Mini Risk Assessment
Arrowhead Scale: *Unaspis yanonensis* (Kuwana)
[Hemiptera: Diaspididae]

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Figure 1. *U. yanonensis*: (A) drawings of adult female shield (upper left), female, male shield, and males and females on a leaf; (B) enlarged photo of scales on a leaf; (C) scales colonizing branches and leaves. Images not to scale.
[Images from (A) http://www.eppo.org/QUARANTINE/insects/Unaspis_citri/UNASCI_images.htm; (B) http://www.nougyo.com/data/bug/images/g023_yanonekaigaramusi.jpg;
(C) http://perso.wanadoo.fr/scanice/images/Insectes0312/Cochenille%20X%20sur%20Rameau%20Oranger.JPG].

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Introduction

Unaspis yanonensis, also known as the arrowhead scale, is a major pest of citrus (Blackburn and Miller 1984)}(CAB 2004). The insect is considered native to China but has invaded and spread though much of Japan (Matsumoto et al. 2003c) and, from separate introductions, France and Italy (EPPO 1989). *Unaspis yanonensis* does not currently occur in the US. Risks associated with this pest have been evaluated previously by USDA-APHIS (Blackburn and Miller 1984, Cave and Redlin 1996), Biosecurity Australia (BA 2002), and EPPO (EPPO 1989, 2004b, c). In Australia, *U. yanonensis* is noted as a pest of concern on unshu mandarine imported from Japan. An introduced pest in France and Italy, *Unaspis yanonensis* was considered an EPPO A2 quarantine pest for several years. However, there has been no significant spread of this pest in Europe, and reported economic impact is negligible as this insect does not occur in citrus growing areas. As a result, the pest status of *U. yanonensis* in Europe may be re-evaluated (CABI/EPPO 1997, CAB 2004). In the US, Cave and Redlin (Cave and Redlin 1996) considered the likelihood of successful establishment to be high and the economic and environmental consequences to be high. The purpose of the current “mini” pest risk assessment is to further evaluate several factors that contribute to risks posed by *U. yanonensis* and apply this information to the refinement of sampling and detection programs.

1. **Ecological Suitability. Rating: Medium.** *Unaspis yanonensis* is present in Asia, and to a limited extent in Europe. Appendix A provides a detailed list of the reported worldwide distribution of this scale.

   In general, *U. yanonensis* occurs in climates ranging from hot and semi-arid to and cool and dry, with seasonal rainfall. The reported distribution of *Unaspis yanonensis* suggests that the pest may be most closely associated with biomes characterized as: mediterranean scrub; temperate broadleaf and mixed forests; and tropical and subtropical moist broadleaf forests. This scale reportedly thrives in hot and shady conditions (Bénassy and Pinet 1972). Consequently, we estimate that approximately 30% of the continental U.S. would have a suitable climate for *Unaspis yanonensis* (Fig. 2). See Appendix A for a more complete description of this analysis.

   Based on the information regarding the geographic distribution of this pest reveiwed to date, we question the presence of *Unaspis yanonensis* in Fiji for several reasons. Historically, this scale has been reported from Australia, India, Indonesia, Malaysia, Pakistan, the Philippines, Thailand and Vietnam. However, subsequent reports suggest that these geographic accounts are dubious (CIE 1988). *Unaspis yanonensis* is also reportedly present in Fiji, and even though it is climatically possible for this scale to occur in this region (Fiji is included in our climate analysis), it is not currently known to occur in any other location in Oceania. In future research, the presence of *U. yanonensis* in Fiji should be confirmed, especially because a close relative, *U. citri*, also occurs on the island and elsewhere in Oceania (EPPO 2004c).

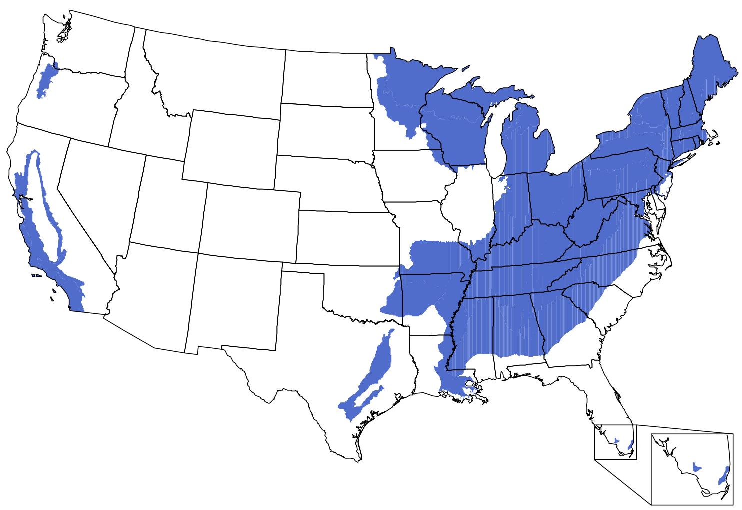

Figure 2. Predicted distribution (shaded blued) of *Unaspis yanonensis* in the contiguous US.

Figure 2 illustrates where *U. yanonensis* is most likely to encounter a suitable climate for establishment within the continental US. This prediction is based only on the known geographic distribution of the species. Because this forecast is based on coarse information, areas that are not highlighted on the map may have some chance of supporting populations of this exotic species. However, establishment in these areas is less likely than in those areas that are highlighted. Initial surveys should be concentrated in the higher risk areas and gradually expanded as needed.

2. **Host Specificity/Availability. Rating: High/Medium.** *Unaspis yanonensis* feeds on foliage, young stems and fruit, of four plant genera within two families (Rutaceae: *Citrus*, *Fortunella*, and *Poncirus*; Rubiaceae: *Damnacanthus*). See Appendix E for more information on life stages and feeding behavior of this scale. Table 1 summarizes literature reports of known host species.

Table 1. Host plants of *Unaspis yanonensis*:

Hosts	References
Chinese orange	(Kuwana 1923)
citron or citronniers (*Citrus medica*)	(Bénassy and Pinet 1972)
citron, finger (*Citrus medica* var. *sarcodactylus*)	(Kuwana 1923, Murakami 1970)
citrus hybrid 'Hyokan'	(Kuwana 1923)
citrus hybrid 'Iyomikan'	(Kuwana 1923)
citrus hybrid 'Jokan'	(Kuwana 1923)
citrus hybrid 'Komikan'	(Kuwana 1923)
citrus hybrid 'Ujukitsu'	(Kuwana 1923)

Hosts	References
Citrus sp.	(Cheo 1935, Nohara 1962, Murakami 1970, Uemura and Shiyomi 1975, Bénassy 1977, Ohgushi et al. 1977, Korenaga et al. 1978, USDA 1979, Ohkubo 1980, Huang et al. 1981, 1983, Blackburn and Miller 1984, Tang 1984, Takagi and Ogata 1985, Yukinari and Kagawa 1985, Korenaga 1986, Takagi and Ujiye 1986, Takagi 1986, Wang et al. 1987, CIE 1988, Onillon 1988, EPPO 1989, Itioka and Inoue 1989, Xue and Zhang 1989, Ren et al. 1990, Song et al. 1990, Takagi and Ogata 1990, Adachi and Korenaga 1991, Ren et al. 1991, Rose et al. 1991, Takagi 1991, Adachi and Korenaga 1992, Ren et al. 1992b, CABI/EPPO 1997, Kreiter et al. 1998, Wang et al. 2001, Matsumoto et al. 2002, Takagi 2002, Matsumoto et al. 2003a, b, Matsumoto et al. 2003d, CAB 2004, Matsumota et al. 2004, Matsumoto et al. 2004b)
clémentiniers or clementine (*Citrus clementina*)	(Bénassy and Pinet 1972)
Damnacanthus sp.	(Blackburn and Miller 1984)
grapefruit (*Citrus x paradisi*)	(USDA 1979, CAB 2004)
kumquat (*Fortunella* sp.)	(Blackburn and Miller 1984)
kumquat, oval (*Fortunella japonica* var. *margarita*)	(Murakami 1970)
kumquat, round (*Fortunella japonica*)	(Kuwana 1923, Murakami 1970)
kuroshima-mikan (*Citrus depressa*)	(Nakao et al. 1985)
lemon (*Citrus limon*)	(Bénassy and Pinet 1972, USDA 1979, Longo et al. 1995, CAB 2004)
lime (*Citrus aurantifolia*)	(USDA 1979)
mandarin (*Citrus reticulata*)	(Bénassy and Pinet 1972, Murakami et al. 1974, USDA 1979, Longo et al. 1995, CAB 2004)
mandarin, mediterranean (*Citrus deliciosa*)	(Murakami 1970, CAB 2004)
mandarin, Ponkan (*Citrus reticulata* 'Ponkan')	(Murakami et al. 1974)
mandarin, Satsuma (*Citrus unshiu* (= *Citrus nobilis* var. *unshui*))	(Furuhashi 1974, Korenaga and Sakagami 1978) (Kuwana 1923, Murakami 1970, Murakami et al. 1974, Takagi 1983, Ogihara et al. 1989, Mizobuchi et al. 1995, Nakao et al. 1996, Itioka et al. 1997, BA 2002, Matsumoto et al. 2002, 2003a, b, Matsumoto et al. 2003c, Matsumoto et al. 2003d, CAB 2004, Matsumota et al. 2004, Matsumoto et al. 2004a, b)

Hosts	References
orange (*Citrus* sp.)	(Longo et al. 1995, Matsumoto et al. 2004a)
orange, bitter (*Citrus aurantium* sub. sp. *amara*)	(Kuwana 1923)
orange, hardy (*Poncirus trifoliata*)	(Kuwana 1923, Murakami 1970)
orange, Japanese summer (*Citrus natsudaidai*)	(Kuwana 1923, Murakami 1970, Furuhashi 1974, Ohkubo 1980)
orange, navel (*Citrus sinensis*)	(Kuwana 1923, Bénassy and Pinet 1972, Murakami et al. 1974, USDA 1979, CAB 2004)
orange, sour or bigaradier (*Citrus aurantium*)	(Bénassy and Pinet 1972, USDA 1979)
orange, storehouse (*Citrus aurantium* var. *daidai*)	(Murakami 1970)
orange, tachibana (*Citrus tachibana*)	(Matsumoto et al. 2003a)
orange, tankan (*Citrus tankan*)	(Murakami et al. 1974)
Poncirus sp.	(Blackburn and Miller 1984)
pummelo (*Citrus maxima* (= *C. grandis*))	(Kuwana 1923, Murakami 1970, Bénassy and Pinet 1972, Murakami et al. 1974, USDA 1979)

See Appendix B for maps showing where various hosts occur in the contiguous US.

3. **Survey Methodology. Rating: Low.** Surveys for *U. yanonensis* will have to rely on visual inspection of potential host plants. No chemical attractants have been identified to aid in monitoring, nor have light traps proven effective to assess the size of populations.

   Unaspis yanonensis occur on leaves and twigs (Itioka and Inoue 1989, CAB 2004). Consequently, branches with leaves are an appropriate sample unit. Infested trees may have discolored leaves, wilted leaves, leaf drop, and branch dieback (EPPO 1989). For population monitoring in heavily infested areas, six branches with 80-300 current-year leaves from each of 12-15 trees are commonly collected (Itioka et al. 1997, Matsumoto et al. 2003c). The number of immature and mature females was counted, and counts were expressed per 100 leaves (Itioka et al. 1997, Matsumoto et al. 2003c). When populations of *U. yanonensis* dropped, it was necessary to sample 400-600 leaves per tree (Itioka et al. 1997). In some research applications, 40-80 leaves were collected per "plot" and all individuals beyond the second instar were counted (Murakami et al. 1974, Matsumoto et al. 2002). Wang et al. (1987) suggest that samples for females should come from the upper and lower canopy and, for larvae, from the middle of the canopy. In a review of methods for integrated pest management of *U. yanonensis*, Ohkubo (1980) comments on the difficulty of visual sampling relative to making treatment decisions.

To speed the process of evaluating *U. yanonensis* densities in an orchard, Itioka and Inoue (1989) developed a grading method in which scale densities on a tree are classified as grade 1 (x<0.1; x=adult females per leaf), grade 2 (0.1<x<0.7), grade 3 (0.7<x>1.1), or grade 4 (x>1.1). Assignment to grade is based on rapid visual assessment of a number of leaves rather than counting each individual. Matsumoto et al. (2003c) and Itioka et al (1997) used the infestation grade method on orchards with hundreds of trees.

U. yanonensis tend to be highly aggregated within an orchard (Wang et al. 1987, Itioka and Inoue 1989, Liu et al. 1990)). Aggregation can be problematic when the goal of sampling is to estimate the mean density of scales per plant. Aggregation is less of a concern when the goal is simply to detect one or more individuals. If we can assume that (i) an orchard is relatively large, (ii) inspection of tree always locates *U. yanonensis* when it are present, and (iii) trees are selected at random, simple binomial statistics can be used to calculate the number of trees that should be inspected to achieve a desired probability of locating *U. yanonensis* when it is present in an orchard. Figure 3 illustrates how the number of required samples changes as the proportion of trees with *U. yanonensis* and/or the desired probability of detecting at least one infested tree changes. In general, more samples are required as the desired probability of detection increases and as the proportion of plants with insects decreases (i.e., the insects become rarer in the environment).

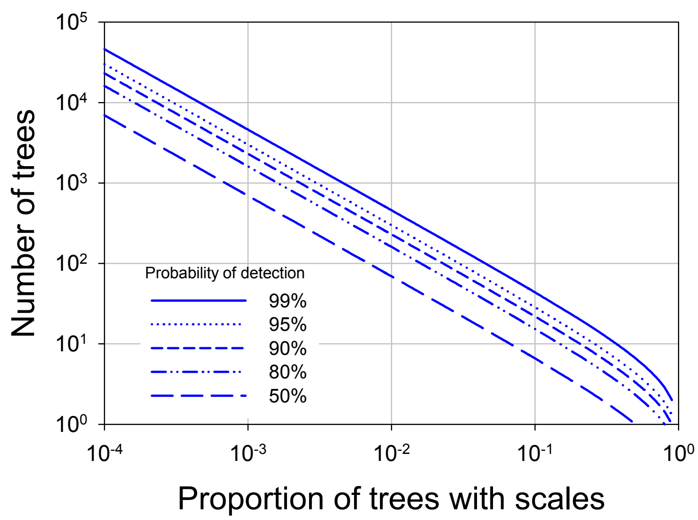

Figure 3. Required number of trees to be inspected to detect *U. yanonensis* in relation to the proportion of trees with scales and the desired probability of detecting *U. yanonensis* when it is present. This figure assumes random sampling from a large environment.

4. **Taxonomic Recognition. Rating: Medium.** *U. yanonensis* may be taxonomically confused with other armored scales of citrus, particularly with a close relative, *U. citri*, which reportedly occurs in North America (including: Bermuda, Mexico, California, Florida, Georgia, and Louisiana), Africa, Asia, Central and South America, and Oceania (Blackburn and Miller 1984, CABI/EPPO 1997, CAB 2004, EPPO 2004c). These closely related species overlap somewhat with respect to host range (citrus) and geographic distribution. *U. citri* is reportedly found less often on fruit compared to *U. yanonensis*(CABI/EPPO 1997), however this may be variable depending on availability of suitable hosts, abundance of natural enemies, and other factors. Detailed comparisons, keys and figures of morphological characters distinguishing *U. yanonensis* and *U. citri* are provided by EPPO (2004c), USDA-APHIS (Blackburn and Miller 1984), Rao (1949), and others. Adult females may be positively identified by close examination of morphological characters by a taxonomist.

   For a detailed description of the morphology of *U. yanonensis*, see Appendix C.

5. **Entry Potential. Rating: High.** *Unaspis yanonensis* have been intercepted at least 4,900 times at US ports of entry between 1985 and 2004; unspecified "*Unaspis* sp." were reported 11 times over the same period (incomplete records complicate the accuracy of these counts) (USDA 2005a). Collectively, 246 (±20 standard error of the mean) interceptions have been reported annually (USDA 2005a). The majority of interceptions have been associated with international airline baggage (58%), ship stores (21%) and ship quarters (10%). Most interceptions were reported from Honolulu, HI (82%), Blaine, WA (9%), and San Francisco, CA (4%). These ports are the first points of entry for infested material coming into the U.S. and do not necessarily represent the final destination of infested material. Movement of potentially infested material is more fully characterized in the next section.

   Interceptions of *U. yanonensis* were overwhelmingly associated with citrus (>99% of all interceptions). Non-citrus (*Citrus* spp.) plants that were infested with *U. yanonensis* included "Cycadaceae" (0.03%); mango, *Mangifera indica* (0.03%); round kumquat, *Fortunella japonica* (0.03%); unspecified "plant" (0.03%); and kumquat, *Fortunella* sp. (0.02%).

   The medium rating assigned to this element has a modest degree of uncertainty. Each year between 1985 and 2004, 167 (±32) scales have been intercepted and identified only as "Diaspididae" (USDA 2005a). If a ~25% of these scales were *U. yanonensis*, which seems possible, a high rating would be warranted.

6. **Destination of Infested Material. Rating: High.** When an actionable pest is intercepted, officers ask for the intended final destination of the conveyance. Materials infested with *Unaspis yanonensis* or *Unaspis* sp. were destined for 28 states, including the District of Columbia, in the contiguous US (USDA 2005a).

On the US mainland, the most commonly reported destinations were California (9%) and Washington (6%); however, Hawaii, by far, was the most common intended destination (81%). We note that portions of California have a climate and hosts that would be suitable for establishment by *Unaspis yanonensis*.

7. **Potential Economic Impact. Rating: High.** *Unaspis yanonensis* is an important pest of citrus in Asia, and has been reported as the most destructive citrus pest in Japan since its discovery in 1907 (Ohkubo 1980, Blackburn and Miller 1984). The economic impact of *U. yanonensis* is difficult to measure, especially when it occurs in mixed populations with other scales (Onillon 1988, EPPO 2004c). Feeding of foliage, stems, and ripening and mature fruit by the scale causes a wide array of damage, all of which predisposes fruit and other plant parts to further damage by secondary pests including microorganisms and fruitflies (CAB 2004, EPPO 2004c). Host damage includes chlorotic-necrotic spots foliage; premature leaf drop; irregular stem growth and stem, limb dieback (scar tissue over sealed wounds may result in split stems); external pits and spots on fruit skin and irregularly shaped fruit; premature ripening, fruit drop and rot (Blackburn and Miller 1984, CAB 2004, EPPO 2004c). Tree dieback may also result from heavy pest attack, however the mechanisms causing death are not well known (Ohkubo 1980, CAB 2004). Severe attack during the springtime (threshold of 8 females per leaf) can result in tree death within a year (reviewed in Ohkubo 1980).

   Feeding damage by scales typically renders fruits and vegetables unmarketable, or significantly lowers crop value (EPPO 2004a). Studies showing a correlation between fruit infestation and pest density have resulted in the development of models used to estimate economic damage and threshold levels (Murakami 1970, Ohkubo 1980). The economic threshold for high valued citrus crops is low, with the acceptable tree injury corresponding to less than 1% fruit infestation [pest density corresponding acceptable injury level = 0.5-1 scale per leaf] (Ohkubo 1980). Even light infestations may cause significant leaf drop which has an overall impact on factors such as yield, tree health and fruit quality. The value of infested fruit is considerably lower than that of premium, blemish-free fruit (Ohkubo 1980, CAB 2004). Presence of this pest may be detrimental because establishment and spread could jeopardize crops, domestic and foreign forest product industries, and the nursery trade (Blackburn and Miller 1984).

8. **Potential Environmental Impact. Rating: Medium.** In general, newly established species may adversely affect the environment in a number of ways. Introduced species may reduce biodiversity, alter forest composition or disrupt ecosystem function, jeopardize endangered or threatened plants, degrade critical habitat, or stimulate use of chemical or biological controls. *Unaspis yanonensis* 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.

Unaspis yanonensis has a fairly narrow host range, feeding primarily on citrus hosts within the family Rutaceae, and on one additional host (*Damnacanthus*) in the family Rubiaceae [see 'Host Specificity']. No federally listed threatened or endangered plant species are closely related (i.e., same genus) to known hosts (or potential hosts) of *U. yanonensis* (USDA NRCS 2004).

9. **Establishment Potential. Rating: High.** Our initial predictions suggest that nearly 30% of the US has a climate that could support populations of *U. yanonensis* (Fig. 2). Citrus production areas in the southern and western US fall within or adjacent to regions predicted to be climatically suitable for this insect. Given the degree of uncertainty associated with the climatic assessment, this insect poses a threat to most citrus production areas within the US. Further, interception records indicate that the insect is introduced regularly at a high rate, relative to other pests. As a result, the potential for establishment seems high.

   See Appendix D for a more detailed description of the biology of *U. yanonensis*.

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Appendix A. Geographic distribution and 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 (Table A1). Using a geographic information system (e.g., ArcView 3.2), 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. 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. 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. Finally, the set of selected biomes was compared to only those that occur in the US.

Table A1. Reported geographic distribution of *Unaspis yanonensis*:

Locations	Reference(s)
Armenia	(USDA 2005b)
Australia [1]	(USDA 1979, Blackburn and Miller 1984, CABI/EPPO 1998, CAB 2004)
China	(Kuwana 1923, USDA 1979, Blackburn and Miller 1984, EPPO 1989, Matsumoto et al. 2003a)
China (Anhui and Nei Mongol)	(USDA 2005b)
China (central)	(CIE 1988)
China (Chekiang - Hangchow, S. Chekiang)	(Cheo 1935)
China (Chungking or Chongqing)	(Huang et al. 1981, 1983)
China (Fuijan Province - Shaxian)	(Huang et al. 1981)
China (Fujian Province - north central)	(Song et al. 1990, Wang et al. 1994)
China (Fujian Province)	(CIE 1988, CABI/EPPO 1998, Gong et al. 1999, CAB 2004)
China (Fukien - Foochow)	(Cheo 1935)
China (Gansu)	(Huang et al. 1981)
China (Guangdong)	(Huang et al. 1981, CIE 1988, CABI/EPPO 1998, CAB 2004)
China (Guangxi)	(CIE 1988, CABI/EPPO 1998, CAB 2004)
China (Guizhou)	(Huang et al. 1981, Ren et al. 1991)
China (Hebei)	(CIE 1988, CABI/EPPO 1998, CAB 2004)
China (Henan)	(Huang et al. 1981, CABI/EPPO 1998, CAB 2004)
China (Hong Kong) [1]	(USDA 1979, Blackburn and Miller 1984, CABI/EPPO 1998, CAB 2004)
China (Hua Ning)	(Zhong et al. 1992)

Locations	Reference(s)
China (Huaxi in Guizhou Province)	(Ren et al. 1992a, b)
China (Hubei)	(Huang et al. 1981, CABI/EPPO 1998, CAB 2004)
China (Hunan - Changsha)	(Cheo 1935)
China (Hunan - Qianyang)	(Huang et al. 1981)
China (Hunan)	(CABI/EPPO 1998, CAB 2004)
China (Hupeh - Hankow, I-chang, Wuchang)	(Cheo 1935)
China (Jiangsu)	(Huang et al. 1981, CABI/EPPO 1998, CAB 2004)
China (Jiangxi)	(Huang et al. 1981, CABI/EPPO 1998, CAB 2004)
China (Kiangsi - Kanchow)	(Cheo 1935)
China (Kiangsu - Nanking, Soochow)	(Cheo 1935)
China (Kwangtung - Sunwui)	(Cheo 1935)
China (northern)	(Tang 1984)
China (Shaanxi)	(CIE 1988, CABI/EPPO 1998, CAB 2004)
China (Shanghai)	(Kuwana 1923, Cheo 1935)
China (Shanxi)	(Huang et al. 1981, CIE 1988, CABI/EPPO 1998, CAB 2004)
China (Sichuan)	(Huang et al. 1981, CIE 1988, Rose et al. 1991, CABI/EPPO 1998, CAB 2004)
China (southern)	(Matsumoto et al. 2002, Matsumoto et al. 2003c, Matsumoto et al. 2003d, Matsumota et al. 2004)
China (Xizhang)	(CABI/EPPO 1998, CAB 2004)
China (Yuanjiang)	(Matsumoto et al. 2003a)
China (Yunnan)	(Huang et al. 1981, CABI/EPPO 1998, CAB 2004)
China (Zhejiang)	(Huang et al. 1981, CIE 1988, CABI/EPPO 1998, CAB 2004)
England [2]	(CABI/EPPO 1998, CAB 2004)
Fiji [4]	(Blackburn and Miller 1984, CABI/EPPO 1998, CAB 2004)
France	(Bénassy and Pinet 1987, Bénassy 1988, EPPO 1989, Rose et al. 1991, CABI/EPPO 1998, CAB 2004)
France (Alpes-Maritimes)	(Bénassy and Pinet 1972, CIE 1988)
France (Beaulieu-sur-mer on the Cote d'Azur)	(Bénassy and Pinet 1972, Blackburn and Miller 1984)
France (Eze-sur-Mer, Saint-Jean-Cap-Ferrat, Villefranche-sur-Mer)	(Bénassy and Pinet 1972)
France (French Riviera)	(Bénassy and Pinet 1972, Kreiter et al. 1998)
France (southern)	(CIE 1988)
India [1]	(Blackburn and Miller 1984, EPPO 1989, CABI/EPPO 1998, CAB 2004)
Indonesia [1]	(Blackburn and Miller 1984, EPPO 1989, CABI/EPPO 1998, CAB 2004)
Italy	(EPPO 1989, CABI/EPPO 1998, CAB 2004)
Italy (northwestern)	(Longo et al. 1995)

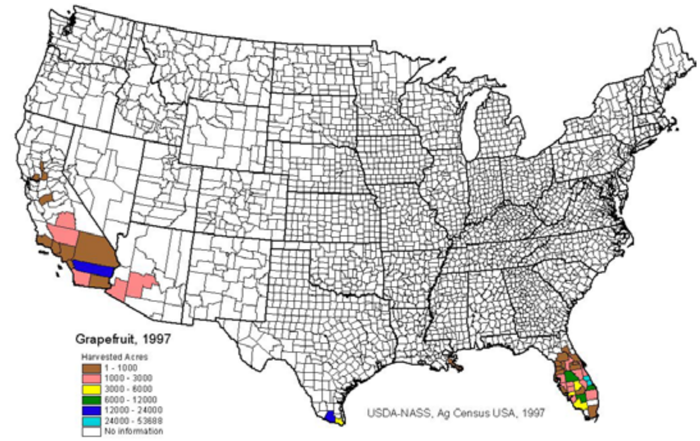
Locations	Reference(s)
Japan	(USDA 1979, Ohkubo 1980, Blackburn and Miller 1984, Takagi and Ogata 1985, Bénassy and Pinet 1987, Bénassy 1988, EPPO 1989, Takagi and Ogata 1990, Rose et al. 1991, Mizobuchi et al. 1995, Itioka et al. 1997, BA 2002, Matsumoto et al. 2002, 2003a, b, Matsumoto et al. 2003c, Matsumoto et al. 2003d, Matsumota et al. 2004, Matsumoto et al. 2004a, b)
Japan (Aichi)	(Murakami 1970)
Japan (Akitsu)	(Ogihara et al. 1989)
Japan (Chiba)	(Murakami 1970)
Japan (Fukui)	(Murakami 1970)
Japan (Fukuoka)	(Kuwana 1923, Murakami et al. 1974, CIE 1988, Takagi 1991)
Japan (Gifu)	(Murakami 1970)
Japan (Hagi-city in Honshu)	(Nohara 1962)
Japan (Hiroshima)	(Kuwana 1923, Murakami 1970, Korenaga et al. 1978, Korenaga et al. 1981, Korenaga 1986, CIE 1988)
Japan (Honshu)	CAB/EPPO quar. Map 1998(Kuwana 1923, Murakami 1970, CAB 2004)
Japan (Hyogo)	(Murakami 1970)
Japan (Ibaragi)	(Murakami 1970)
Japan (Kagawa)	(Kuwana 1923)
Japan (Kagoshima Prefecture - Nagashima)	(Nakao et al. 1985)
Japan (Kagoshima)	(Kuwana 1923, Murakami et al. 1974, Ohkubo 1980, CIE 1988)
Japan (Kanagawa)	(Murakami 1970, Korenaga et al. 1978, Korenaga et al. 1981, Korenaga 1986)
Japan (Kuchinotsu)	(Takagi 1983, Takagi and Ujiye 1986)
Japan (Kumamoto)	(Kuwana 1923, Murakami et al. 1974, Korenaga et al. 1978, Korenaga et al. 1981, Korenaga 1986, CIE 1988)
Japan (Kyoto)	(Murakami 1970, Matsumoto et al. 2003a)
Japan (Kyushu - southern)	(Murakami et al. 1974)
Japan (Kyushu or Kiushiu)	(Kuwana 1923, Murakami 1970, Korenaga 1986, CIE 1988, CABI/EPPO 1998, CAB 2004)
Japan (Loochoo Islands)	(Murakami 1970)
Japan (Maizuru)	(Matsumoto et al. 2003a)
Japan (Mei)	(Murakami 1970)
Japan (Miyasaki)	(Kuwana 1923)
Japan (Miye)	(Kuwana 1923)
Japan (Nagasaki Prefecture - Ikiriki)	(Kuwana 1923, Takagi 2002)
Japan (Nagasaki Prefecture)	(Kuwana 1923, Murakami 1970, Murakami et al. 1974, Ohkubo 1980, Blackburn and Miller 1984, CIE 1988, Adachi and Korenaga 1991, 1992, Matsumoto et al. 2003a)
Japan (Nara)	(Murakami 1970)
Japan (Okayama)	(Murakami 1970)

Locations	Reference(s)
Japan (Okinawa)	(Blackburn and Miller 1984)
Japan (Okitsu in Shizuoka Prefecture)	(Korenaga et al. 1974, Sakagami and Korenaga 1982, 1985, Korenaga 1986)
Japan (Omura City)	(Ohgushi et al. 1977)
Japan (Osaka)	(Murakami 1970)
Japan (Ryukyu Archipelago)	(CIE 1988, CABI/EPPO 1998, CAB 2004)
Japan (Saga)	(Kuwana 1923)
Japan (Shikoku)	(Kuwana 1923, Murakami 1970, Korenaga 1986, CABI/EPPO 1998, CAB 2004)
Japan (Shizuoka Prefecture)	(Murakami 1970, Korenaga and Sakagami 1978, Korenaga et al. 1978, Korenaga et al. 1981, Blackburn and Miller 1984, Korenaga 1986, CIE 1988, Takahashi et al. 1990, Adachi and Korenaga 1991, Mizobuchi et al. 1995, Matsumoto et al. 2003a, Matsumoto et al. 2003d)
Japan (Tokushima)	(Yukinari and Kagawa 1985)
Japan (Tottori)	(Murakami 1970)
Japan (Wakayama Prefecture)	(Murakami 1970, Murakami et al. 1974, Itioka and Inoue 1989, Matsumoto et al. 2002, 2003a, b, Matsumoto et al. 2003c, Matsumoto et al. 2003d, Matsumota et al. 2004, Matsumoto et al. 2004a, b)
Japan (Yamaguchi)	(Kuwana 1923, Murakami 1970, CIE 1988)
Japan (Yamanashi)	(Murakami 1970)
Japan (Yehime)[5]	(Kuwana 1923)
Korea	(USDA 1979, Blackburn and Miller 1984, CIE 1988, EPPO 1989)
Korea, Democratic People's Republic	(CABI/EPPO 1998, CAB 2004)
Korea, Republic	(CABI/EPPO 1998, CAB 2004)
Malaysia[1]	(Blackburn and Miller 1984, EPPO 1989, CABI/EPPO 1998, CAB 2004)
Mediterranean region	(EPPO 2004a)
Myanmar (formerly Burma)[1]	(Blackburn and Miller 1984, EPPO 1989, CABI/EPPO 1998, CAB 2004)
Pakistan[1]	(Blackburn and Miller 1984, EPPO 1989, CABI/EPPO 1998, CAB 2004)
Philippines[1]	(USDA 1979, Blackburn and Miller 1984, EPPO 1989, CABI/EPPO 1998, CAB 2004)
Switzerland[3]	(CABI/EPPO 1998, CAB 2004)
Taiwan[5]	(Blackburn and Miller 1984, CABI/EPPO 1998, CAB 2004)
Thailand[1]	(USDA 1979, Blackburn and Miller 1984, EPPO 1989, CABI/EPPO 1998, CAB 2004)
Tibet	(CIE 1988)
Vietnam[1]	(Blackburn and Miller 1984, EPPO 1989, CABI/EPPO 1998, CAB 2004)

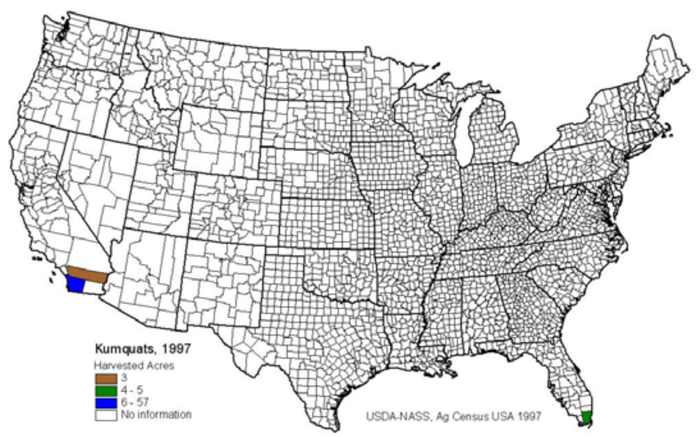
1. Absent; dubious record (CIE 1988, CABI/EPPO 1998, CAB 2004)
2. Absent; intercepted (CABI/EPPO 1998, CAB 2004)

3. Absent; not established (CABI/EPPO 1998, CAB 2004)
4. Present. Though it is climatically possible for this pest to occur in this region, *U. yanonensis* is not currently reported anywhere else in Oceania, therefore the validity of this record is questionable. Morphologically similar *C. citri* also occurs in Fiji and elsewhere in Oceania.
5. Absent; eradicated

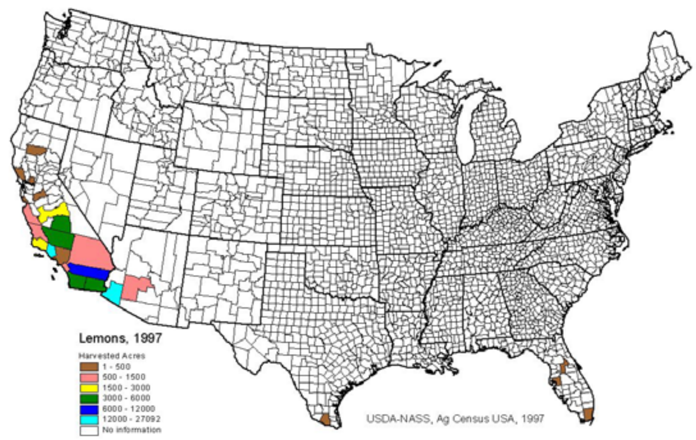
Appendix B. Host distribution for *Unaspis yanonensis* in the contiguous US.



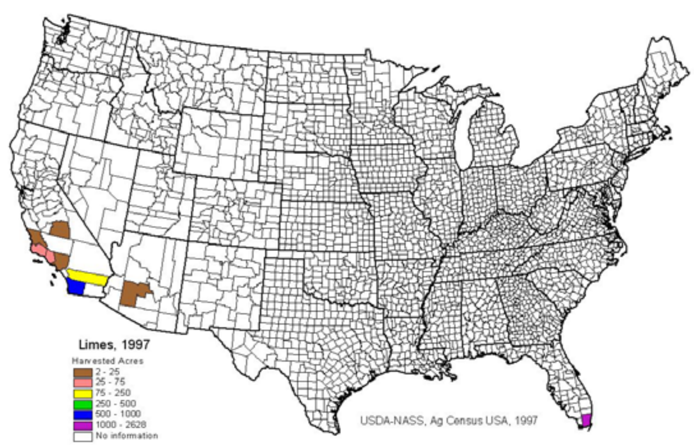
Map 1. Grapefruit (*Citrus x paradisi* [*maxima x sinensis*])



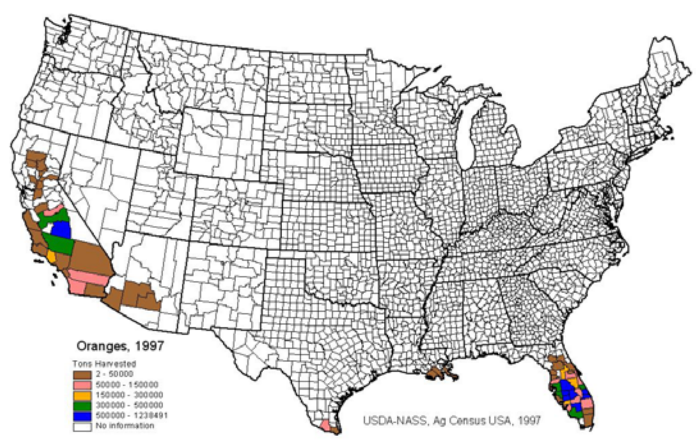
Map 2. Kumquat (*Fortunella* spp.)



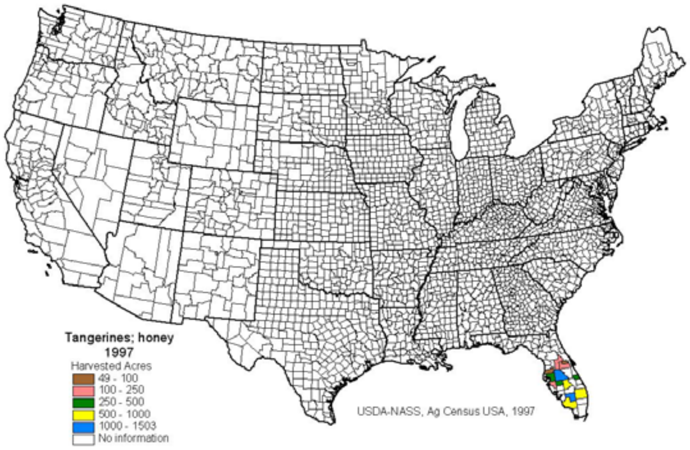
Map 3. Lemon (*Citrus limon*)



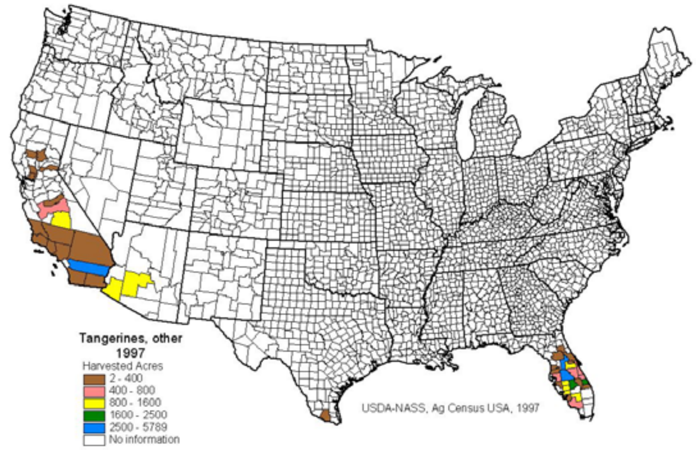
Map 4. Lime (*Citrus aurantifolia*)



Map 5. Orange (*Citrus* spp.)



Map 6. Tangerine, honey (*Citrus reticulata*)



Map 7. Tangerine, other (*Citrus reticulata*)

Appendix C. Taxonomy and morphology of *Unaspis yanonensis* (Kuwana)

Unaspis (=*Prontaspis*) *yanonensis* was described by Kuwana (1923). Subsequent descriptions have been published by Rao (1949) and others.

Synonyms

"*Chionaspis citri*; Kuwana, 1907. Misidentification; discovered by Kuwana, 1926
Prontaspis yanonensis Kuwana, 1923. Type data: JAPAN: Kyushu, Ikiriki, near Nagasaki, on *Citrus* sp.
Unaspis yanonensis; Takahashi & Kanda, 1939. Change of combination
Unaspis janonensis; Ter-Grigorian, 1969. Misspelling of species name
Unaspis yannonensis; Chou, 1982. Misspelling of species name" (USDA 2005b).

Our summary of currently recognized synonyms does not include all historical accounts of misidentification [such as *Pronaspis yanonensis* recorded in the U.S. by Cheo (1935)], some of which may have been *U. citri*. This species has several synonyms (Kuwana 1923).

Description

For complete accuracy, the following morphological descriptions are quoted from Kuwana (1923) and Rao (1949).

The adult female

"*The Scale*: The scale of the female is of a dirty blackish-brown color with a gray margin; the exuviae are pale yellow, and elongate in form. There is a central ridge from which the sides of the scale slope away like the roof of a house. The ventral scale is white, and does not meet in the middle. Length 2.84 to 3.56 mm, width at the broadest point 1.40 to 1.92 mm" (Kuwana 1923).

"*The Body*: The body of the female is elongate in form, distinctly segmented; the anterior margin with the end rounded; constrictions at the sutures distinct, especially so on the two segments preceding the penultimate one. The antennae are represented by minute tubercles bearing one short hair. The mouth parts are well formed, rostral loop very long. Two pairs spiracles prominent. There are more than twelve spine-like plates or gland spines at the side of the penultimate segment. Length about 2.5 mm., width 1.0 mm" (Kuwana 1923).

"*The Pygidium*: Rather large and parabolic in shape. There are three pairs of well developed lobes; the median ones large, somewhat sunken into the pygidium, not close to each other, diverging and serrated at the inner margin; the second lobes broad and deeply notched, the outer lobules slightly smaller; the third lobes slightly smaller than the second, but well developed and somewhat similar in shape. The arrangement of the gland spines is as follows: one just outside the median lobe, one just outside the outer lobule of the second lobe, one beyond the outer lobule of the third lobe, one about half way between this and the base of the pygidium, and a group of five or six (sometimes more) immediately cauded of the base of the pygidium. The spines are as shown in the figure. Anns circular, slightly nearer to the base than to the apex of the pygidium; circumgenital gland-orifices wanting; marginal gland-orifices as follows: the first between the first and second lobes on a slight prominence, the second also on a slight prominence and between the second gland spine and the inner lobule of the third lobe; the third just beyond the second, opening at the outer angle of the inner lobule of the third lobe; the fourth a little beyond this, slightly inside the margin and apparently opening into a pocket; the fifth on a slight protuberance beyond the fourth gland spine; and the sixth a little beyond the preceding one. The dorsal gland orifices are very numerous, variable. Micropores so far as observed are as indicated" (Kuwana 1923).

"Scale of the female broadly elongate, flat, with a distinct median ridge, blackish brown with lighter margin, exuvia pale yellow. Length 2.5-3 mm, greatest width 1.5-2 mm. Scale of the male of the type common to the genus" (Rao 1949).

" *Recognition characters*. Adult female with the prosoma strongly sclerotized, occupying about two-thirds of the length of the body, rather cuneiform and with its posterior angles projecting and acute. Remainder of the body slightly sclerotized throughout at maturity, the two prepygidial abdominal segments quite strongly lobed laterally. Median pygidial lobes quite small, forming a slight notch in the apex of the pygidium, their mesal margins slightly longer than the lateral margin and irregularly serrate. Second and third lobes about equal to each other, their lobules of about the same size. Dorsum of the pygidium with great numbers of macroducts, the total being as great as 150. Anterior spiracles with a cluster of about 15 associated pores. Perivulvar pores lacking" [Fig. C1] (Rao 1949).

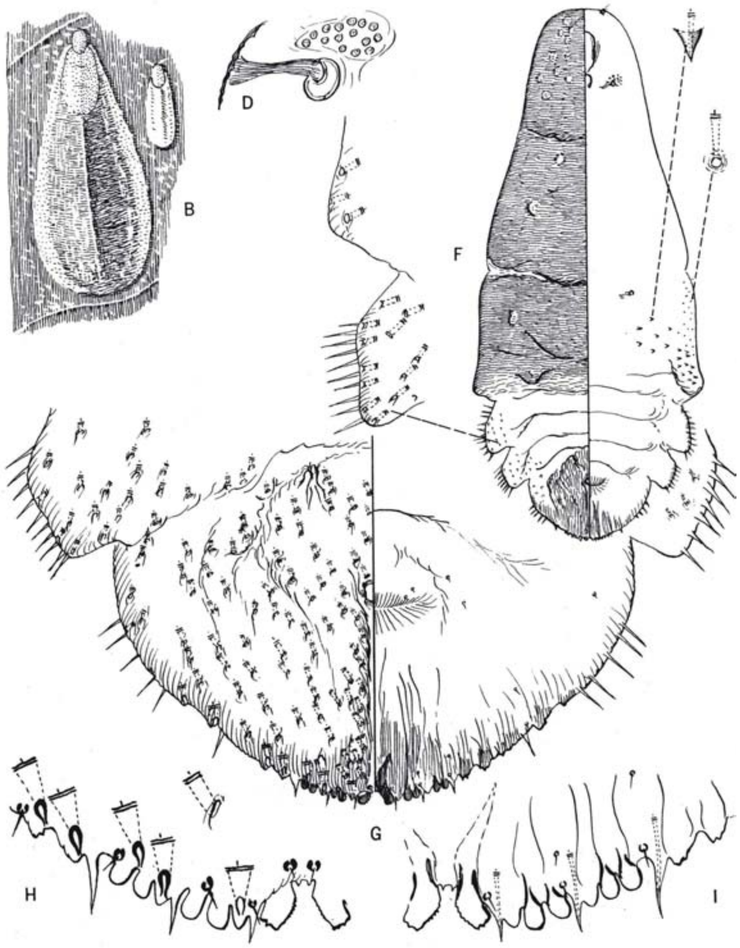


Figure C1. *Unaspis yanonensis* adult: (A, C and E not shown); B. Habit; D. Anterior spiracle of adult female; F. Body of female; G. Pygidium of adult female; H and I. Details of dorsal and ventral sides, respectively, of pygidial margin of adult female. [Figure from Rao (1949)].

The adult male

"*The Scale*: Long, white, distinctly carinatod. Exuviae pale brownish yellow. Length about 1.25 to 1.56 mm., width 0.48 to 0.75 mm" (Kuwana 1923).

"*The Body:* Wing expanse 1.76 mm., length of the body exclusive of the style .45 mm., style .36 mm. General color orange yellow, eyes deep dark brownish purple, antennae and legs pale yellow. Head rounded, somewhat pointed at the apex. The antennae composed of ten segments, the first two being much shorter and thicker than the others. The total length of a typical antenna is about 0.54 mm. All the segments except the first two bear rather long fine hairs. The measurements of the antenna1 segments in microns are as follows:

I	II	III	IV	V	VI	VII	VIII	IX	X
19	19	76	76	76	76	76	57	61	57
19	19	76	76	76	76	76	57	63	46

The thoracic band is of a light brown color. The wings extend beyond the tip of the style when resting on the body. The halteres are club-shaped, with the slender hook arising from the tip of the club. The legs are slender and hairy, similar; femur is only a little longer than tibia, but the former much broader; tarsus shorter than the tibia and with a curved claw; digitules as usual. The measurements of the different parts of the hind leg are: coxa 0.04 mm., trochanter and femur 0.15 mm., tibia 0.11 mm., tarsus 0.07 mm., claw 0.02 mm" (Kuwana 1923).

"Abdominal segments well defined, narrowing slightly towards the posterior end, which is furnished with a sharp style. All segments bear very fine hairs" (Kuwana 1923).

The immature forms

"*The Egg:* The egg is oval in shape, measuring about 0.18 mm., in length and 0.09 mm., in width. The color is orange yellow with the surface entirely smooth" (Kuwana 1923).

"*The First Larval Stage:* The active, or first larval stage of the insect is a flat oval-shaped creature, pale yellow in color, wjth the posterior end yellowish brown. The total length of the body is about 0.23 mm. and the greatest width 0.14 mm" (Kuwana 1923).

"The antennae are five segmented, the last being the longest and distinctly annulate; segments one to four bear one hair, while the distal segment bears several. A pair of relatively large glandular pores with very strongly curved cylindrical ducts; on the dorsa1 surface near the front. The mouth parts are well formed, with the rostal loop long. Eyes prominent and purple in color, placed at the sides behind the antcnnae. The three pairs of legs are similar and well developed; the femur longer and highly convex at the outer margin; the tibia short, less than half the length of the tarsus; the claw very large and slightly curved; the digitules prominent. The margin bears about thirty hairs. There are three pairs of small lobes at the posterior end; the median pair longest, the second and third smaller and similar; near the base of these lobes on the inner side is a spine which extends slightly beyond the tip of the lobe. There are two other similar spines beyond the lobes and two very long hairs at the caudal end between the median lobes. The general shape of the male and female are alike, but the former is slightly deeper in color" (Kuwana 1923).

"*The Second Larval Stage, Female*: After the first moult the body of the insect is greatly increased in size, and now all the characters of the pygidium are distinct, but the legs are entirely lost and the antennae are rudimentary and of a single segment. The length of the body is about 0.31 mm. and the width 0.21 mm" (Kuwana 1923).

"The pygidium is round, with the median portion depressed. There are three pairs of conspicuous lobes with a spine arising from the base of each; the first or median pair serratulate; the second and third divided into two, with the outer lobule smaller. There are four pairs of gland spines, the first between the median and the second lobes, the second between the second and third lobes, and the two others beyond the same. The marginal gland orifices as follows; one between the first and second lobes, one between the second gland spine and the inner lobule of the third lobe, and two more beyond the third gland spine. After the second moult the female reaches the adult stage" (Kuwana 1923).

"*The Second Larval Stage, Male*: There are no distinguishable differences between the sexes until after the first moult, except in color. The male becomes more elongate after the first moult, and the length of the body is about 0.64 mm" (Kuwana 1923).

"The pygidium is much simpler and not indented at the median portion as in the female. The three pairs of lobes are present but not so prominent. There are two pairs of conspicuous purple eyes, one on the lateral interior margin and the other more dorsal and closer together. The color of the body is yellowish orange, gradually becoming orange. The margina; gland orifices are of six pairs instead of four as in the case of the female. There are a few dorsal gland orifices" (Kuwana 1923).

"*The Propupa, Male*: The general color of the body of the propupa is orange yellow with the abdominal end yellowish brown, while the eyes are very dark purple brown. The dorsal eyes are just posterior to the antennal sheaths, while the ventral eyes are larger, closer together, and a little more caudad than the dorsal ones. The sheaths of the antennae, legs and wings are visible. However, they are all more rudimentary and more closely appressed to the body than in the next stage" (Kuwana 1923).

"*The Pupa, Male*: The color of the body is the same as that of the propupa. The ventral eyes are larger and almost touch each other. They are situated a short distance from the anterior margin, while the dorsal pair is wider apart and somewhat closer to the anterior margin. The sheaths of the antennae, wings, and legs are evident and ordinarily lie close to the body along the ventral margin. The style is now prominent. The length of the body exclusive of the style is about 0.80 mm., the style 0.15 mm., and the greatest width 0.30 mm" (Kuwana 1923).

Appendix D. Biology of *Unaspis yanonensis*

Population phenology

In China and Japan, *Unaspis yanonensis* typically has between 2-4 generations annually, though the final (third and rarely, a fourth) generation may occur only when late summer - autumn temperatures exceed 24°C (Kuwana 1923, Murakami 1970, Blackburn and Miller 1984, Song et al. 1990, Adachi and Korenaga 1991). The third or final generation may be a partial generation in the event of unfavorable temperatures (Kuwana 1923). Population dynamics are influenced by several factors including climate (temperature), host availability and quality (location of feeding site on host), population size, abundance of natural enemies, and microclimate characteristics including exposure to sunlight (Nohara 1962, Murakami 1970, Wang and Chen 1989, Adachi and Korenaga 1991). *Unaspis yanonensis* feeds on foliage, small diameter stems (especially 1 year old growth) and fruit of primarily citrus hosts (Ohkubo 1980). Scales appear to prefer shade and high temperatures and have been observed to live longer when feeding occurs on portions of the host plant below mid-crown height (Nohara 1962), though longevity may be due in part to other factors.

U. yanonensis egg-laying peaks are thought to be controlled chiefly by temperature and ovovipary. In ovoviparous species, eggs remain in the ovary until near completion of embryonic development, and egg production temporarily stops when a certain capacity is reached, then resumes after oviposition begins. There are typically two egg-laying peaks per generation that are thought to be separated by a period of rest. Subsequently, there are two distinct peaks in appearance of larvae (Murakami 1970, Adachi and Korenaga 1991). Peaks occur 10-15 days and about 30 days after emergence begins; the first peak of the first generation being the most prominent (Murakami 1970).

U. yanonensis overwinters primarily as fertilized adult females, but in warmer regions, a small percentage (approx. 20%) of the population may overwinter as second instars (Kuwana 1923, Murakami 1970, Blackburn and Miller 1984). Males overwinter as developing embryos or second instars. Winter mortality is highly variable depending largely on location characteristics (latitude, altitude, etc.) and development stage. Reported winter mortality for mature adults, immature adults and second instars ranges from 34-90%, 23-80%, and 2-30%, respectively (Murakami 1970). The sex ratio of this scale varies in each generation and is not well understood as rearing studies under laboratory conditions have produced varying results. Kohno et al. (cited in Murakami 1970) reported 5.5 and 1.5 times as many males compared to females in the first and second generations, respectively, and third generation with a 3:2 female:male ratio.

In Nagasaki, Japan there are typically 3 generations annually, Here, the life cycle duration is 65 days, 55-64 days, and approximately 245 days for the first, second, and overwintering generations, respectively. Duration of the overwintering generation depends primarily on temperature and may require development time of up to 8 months (Kuwana 1923). Crawler emergence begins in late May, August, and September – early October for the first, second, and third generations, respectively (Kuwana 1923).

In Shizuoka Prefecture, Japan, there are usually 3 generations. Peak emergence of crawlers may be observed early to mid May, late July-early August, and mid to late September for first through third generations, respectively. The first generation life cycle requires about 75 days (Blackburn and Miller 1984). Numerous studies based on 16 years of scale observations and approximately 20 years of meteorological data have occurred in this region. Sakagami et al. (1981) studied *U. yanonensis* under photoperiodic and constant temperature conditions. Females kept above 24°C for a minimum of 10 days, followed by a mean temperature of 14°C produced eggs. However, egg production did not occur when the following mean temperature was near 12°C, and egg hatch did not occur when the following treatment was near 11°C. Under laboratory and field conditions in autumn, it was noted that larval emergence ceased when mean temperature was below 11°C. In a subsequent study, Sakagami and Korenaga (1985) reported that a mean temperature of 24°C for a minimum of 10 days was necessary for egg development and oviposition to occur. In another study, Sakagami and Korenaga (1982) reported a developmental threshold temperature of 13°C for egg development within ovaries of overwintering females.

Korenaga et al. (1976) studied development of the first generation under fluctuating temperatures. Growth chamber temperature was changed twice daily at 6 AM and 6 PM. Temperature differences of 3, 6 and 10°C between daytime and nighttime were tested. Average day and night temperatures were maintained between 18-30°C (±3°C). With the day/night temperature difference of 6°C and a mean temperature range between 18-27°C, the rate of development was linear; maximum growth for the first instars was near 28°C, and 27°C for second instars and preovipositional adults, respectively; while development was inhibited above these temperatures. Developmental thresholds and development times (expressed in degree-days above the specified threshold) are summarized below for each life stage.

Life Stage	**Developmental threshhold (°C)**	**Thermal constant (accumulated degree-day requirement)**
First instar larvae (female)	9.6	192
Second instar larvae (female)	8.8	275
Adult (preovipositional)	12.6	400

(modified and reproduced from (Korenaga et al. 1976)).

In Hua Ning, China, there are 2 generations annually. Here, *U. yanonensis* overwinters primarily as adult females. There are 4 egg-laying peaks beginning in mid February, followed by others in mid to late April, mid to late June, and mid August (Zhong et al. 1992).

In north central Fujian Province, China, there are typically 3 generations annually. Four generations (or partial generation) are possible in warmer years. Oviposition begins near temperatures of 18°C in mid April, and larval densities of the first generation peak in late April, second generation in early to mid July, and third generation in early September to early October. If a fourth generation occurs, another larval peak may be observed in December (Song et al. 1990).

In the Mediterranean region there are 2 generations annually (EPPO 2004a). In France, *U. yanonensis* overwinters as fertilized adult females. Emergence peaks are observed in April and July. Survival under natural conditions has been observed at about 57-60% and 41-43 % for first and second generations, respectively (Bénassy and Pinet 1972, Blackburn and Miller 1984).

Stage specific biology

This scale is described by Itioka and Inoue (1989) and Itioka et al. (1997) as sexually dimorphic. Females have two larval instars, an immature adult stage, and a mature adult stage; and males have two larval instars, propupa, pupa, and an alate (winged) adult stage. Except for crawler and winged adult stages, the scales are immobile once they have settled to feed. Kuwana (1923) fully describes the biology of *U. yanonensis*. In addition, Murakami (1970) provides a thorough review of studies on the biology and ecology of *U. yanonensis* prior to 1970.

Adult

Takagi (1991) suggests that there are two stages of adulthood in females that may be estimated by scale cover size; scale covers measuring < 2.7 mm in length are considered immature, while those measuring > 3mm are considered mature. Females mate after their final molt (Murakami 1970). Body color changes from yellow to dark orange with maturation. Eggs are visible through the cuticle. Egg-laying is concealed under the scale of the female. Females oviposit varying numbers of eggs depending on the generation, with the fewest eggs produced in the final generation (Murakami 1970). Korenaga and Sakagami (1978) showed that average egg production varied by generation in Shizuoka Prefecture, Japan. The average number of ovarian eggs was 134.3 and 109.4 for overwintering and first generations, respectively. In Nagasaki, Japan, the average number of eggs produced by females of the overwintering, first and second generations was 196, 177, and 133, respectively (Kuwana 1923). Oviposition occurs daily for about 10 days, and continues less regularly thereafter for a maximum of 80 days (reviewed in Murakami 1970). A maximum of 32 eggs may be deposited by a single female in one day (reviewed in Murakami 1970). In Shizuoka, Japan, an average of 110, 170, and 40 emerged larvae were tallied from a female representative (one per generation) of overwintering through final generations, respectively (reviewed in Murakami 1970).

Following the pupal molt, the male is winged, but remains inactive within the cast pupal skin for a short time. Afterwards, the male begins to search for a mate. The male dies after mating. Under laboratory conditions at temperatures ranging from 12-22°C, adult males lived 55 hours on average (Kuwana 1923).

Egg

Egg maturation in the ovary is rapid, transitioning from immature eggs between day 15 and 20. In laboratory studies at 20°C, incubation typically occurred in 1 hour (Kuwana 1923). Eggs remain in the female ovary through near completion of embryonic development. Individual scales hatch out in about 20-30 minutes, with overall hatching occurring in about a day (Kuwana 1923). The majority of hatching and crawling occurs during daylight hours (Wang and Chen 1989). Under laboratory conditions, average hatching to settling period for males and females has been reported at 15.7 and 17.6 h, respectively (Wang and Chen 1989). Larval emergence may be estimated by observing the formation of blastoderm and yolk in ovarian eggs (Murakami 1970).

Larva

There are two larval instars, the first of which lasts 8-16 days for females and males (Kuwana 1923). The duration of the second instar stage is variable depending on the season (range of 15-28 days reported for females; and 15-17 days for males during the summer, and near 30 days in late autumn). Newly hatched larvae remain under the maternal scale then emerge, crawl and settle to feed on small stems, leaves or fruit within a period of 3 hours (Kuwana 1923, Murakami 1970). A cotton thread-like secretion covers the males, while the immature females are covered by a combination of the white cottony and grey wax secretion, bringing about a notable variation in color and appearance (Kuwana 1923). It has been observed that early season crawlers generally settle on small stems and foliage and not on developing fruit, while intermediate and late season crawlers have been observed more on fruit rather than leaves (Kuwana 1923, Blackburn and Miller 1984).

Larval mortality is approximately 30, 78 and 52 % in the first through third generations, respectively (reviewed in Murakami 1970).

Propupa (Male)

This stage occurs following the second instar molt; however there is no significant difference in appearance. The natural duration of this life stage is unknown, but under laboratory conditions it lasts between 17-36 h (Kuwana 1923).

Pupa (Male)

This stage follows the propupa molt and lasts approximately 36-108 h. Body color is yellow-orange (Kuwana 1923).