transverse bans white, apical margin white. Tegula light brown and white (black scales at caudomedial apex). Mesothorax with light brown and brown scales, some tipped white. Underside of thorax white. Prothoracic femur fuscous and cream; tibia with lateral scale tufts not extending beyond first tarsal segment, cream and fuscous, subapical spot black; tarsal segments cream. Mesothoracic femur fuscous and cream; tibia fuscous and cream; inner spur less than twice the length of outer spur, mediolateral surface broadly devoid of scales on both spurs; tarsal segments 1-4 fuscous with cream apical rings, segment 5 cream. Metathoracic femur cream and fuscous; tibia cream, rufous, and fuscous; tarsal segments 1-4 cream with bases fuscous, segment 5 cream.

***Forewing*:** ♂: Length 12-16mm; ground color brown; basal line absent; longitudinal black dash at base absent; R vein from base to reniform spot gray; basal triangular scale patch between R and Cu veins brown bordered by white [see Fig. C4 for description of forewing venation]; basal half circle scale patch below Cu vein light brown bordered by black; antemedial line black, indistinct; claviform spot absent; basal scale patch small, gray, from midway between M and anal veins to anal vein; gray patch covering anal cell and half of cell CuA2 absent; oblique brown mark from fifth outer marginal spot to vein CuA2 absent; curved white line from antemedial line to postmedial line absent; orbicular spot on oblique trapezoid, cream, with a light brown center bordered by light brown to black; reniform spot brown outlined in white on proximal border, distal apex is triangular light brown spot outlined in white, a white distal border extending to middle; white scales along Cu vein from orbicular spot to junction of veins M3, CuA1 which extend down to veins M3, CuA1, and CuA2 to postmedial line; postmedial line indistinct, black variably bordered by white from middle to posterior margin; postmedian band pale gray and with an elliptical brown spot along subterminal line; black scale patches in middle of cells M2 to CuA1 in postmedian area; subterminal line a light brown band bordered by white; apex with a few white scales, no distinct patch; dark gray spindle-shaped spots along outer margin; fringe gray. Underside ground color pale gray; outer margin with black crescent-shaped spots; reniform spot gray.

♀: Length, 13-16mm. Longitudinal black dash at base absent; R vein not a contrasting color; gray patch covering anal cell and half of cell CuA2 absent; curved white line from antemedial line to postmedial line absent; orbicular spot and oblique trapezoid, cream, with a gray center, bordered by thin black line distally; reniform spot more gray with a light brown to gray apical spot outlined in white; postmedian band less distinct and tends to be more brown; black scale patches in middle of cells R4 to CuA2, patch in R4 basal to other patches, patch in R5 consisting of only a few scales in postmedian area.

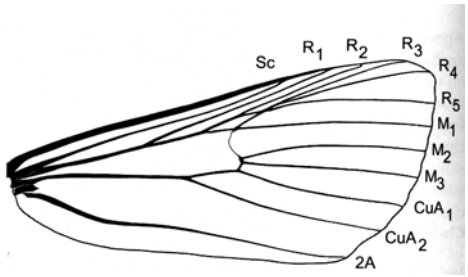


Figure C4. General diagram of forewing venation [Reproduced from Pogue (2002)]

***Hindwing*:** Ground color white; apex, outer margin to vein CuA2, and distal ends of veins Rs to CuA2 with light brown scales [see Fig. C5 for a description of hindwing venation]; fringe white. Underside ground color white; costal cells C and Sc cream speckled with pale gray scales; outer margin with a few faint gray spots in middle of cells Sc to CuA1; no spot on underside.

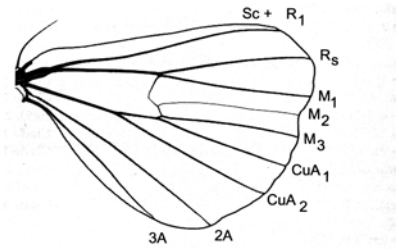


Figure C5. General diagram of hindwing venation [Reproduced from Pogue (2002)]

***Variation*:** Variation can be found in the forewing ground color of this species and male external morphology is somewhat different from the female. Also, the orbicular spot is larger in the male than in the female.

***Abdomen*:** ♂: Dorsum pale gray; venter cream to pale gray; disto-lateral black spots on sternites absent (can be indistinct to absent); 8th tergite with spiculate patches present on caudal margin.

♀: Fine dense scales on 8th segment cream.

***Male Genitalia*:** Uncus curved; slender, gradually narrowing toward pointed apex; setae absent or few. Scaphium elongate, weakly developed. Tegumen lacking a pair of projecting arms on upper third. Costa straight. Costal processes narrow, elongate; at base of costa on inner edge; perpendicular to costa of valve. Cucullus apex truncate; not produced (Fig. C6). Anellifer with lightly sclerotized plate bearing setae present. Ampulla elongate, slightly curved with a decurved apex; extends beyond apex of valve (Fig. C6). Clasper proper absent. Clavus a minute round projection. Sacculus widest at one-fourth its length, tapering distally; apex pointed. Valvula wider than valve; well differentiated from valve, apex free; apex truncate; indentation large, ventral margin round. Coremata elongate, more than 0.5 length of valve; in form of double lobe (Fig. C7). Juxta broad rectangular band with ventrolateral projections, median process not constricted, ventral margin concave. Anellus membraneous. Vinculum U-shaped with parallel arms and a robust base. Aedoeagus straight; coecum smaller in diameter than shaft; patch of spines absent on apex of membraneous sheath surrounding aedoeagus. Vesica curving ventrally; short, less than 0.75 length of aedoeagus; apicobasal cornutal patch a wide ribbon; length moderate, extending to before middle of vesica; cornuti in form of minute flat granules; lateral cornutal patch an elongate elliptical area; a mixture of small spines distally and large spines apically; dense cornutal patch subapical on vesica; distal cornutus a bulbous elliptical plate, apex pointed.

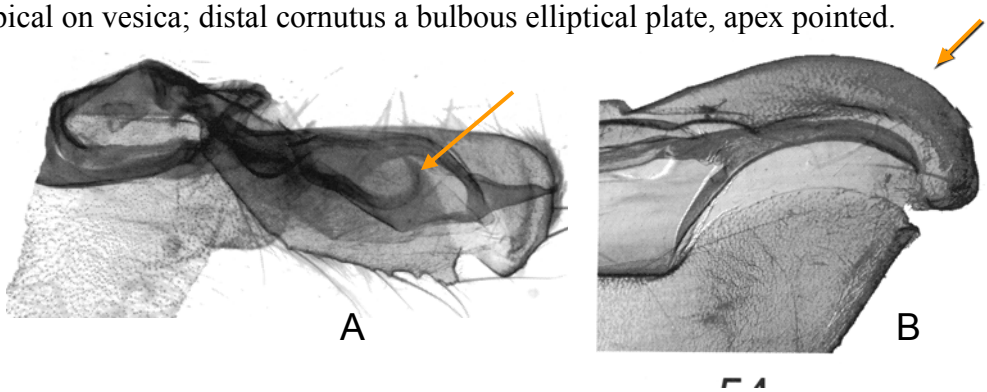


Figure C6. Male genitalia of *Spodoptera littoralis*; arrows indicate A: ampula, B: cucullus [Reproduced from Pogue (2002)].

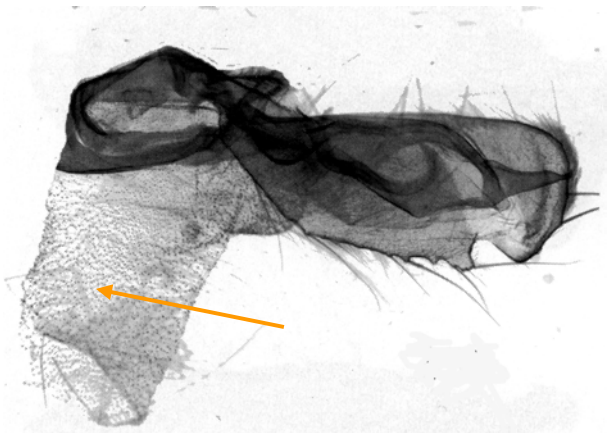


Figure C7. Male genitalia of *Spodoptera littoralis*; arrows indicate coremata [Reproduced from Pogue (2002)].

***Female Genitalia*:** Ventral plate of ostium bursa with height greater than width; distal margin straight; ventolateral invaginated pocket of 8th sternite absent (Fig C8). Ductus bursae short (length less than twice width); completely sclerotized. Appendix bursae membraneous. Corpus bursae bulbous, length is less than twice width; striate convolutions. Signum in apical half of corpus bursae; short, length less than 0.65mm; forming greater than a 45 degree angle to vertical axis of corpus bursae.

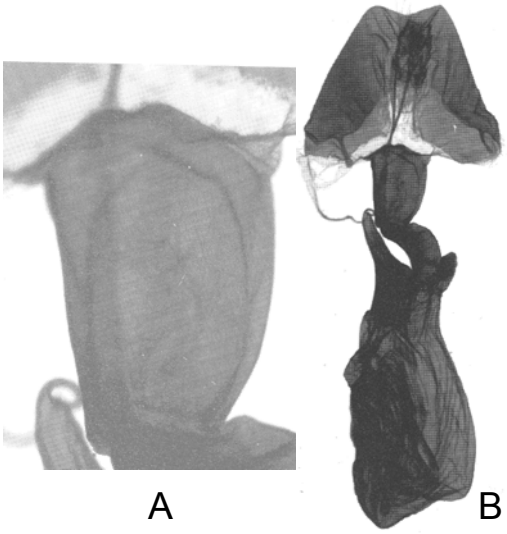


Figure C8. Female genitalia of *Spodoptera littoralis*; A: ostium bursa plate, B: habitus [Reproduced from Pogue (2002)].

***Larva*:** The head and frons are brown and the cutting edge of the mandible is serrate. The pronotum dorsolateral stripe is absent or inconspicious, with a few faded spots at the margins and the mid-dorsal stripe is narrower than the dorslateral stripe (Fig. C9). The mesothoracic segmental spot is round with a white spot at the base of the segmental spot with the lateral dark spot absent. The abdomen is smooth, with an inconspicuous middorsal stripe, narrower than dorsolateral stripe. Segmental spots on abdominal segments 7 and 8 larger than on 1-6; wide on segments 1 and 8, almost extending to middorsal stripe with a white spot mid-basally in segmental spot (Fig. C9). Segment 1 without lateral dark spot and segments 2-6 without lateral dark spots in spiracular band. Dorsolateral stripe yellow, and spiracles with black border and brown center. Subspiracular stripe continuous through abdominal segment 1.

Figure C9. Larva of *Spodoptera littoralis*; A: Lateral view, B: Dorsal view. [Reproduced from Pogue (2002)].

Similar species:
[Description from Pogue (2002)].
Larvae: *Spodoptera littoralis* can be confused with *S. exigua*, but *S. littoralis* larva are either light or dark brown, and in *S. exigua* they can be brown or green (Brown & Dewhurst 1975). *Spodoptera littoralis* is also larger than *S. exigua*. *Spodoptera littoralis* larvae can also be confused with *S. litura* larvae, but *S. litura* larvae have bold lateral spots present from the mesothorax to the eighth abdominal segment.

***Adults*:** External color and pattern are almost indistinguishable from *S. litura* (Fig C10) See species diagnosis (above) for distinguishing characteristics.

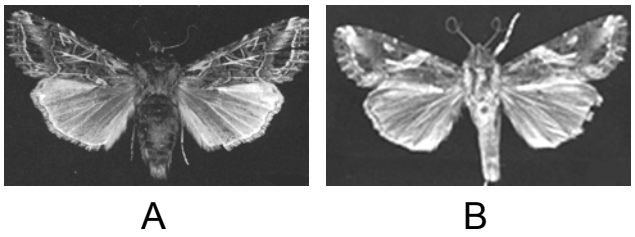


Figure C10. Adult *Spodoptera* spp.; A: *S. littoralis*, B: *S. litura* [Reproduced from Pogue (2002)].

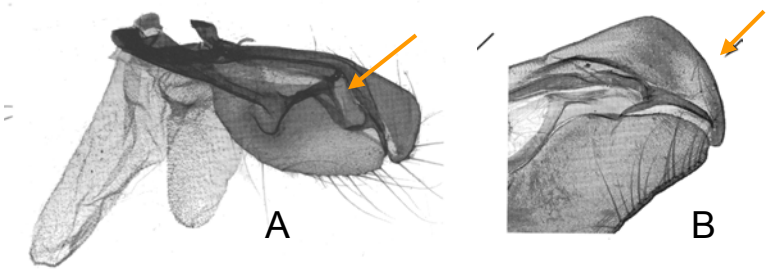


Figure C11. Male genitalia of *Spodoptera litura*; arrows indicate A: ampula, B: cucullus [Reproduced from Pogue (2002)]

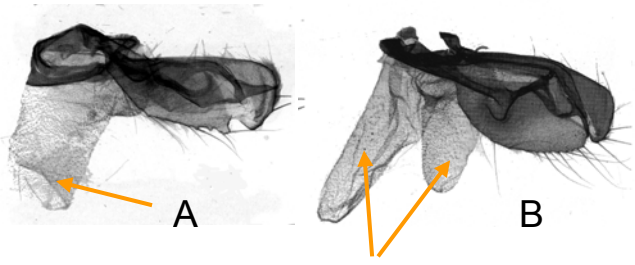


Figure C12. Coremata (indicated by arrows) of male genitalia; A: *Spodoptera littoralis*, and B: *Spodoptera litura* [Reproduced from Pogue (2002)]

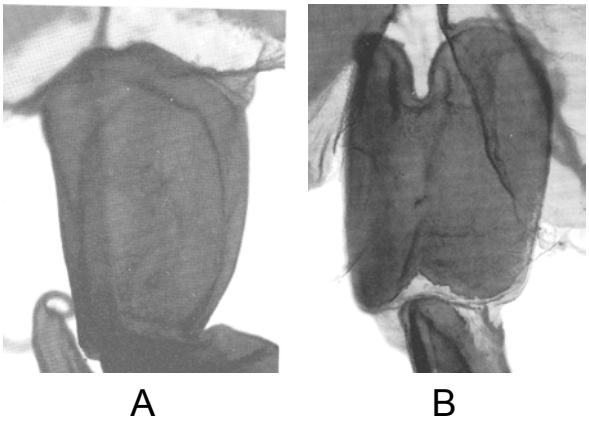


Figure C13. Ostium bursa plate of female genitalia; A: *Spodoptera littoralis* and B: *S. litura* [Reproduced from Pogue (2002)].

Figure C14. Habitus of female genitalia; A: *Spodoptera littoralis* and B: *S. litura* [Reproduced from Pogue (2002)].

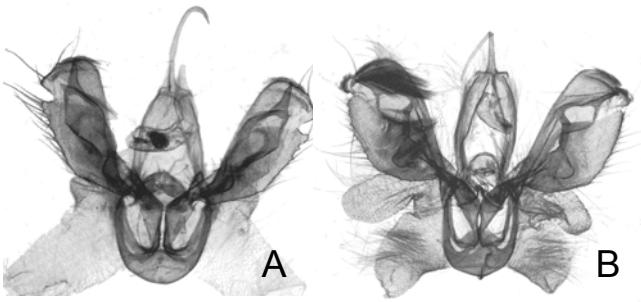


Figure C15. Valves of male genitalia; A: *Spodoptera littoralis* and B: *S. litura* [Reproduced from Pogue (2002)].