Life Stages of California Red Scale and Its Parasitoids

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CALIFORNIA RED SCALE, *Aonidiella aurantii* (Mask.) (fig. 1), is a major pest of citrus that growers have traditionally controlled with insecticides. Populations of California red scale developed resistance to organophosphate and carbamate insecticides in South Africa, Australia and Israel in the 1970s and in California in the 1990s, and these broad spectrum insecticides are losing their effectiveness. An alternate approach to chemical control of California red scale is augmentative biological control as part of an integrated pest management (IPM) approach. Growers can release the insectary-reared parasitoid wasp *Aphytis melinus* DeBach from February through November to augment the native *Aphytis* populations that attack and reduce armored scale populations. This approach can

Figure 1. Scale infested fruit

Figure 2. Inverted female scale with crawlers

suppress armored scale densities below economic injury levels. In years when biological control is less effective, selective narrow range petroleum oil sprays can be used to help reduce scale numbers.This leaflet gives some background that will help growers evaluate the effectiveness of natural enemies of California red scale through knowledge of the scale life cycle, the stages of scale that are attacked by parasites and predators, and the signs of parasitism.

California Red Scale—General Phenology

FEEDING AND DORMANT LIFE STAGES

California red scale start out as mobile **crawlers*** (fig. 2). Crawlers remain mobile only long enough to find a suitable location on a leaf, fruit, or branch to settle on and begin feeding. From this stage onward, all life stages are immobile except for the adult males (fig. 3).

*Words in bold are important terminology needed for identification of scale and parasite stages.

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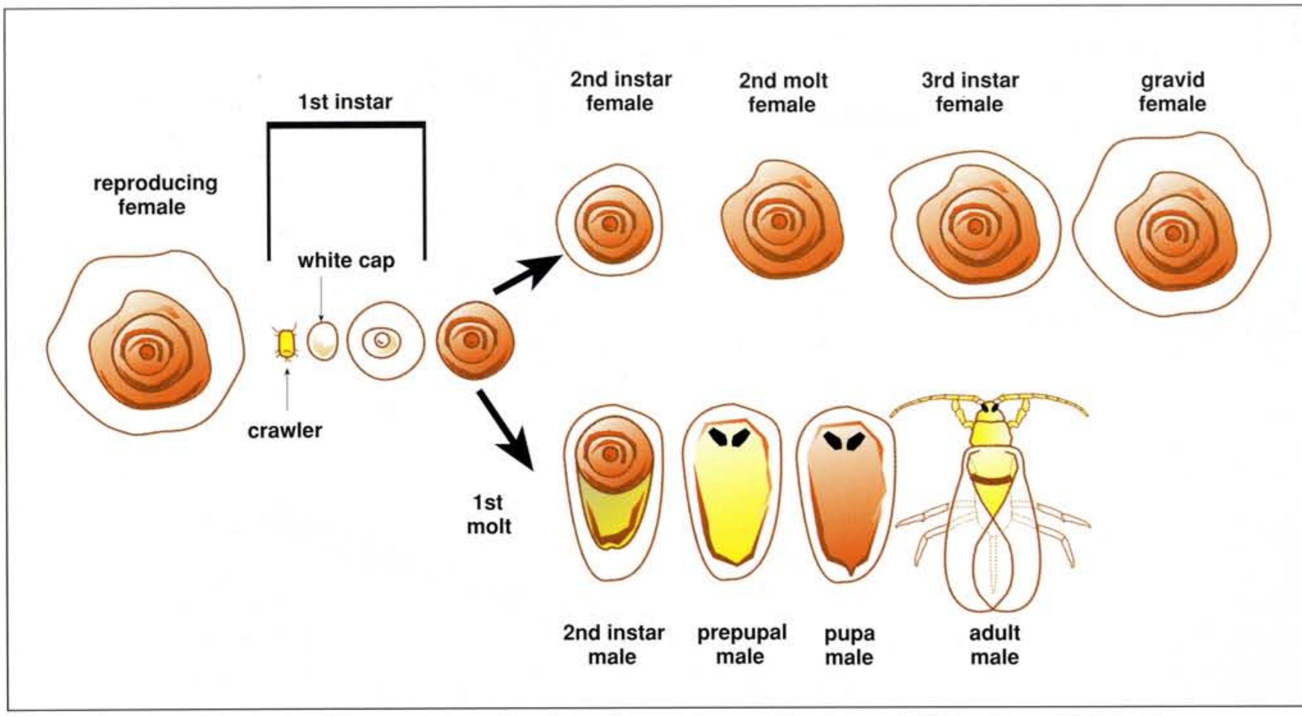

Figure 3. Life cycle of California red scale

There are two distinct types of immobile scale stages: the **instar** or feeding stage and the **molt**, or dormant stage (fig. 4). Immature males complete a single molt and females complete two molts. The distinguishing attributes of the instar stage are (1) the rounded edges of the body of the insect under the cover, (2) the lemon-yellow body coloration, and (3) the ability of the cover and scale body to be separated. The distinguishing attributes of the molt stage are (1) the orange body coloration and (2) the distinct edge where the body and cover meet making separation impossible. Throughout all instar stages, the scale extends its mouth parts (*rostrum*) into the plant. This hair-like feeding tube usually keeps the body of the scale on the plant when the cover is removed.

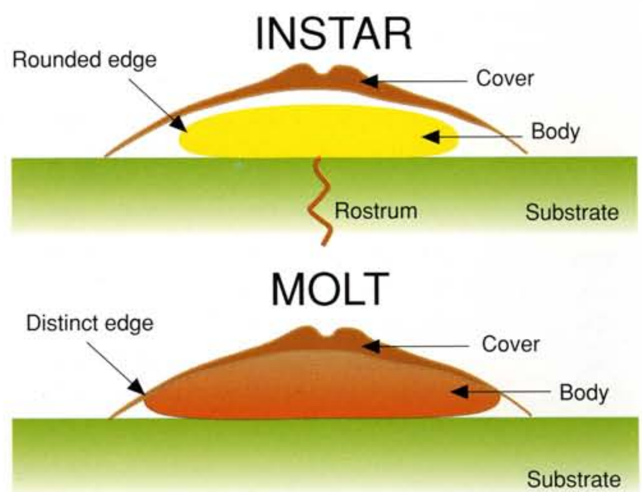

Figure 4. Cross section views of California red scale

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FIRST AND SECOND INSTARS

After the crawlers settle, they begin to feed and secrete a material that covers the scale body and becomes the *white cap* stage (fig. 5). As the scales continue to develop, the top of the cover forms a distinct circular ridge for the *nipple* stage. The cover will eventually flow onto the plant and become whitish-gray. The crawler, white cap and nipple stages are all **first instar** scale. The first instar is the only stage when the cover has no orange pigmentation (fig. 6). The orange pigmentation in the cover of later scale stages results from the molting process. Once first instars stop feeding, the feeding tube is detached and the scale is sealed off inside the cover. This is called the **first molt** and is slightly convex in shape when inverted (fig. 7). The scales remain as first molts for approximately 4 days. Eventually, the scales insert a new feeding tube into the substrate as they transform into **second instars** (fig. 8). All second instars have an orange molt ring roughly the diameter of the first molt. This orange molt ring is the cast skin of the first molt, which becomes incorporated into the cover. By noting and counting the number of pigmented rings in the scale cover you can determine the age and stage of scale. The gray portion of the cover (the skirt) surrounding the molt ring is a new secretion of wax and protein produced by the insect during the second instar. This gray skirt varies in size depending on the age of the second instar (fig. 8).

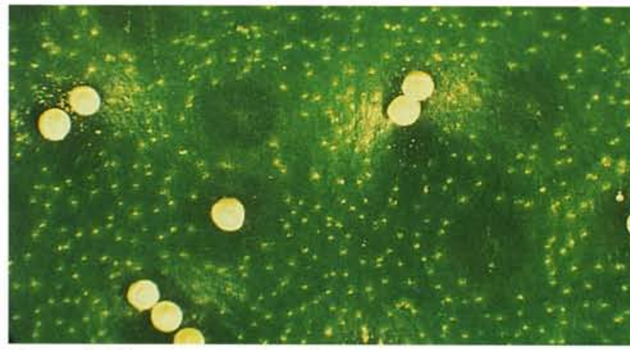


Figure 5. First instar scale; white cap stage

Figure 6. First instar scale

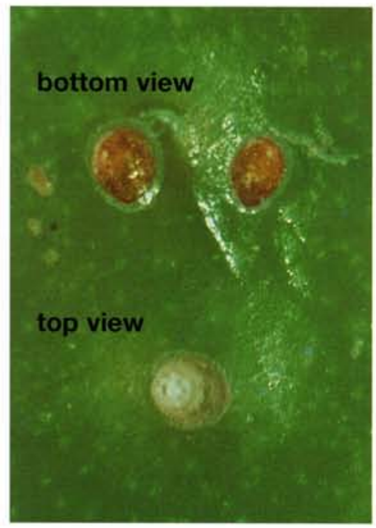


Figure 7.
First molt scale (Note convex underside. Body & cover are sealed together)

Figure 8. Second instar scale (Note body size and gray skirt of the cover increase with age, but the orange molt ring stays the same size)

MALES

As second instar scales continue to develop, second instar males and second instar females develop distinctly different shapes. The males elongate and develop eyes, whereas the females remain circular and do not develop eyes (fig. 9). Male scale complete three distinct immature stages: the second instar male, the prepupal male and the pupal male. **Second instar males** are distin-

Figure 9.
Second instar female (top) and male scale (bottom) with inverted covers

guished by the brown pigmentation of the posterior end or *pygidium* (fig. 10) which is V-shaped . After approximately 5 days, second instar males begin to pupate. This is called the **prepupal male**. This stage is characterized by a slight squaring-off of the distal end and loss of the brown pigmentation (fig. 10). The slight nub at the distal end indicates the early development of the genitalia. In about a day and a half, the prepupal males transform into **male pupae,** which have a distinctly pointed genitalia (fig. 10). **Adult males** emerge about 3 days after pupation (fig. 11).

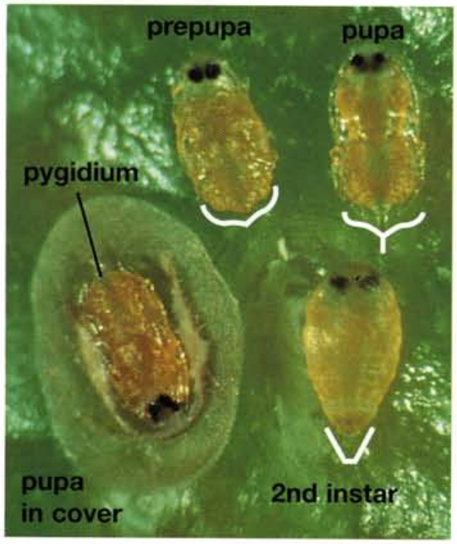


Figure 10. Immature male scale stages

Figure 11. Adult male scale (Note long feathery antennae, close-set eyes, and dark bar across the back)

FEMALES

While second instar males develop into prepupae and pupae, second instar females mature into **second molts** (fig. 12). As with the first molt, the body and cover are sealed together and cannot be separated. Again, live healthy second molts, when inverted, are slightly convex. Dead scales have a similar shape and color, however they are not convex. After molting, which takes approximately 6 days, the females reinsert their rostrum to resume feeding. This is the **third instar** stage (fig. 13). Third instars vary greatly in overall cover and body size. However, the first and second orange molt rings of the cover remain relatively constant in size (fig. 13). Lobes develop on each side of the pygidium during the third instar stage, giving the body a more circular shape than the second instars. The pygidium of the third instar females protrudes out to the edge of the skirt. It is during this stage that mating occurs (fig. 14). Third instars continue to grow, but do not develop into mature females unless mated. Therefore, the length of the developmental period for the third instar females depends on when they mate. After insemination, the pygidium retracts past the lobes of the body so that mating by other males is impossible (fig. 2). At this stage, the body of the **mature female** is sealed inside the scale cover and the female eventually ceases feeding. At this point, the females look similar to the molt stages and will produce crawlers (fig. 2) in approximately 12 days.

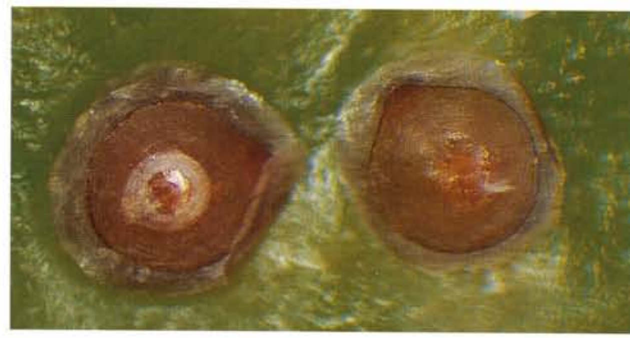


Figure 12. Inverted female second molts (Note body and cover are sealed together)

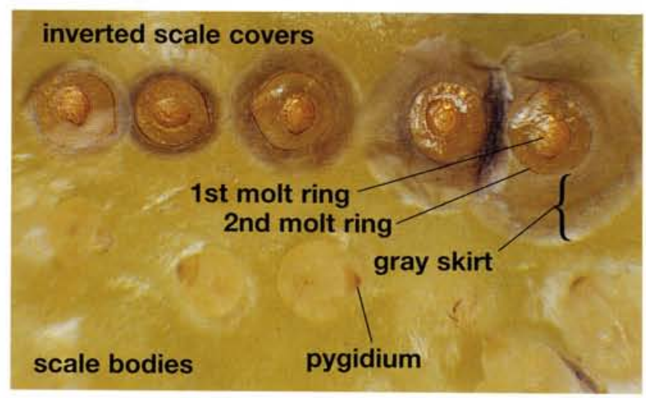


Figure 13. Third instar female scale (Note body size and gray skirt of the cover increase with age, but the orange molt ring stays the same size)

Figure 14. Male scale inseminating a third instar female

Natural Enemies of California Red Scale

Numerous natural enemies are associated with California red scale and each citrus region will have a different combination. This is because each beneficial insect or mite has different temperature and humidity limitations, as well as insect host stage requirements. Recognition of the local natural enemy complex is essential to any effective IPM program. The natural enemy complex in southern California generally consists of the three common wasps: *Aphytis melinus, Comperiella bifasciata,* and *Encarsia perniciosi* (fig. 15, 25 & 29, respectively). In central California, *Aphytis melinus* and *Comperiella bifasciata* are the main components of the natural enemy complex. In interior southern California, *Encarsia perniciosi* was displaced by the introduction of *Aphytis* in 1956. In addition to these natural enemies, there are many generalist predators such as beetles and lacewings.

PRIMARY CONTROL AGENT:

Hymenoptera *Aphytis melinus* DeBach

Aphytis melinus DeBach is the primary natural enemy associated with California red scale (fig. 15). This external wasp or *ectoparasitoid* inserts its ovipositor through the scale cover and deposits its egg(s) on the top (dorsal) or bottom (ventral) side of the scale insect body. Prior to laying an egg, *Aphytis* paralyzes the scale by inserting the ovipositor into the body and injecting venom. The paralysis is permanent, and even if eggs are not deposited the scale will eventually die from the venom. The food available to developing *Aphytis* offspring is determined by the size of the scale body when it was paralyzed.

Life stages

Egg stage. Aphytis **eggs** are teardrop-shaped and translucent (fig. 16). Healthy eggs are deposited on the ventral or dorsal side of the scale body. Often, eggs are deposited in creases, especially around the pygidium. Eggs may become damaged or flattened if suitable scale stages are not found, since competition for desirable scale stages often results in more than one *Aphytis* parasitizing a single host (*superparasitism*). Flattened eggs are usually found on the ventral side of the scale cover, on the plant, and on the insect body. Unlike healthy eggs, flattened eggs are very difficult to see using a hand lens in the field. A condition often associated with superparasitism and easily seen with a hand lens is scale **mutilation** (fig. 17). When *Aphytis* inserts its ovipositor into the scale

Figure 15. ***Aphytis*** **female penetrating gray skirt of the cover to deposit egg on a third instar scale body**

Figure 16. ***Aphytis*** **egg on third instar scale body (scale cover removed)**

Figure 17. ***Aphytis*** **mutilation marks on third instar scale bodies caused by the ovipositor**

body, dark rusty brown mottled spots often appear on the scale. These are the wound response marks of the scale insect. Mutilated scale seldom host healthy *Aphytis* eggs or larvae. Recognizing superparasitism and mutilation is an important tool for assessing *Aphytis* activity.

Larval stage. After 2 days* *Aphytis* eggs hatch into **larvae** (fig. 18). Individuals in this stage vary the most in size. To recognize this stage, look for an elongate sac with body segments. As the larvae feed, gut material becomes visible through the opaque segmented body. The gut material changes in color from golden yellow to brown as the larvae mature.

Prepupal stage. In about 5 days, larvae develop into **prepupae** (fig. 19). This stage is similar to the larval stage (opaque with segments) except it lacks the coloration in the gut. Larvae excrete the gut material from the body as *meconial pellets* as they transform into the prepupal stage (fig. 19). These pellets are easily seen at low magnification (5X to 15X), and they remain under the empty scale cover even after the adult *Aphytis* emerges.

Pupal stage. After about one day the *Aphytis* prepupae complete pupation. Initially, **pupae** have no eye color but over 4–5 days eventually develop eye pigmentation progressing through a sequence of colors. The eye pigment first turns pink, then transforms to red, then reddish brown and finally green (fig. 20). The **adult** *Aphytis* (fig. 15) emerge about one day after the eyes turn green.

Host feeding. Adult female *Aphytis* will feed on honeydew, but will also **host-feed** for nutrition to produce more eggs. When host-feeding, *Aphytis* probes the scale body as it does before oviposition, but even more extensively. Then it feeds on the body fluids that ooze from the wounds. The signs of host-feeding are difficult to see using a hand lens in the field. The bodies of host-fed scales are usually collapsed, leaving only the outer skin of the scale body. Host-feeding occurs when *Aphytis* depletes its eggs because of oviposition or absorption. Thus, *Aphytis* feeds on small scale while searching for suitable hosts upon which to lay eggs. Host feeding kills a substantial percentage of California red scale beyond those killed through parasitism. Occasionally, there may be some signs similar to mutilation, as discussed above (fig. 17).

Aphytis and scale remains. As larvae, *Aphytis* feed by inserting their mouth parts into the scale body and siphoning out the body fluids. Therefore, the **remains of the scale** insect after being consumed are the emaciated, collapsed walls of the body (fig. 21). The **remains**

Figure 18. ***Aphytis*** **larvae (L) on third instar scale bodies (Note variation in size and number of larvae on each scale)**

Figure 19. ***Aphytis*** **prepupa excreting meconial pellets**

Figure 20. ***Aphytis*** **pupae: from left to right, clear, pink, red, reddish-brown, and green eye color (Note meconial pellets)**

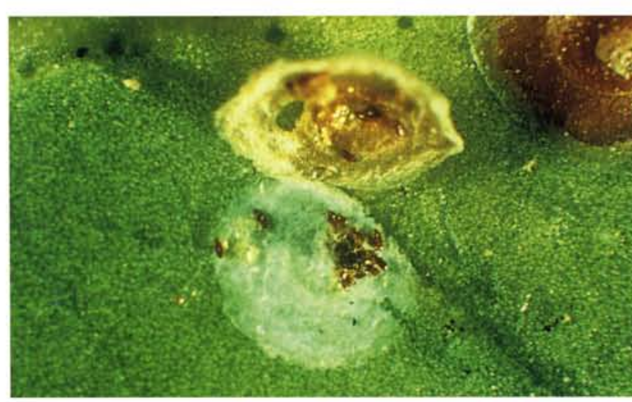


Figure 21. Scale and ***Aphytis*** **remains: dried scale body and cover with exit hole (top), scattered meconial pellets, and pupal case of** ***Aphytis*** **(bottom)**

* All day development periods rounded off to the nearest day and based on constant temperature & relative humidity of 26.7° C and 60% R.H.

of the ***Aphytis*** after emergence are pieces of shiny brown pupal case and meconial pellets scattered under the scale cover (fig. 21).

Host preference

Not all scale stages are consistently available or of equal quality. *Aphytis* can only parasitize certain scale stages and of those, it prefers large scale (chart 1). A female *Aphytis* must make three basic choices.

Host stage. Aphytis prefer scale in the **instar stage** over those that are molting. The scale body during the instar stage is soft and easily penetrated by the ovipositor (fig. 22). The scale cover is free of the body in this stage; thus *Aphytis* can lay eggs on both the top and bottom surfaces of the scale body. During the molt and mature female stages, the outside of the body hardens and fuses to the cover, making oviposition difficult. These hardened stages present only the ventral surface of the body on which to lay eggs. More importantly, the ventral surface during these stages is very tough, making it difficult for immature larvae to feed. Most immature *Aphytis* die if they have to develop on molting scale.

Host size. Aphytis prefer to oviposit on third instar scale because of their **large size.** By paralyzing the scale before ovipositing on it, *Aphytis* choose the amount of food that will be available to the offspring as it develops. The larger the scale, the larger is the resulting *Aphytis* offspring, or the more offspring that can be produced per scale (fig. 23). Mostly female offspring are produced on third instar scale.

Host accessibility. The only portion of the scale cover that the *Aphytis* ovipositor can penetrate is the gray skirt area surrounding the orange molt circle (fig. 24). The longer a scale has been feeding, the larger the gray skirt area of the cover becomes. Therefore, *Aphytis* may prefer a large second instar scale with a **large skirt**, over a young third instar with a small skirt. Scale access may be more important than overall scale body size in the host selection process.

Figure 22. Female scale from left to right: second molt, third instar with cover removed, and mature female (pygidium retracted) .

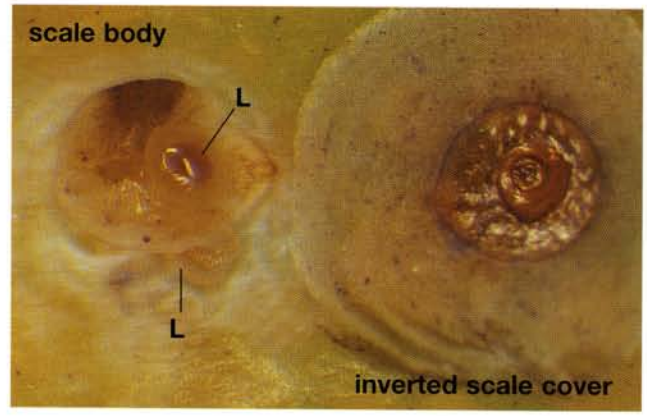


Figure 23. Large host size provides food for several *Aphytis* larvae (L)

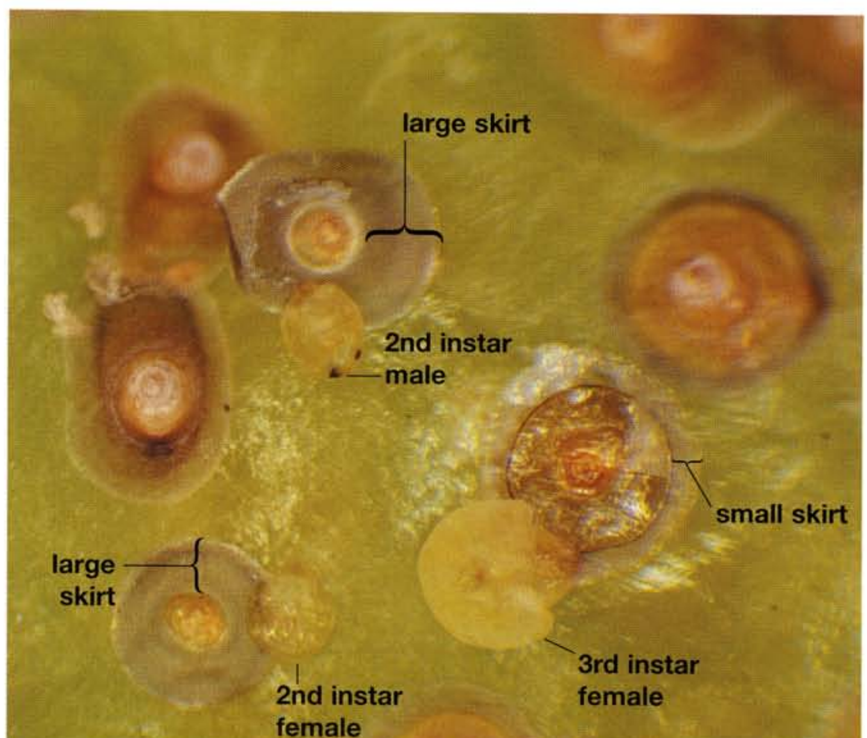


Figure 24. Host accessibility. Large skirt size provides easy access for *Aphytis* oviposition

SECONDARY CONTROL AGENT:

Hymenoptera *Comperiella bifasciata* Howard

The endoparasitoid *Comperiella bifasciata* Howard (fig. 25) is common mainly in arid regions of California, such as in the Central Valley and inland southern California. *Comperiella* are found in coastal areas in low numbers. *Comperiella* coexist with *A. melinus* in all of California's citrus regions. The preferred scale stage for both parasitoids is the third instar female scale (chart 1). *Comperiella* has an advantage over *Aphytis* because it does not paralyze the host, so it can parasitize almost all stages of scale, even the mature female. *Comperiella* deposits eggs inside the body of the scale. After a period of inactivity the larvae develop inside the maturing scale body, which eventually dies.

Figure 25. ***Comperiella*** **adults: an adult female (top) penetrating cover to deposit egg inside scale body and an adult male (inset at left)**

Life stages

Because *Comperiella* eggs and larvae are inside the scale body, it is not possible to see eggs and young larvae with a hand lens in the field. As **larvae** approach pupation, a greenish gray gut material within the larvae is visible with a hand lens through the scale body (fig. 26). If more than one larva is present in a scale, one of the larvae will eventually consume the others. Once the larva pupates, meconial pellets (similar to *Aphytis*) inside the mummified scale body are visible with a simple hand lens (fig. 27). The meconia often form dark parallel lines or a crescent. This is because as the **prepupa** excretes meconia, it wedges between the sides of the pupa and the walls of the mummified scale body. It is important to remember that the meconia of *Comperiella* are always inside the mummified scale body and not scattered freely as with *Aphytis*. This characteristic along with mummification of the scale body is the most definitive way to distinguish *Comperiella* parasitism from *Aphytis* parasitism. The final immature stage of *Comperiella* is the **pupa.** Pupae are opaque just after pupation, but eventually they turn black (fig. 27a, b). This turns the overall color of the scale dark and is easily seen without magnification. Once the adult emerges, the **remains** are the mummified scale body with the meconia inside and an exit hole through the scale cover (fig. 28). These scales usually stay attached to the fruit or leaf unless the fruit continues to grow. Fruit growth loosens the glued-on scale, which causes the mummified scale to slough off the fruit.

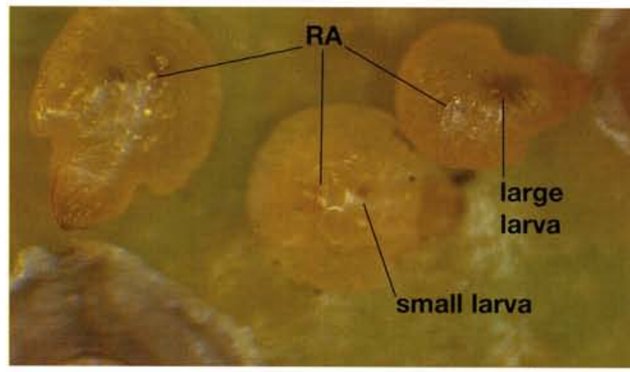


Figure 26. ***Comperiella*** **larvae (L) inside third instar scale bodies (Note puffed out scale body. Note reddish-brown scale rostrum attachment (RA) compared to** ***Comperiella*** **larval gut material)**

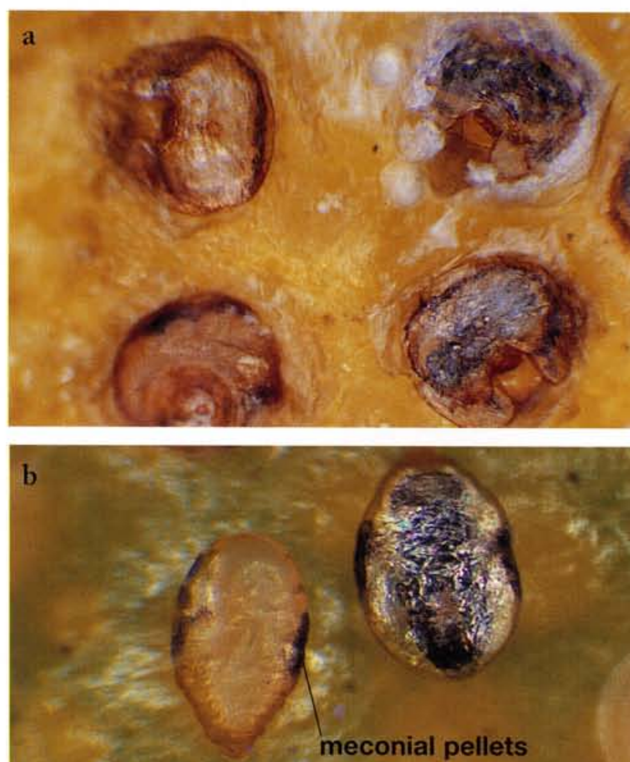


Figure 27. ***Comperiella*** **prepupae (left) and pupae (right) (a) inside female scale and (b) inside male scale (Note meconium is pushed to the edges of the scale body)**

Host Preference

Comperiella prefer third instar and mated female scale for oviposition (chart 1). Offspring develop more rapidly in these stages. *Aphytis* also prefer third instars, and immature *Comperiella* sharing the same host are consumed by immature *Aphytis*. However, various aspects of the behavior and biology of these two parasitoids provide one or the other with an advantage at various times of the year. For example, *Comperiella* survive better during periods of extreme heat and cold. In addition, *Aphytis* can only attack scale for approximately 10 days, while *Comperiella* can attack scales during almost the entire 45 day scale life cycle (chart 1). In the Central Valley, *Comperiella* significantly reduce scale populations during the winter and midsummer, when *Aphytis* are less effective. *Aphytis* compete better in late summer and early fall because *Aphytis* have a shorter developmental period and the ability to produce more than one offspring per scale. Parasitism by *Comperiella* is important and far outweighs the cosmetic problem of the mummified scales sticking on the fruit. This is especially true now with the ability of the high pressure, postharvest fruit washer to remove the glued-on mummified scales.

OTHER NATURAL ENEMIES: HYMENOPTERA

Encarsia perniciosi Tower

The endoparasitoid *Encarsia perniciosi* Tower (fig. 29) is established mainly in the coastal regions of central and southern California. *Encarsia* are significantly smaller than *Comperiella* and coexist with *Aphytis* in the coastal regions, but have become rare in the interior coastal valleys of southern California since the introduction of *A. melinus*. In direct competition on the same scale host, *Aphytis* always wins. *Aphytis* will oviposit on second instars previously parasitized by *Encarsia* as readily as on unparasitized second instars. To make matters worse, *Encarsia* do not distinguish second instar scales parasitized by *Aphytis*. *Encarsia* appear even more susceptible to high summer temperatures than *Aphytis*. Because *Encarsia* prefer scale on twigs and *Aphytis* prefer scale on leaves and fruit, these species divide up the scale population and complement each other.

Life stages and host preference

Because they are small, *Encarsia* require less food than either *Comperiella* or *Aphytis*. Like *Comperiella*, *Encarsia* can oviposit in all scale stages (chart 1). In the preferred second instar scale (male or female), an *Encarsia* completes its development in about 19 days, emerging from the second molt or a mummified third instar. In the least desired mature female scale, it completes its development in about 28 days.

Figure 28. Remains of female scale and emerged *Comperiella:* scale cover with exit hole (top), mummified scale body with meconial pellets (bottom)

Like *Comperiella,* scales parasitized by *Encarsia* can only be seen in the field in late **larval**, **prepupal** and **pupal** stages. The distinguishing characteristics are the same as those for *Comperiella* (e.g., mummified scale body and dark lines created from the meconial pellets), since the immature *Encarsia* is inside the scale body (fig. 30). *Encarsia* parasitoids emerge from mummified second molts, third instar scale, and occasionally mature females. *Comperiella* usually emerge from the mature female scale.

Figure 29. *Encarsia* adult

Figure 30. *Encarsia* pupae inside mummified third instar scale

Field Evaluation Procedures

Although photographs and text have dealt solely with California red scale, these evaluation methods can be applied to yellow scale, *Aonidiella citrina* (Coq.), as well. Aside from *Encarsia,* most of the natural enemies of California red scale will also attack yellow scale.

An integrated pest management (IPM) approach to control California red scale and yellow scale reduces pesticide residues so that natural enemies can survive and reproduce. Once this pesticide free environment is established, the capacity to recognize the signs of these natural enemies is imperative if IPM is to be successful.

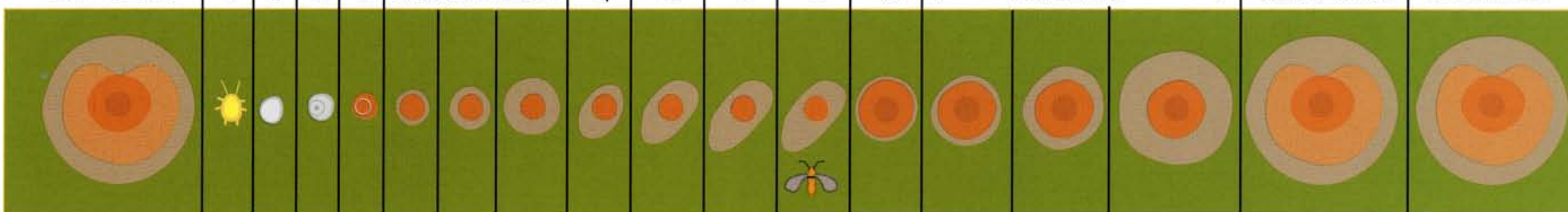
The need for a complex of natural enemies working on California red scale and yellow scale populations cannot be overemphasized. It is only in combination that these beneficial species significantly reduce armored scale densities. The limitation of one organism is often compensated for by the strengths of another. Chart 1 shows the scale stages and the preferences of the three beneficial parasitoids for these stages. For example, the most preferred stage of scale for *Aphytis* is the large third instar with a wide skirt (letter A). However, the next level of preference for *Aphytis* (letter B) is the second instar scale with a wide skirt over small skirted third instar scale (letter C). The yellow shading indicates in which scale stages the parasitoids can be detected with a hand lens. For a field evaluation, all scale with the highest preference ratings (A and B) should be examined first for the presence of parasites. Under good biological control, the majority of these scale stages should be parasitized by *Aphytis, Comperiella* or *Encarsia.* A good indication of eventual biological control is the presence of parasitism of the least desired scale stages (C, D and E). Parasitism by *Comperiella* or *Encarsia* is added proof that natural enemies are controlling scale when *Aphytis* activity is difficult to assess, especially during the heat of summer.

Chart 2 is a decision making flow chart that facilitates effective field evaluations of California red scale and yellow scale populations. Moving down the flow chart you evaluate: (1) the presence of scale, (2) general age structure of the scale population, (3) percentage of scale attacked by *Aphytis* and/or *Comperiella,* (4) when to re-evaluate the scale population for parasitism, and (5) when to consider narrow range oil intervention. The first step in the chart is to look for the presence of scale infested leaves and fruit (box 1). Clean fruit indicates that natural enemies are preventing scale from moving from leaves to fruit. The user should rub leaves (box 2) to see if the scale rub off easily, indicating that they are dead due to previous *Aphytis* or *Comperiella* parasitism (box 3A), or if they adhere to the leaves, indicating that they are healthy (box 3B) or parasitized by *Comperiella.* Then you examine the highly preferred third instar scale to find evidence of *Aphytis* and *Comperiella* parasitism (box 4). If no large third instar scales are found (box 5A), then examine second instar males and large second instar females (box 6A). If these scales are parasitized (box 7A), biological control is adequate, but re-evaluate in three to five days (box 8A) to see how many of the second instar scale escaped parasitism and develop into third instars. If no parasitism is detected (box 7B), re-evaluate in three to five days (box 8B) to see if *Aphytis* attack the scales once they develop into third instars (back to box 1).

The second assessment (box 5B) occurs when third instar scale are present and heavily parasitized; proceed to check second instar scale (males and females). If many second instar scale are also parasitized (box 6B), control is being achieved (box 7C). The final assessment (box 5C) occurs when medium and large third instars are found but no parasitism is detected. Two possible reasons are: (1) most immature *Aphytis* are in the egg and early larval stage and are not detected with the hand lens, or (2) there are no immature *Aphytis* present. You must at this point decide which scenario (box 6C or 6D) best describes the pest management situation in that orchard. If scenario I best describes the situation, (there is some evidence of parasitism but many of the large third instar scale seem healthy), proceed to check second instar scale (box 7D) to see if the previous generation of *Aphytis* are emerging from younger scale. In this situation it is very important to monitor closely and re-evaluate in two to four days (box 8C). You should look closely at Factors 3, 5, 6 and 7 under scenario I. If scenario II best describes the situation in that orchard, then a narrow range oil treatment may be warranted (box 7E).

After assessing the general scale age structure and *Aphytis* parasitism, make note of the following important details. If the scale's population structure contains very few of the most desired stages, look for signs of mutilation marks on less preferred stages that may not be suitable as hosts for reproduction. Host feeding and mutilation on non-host scales is a good sign of control. Look for signs of parasitism and predation by other natural enemies. *Aphytis* is rarely the sole natural enemy attacking a California red or yellow scale population. If the user is in scenario II, it is very important to collect leaves and run an *Aphytis* bioassay. By exposing *Aphytis* to these leaves in a closed container you can determine if pesticide residues are killing the *Aphytis.* Finally, it is important to evaluate scale populations early enough to allow options such as narrow range oil sprays if biological control is insufficient.

					← Feeding →								← Feeding →					
								← Males →				← Females →						
Mature female with crawlers	Crawler	White cap	First Instar	First Molt	←Second instars→			Second instar	Prepupa	Pupa	Winged adult	Second molt	← Third instars →			Mature female	Mature female with crawlers
Mean Number of Degree Days*			55	147	195 →		255	259	330	360	380	307	355 →		465	560	650+
Aphytis						C	B	B	D	E		D	C	A	A	D	
Comperiella			C	C	D	D	C	E	E	E		B	A	A	A	B/C	
Encarsia			B	B/C	A	A	A	C	E			A/B	A/B	B	C	C	

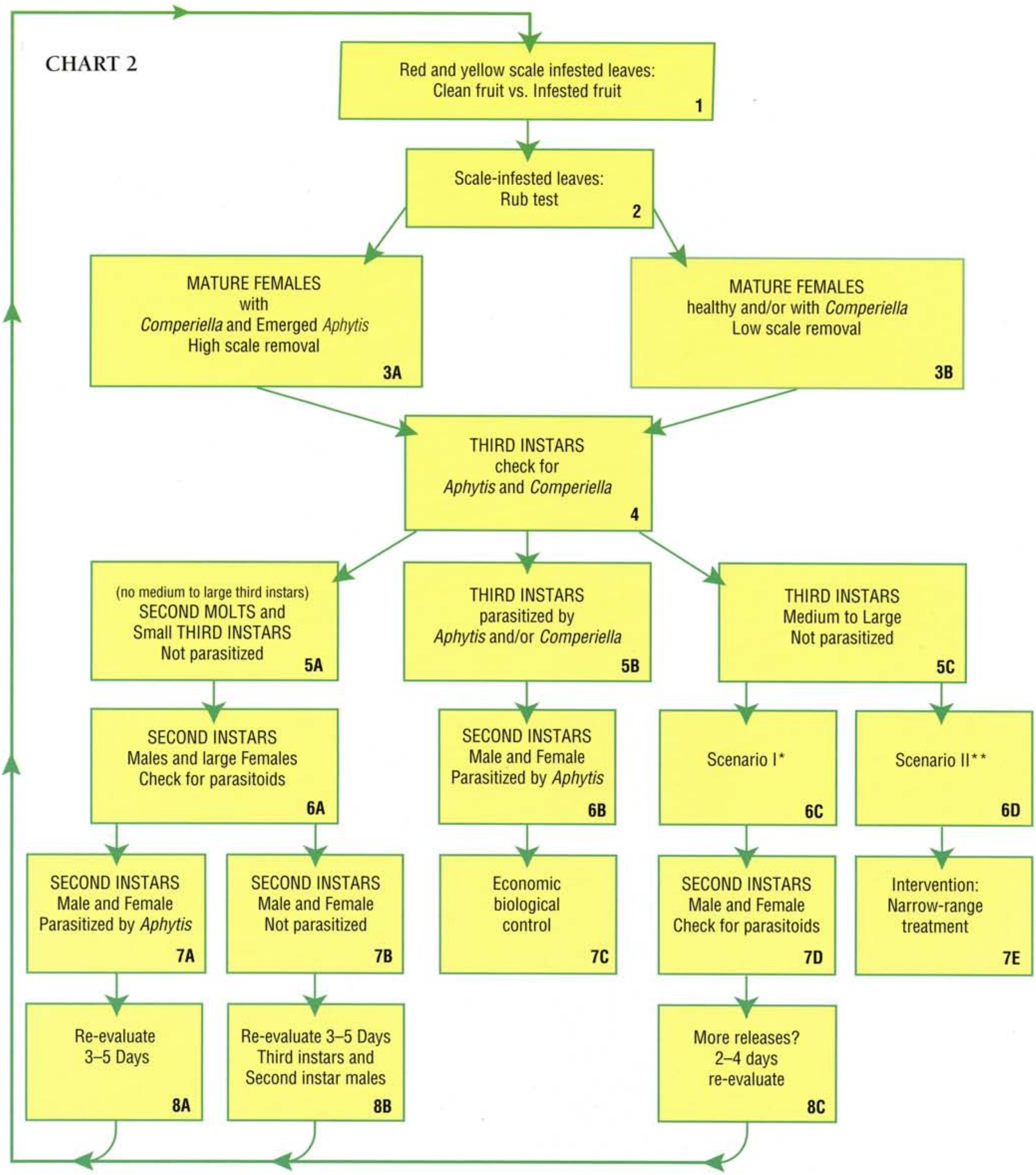


* Estimates: Varies across location & season

Stages in which parasitism is detectable with hand lens

A = most-preferred stage to attack
↓
E = least-preferred stage to attack (rare)

CHART 2



*SCENARIO I

1. *Aphytis* history (block specific)—*Aphytis* are definitely in the orchard.
2. Pesticide Bioassays—Bioassays have been conducted and the results are favorable to *Aphytis* survival.
3. Fruit size—Growth has not yet stopped.
4. *Comperiella*—They are part of the complex of natural enemies.
5. General harvest time—There must be *at least one month* remaining before picking.
6. Time to realize biological control—The scale must still be young enough to be parasitized, coupled with enough time (calendar and/or degree day) for *Aphytis* to be effective.
7. Other natural enemies in the orchard.

**SCENARIO II

1. *Aphytis* releases—Insufficient numbers and/or they were released poorly.
2. No pesticide bioassay or poor survival in bioassay.
3. Low (no) numbers of *Comperiella.*
4. No time for *Aphytis* to catch up.
5. Cannot economically afford to have fruit down-graded.
6. No other natural enemies in the system found.