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PRODUCTION AND COLONIZATION OF IMPORTED NATURAL ENEMIES OF AVOCADO MITE PESTS

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Introduced natural enemies of mite pests of avocado are now being mass-produced by the Department of Biological Control, University of California at Riverside and released in Southern California orchards. The particular natural enemies now being produced are two species of tiny black lady beetles belonging to the genus **Stethorus**, one from India and one from Hawaii. To date about 125,000 **Stethorus** have been released in California avocado orchards. At a later date natural enemies of plant-feeding mites belonging to other families of insects and mites will be introduced, reared and released in avocado orchards.

Members of the genus **Stethorus** are widely distributed predators of tetranychid mites and are often effective in controlling population outbreaks of these mites. Other predators, such as predaceous mites, thrips, and green lacewings, are instrumental in maintaining mite populations at low densities, but generally they are not effective in controlling high-density populations of mites.

Although native species of **Stethorus** are usually present in areas infested with tetranychid mites, it may be desirable to introduce new **Stethorus** species into an environment. Such characteristics as cannibalism, searching capacity, weather tolerance, mite species preferred, and mite-density requirements might favor one species in one microhabitat and another species in another microhabitat. Therefore, introduction of a new **Stethorus** may improve or extend an existing biological balance.

The mass production of **Stethorus** species requires a tremendous supply of host mites. Fleschner (1950) found that **Stethorus picipes** Casey required at least 135 mites to complete development, and that the larvae were capable of consuming up to 486 mites each. If we estimate that 300 mites are required for oviposition and larval development, then approximately 6,000,000 mites would have to be produced to rear 20,000 **Stethorus** adults, which is the present monthly production at the University of California's Riverside insectary.

Several species of mites have been used for rearing **Stethorus** species. Finney (1953) used the six-spotted mite, **Eotetranychus sexmaculatus** (Riley), and Fleschner (unpublished data) used the two-spotted mite, **Tetranychus cinnabarinus** Bois. The Pacific mite, **Tetranychus pacificus** McG., has proved to be superior for mass-production purposes at the Riverside insectary. It produces tremendous populations on Valencia or navel oranges, and it is not sensitive to trace pesticide residues on the fruit. Purifying the air with activated charcoal is not necessary with this mite, as is the case

with the insectary rearing of certain other species of tetranychid mites.

Washed, waxed, and graded oranges are obtained from a packing house and placed in cold storage (45° F.) until needed. Fruit which has been treated with ethylene gas to improve its color is not satisfactory because it frequently decays too soon under insectary conditions. The fruit is prepared for mite infestation by first being placed on hardware-cloth trays which hold 55 size 138 fruit. Briefly, the cold fruit is held in a steam cabinet for "sweating." Then, the tray of moist fruit is placed in a linting box and flocking lint is applied to the fruit. About 25 ml. of flocking is distributed over the curved bottom of the linting box, a horizontal perforated tube one inch above the curved bottom is connected to air pressure, and the flocking is blown up through the hardware-cloth tray and onto the fruit.

Two colors of flocking lint are used to distinguish the DDT-treated from the untreated fruit. All trays of fruit used to sustain the mite culture are linted with a mixture of 10% DDT (standard 50% WP DDT is used), 10% diluent, and 80% green flocking by weight. This prevents various mite predators, particularly predaceous mites, from contaminating the mite culture. Since **Stethorus** adults are sensitive to DDT, the trays of fruit used in the **Stethorus** oviposition units are linted with white DDT-free flocking. The flocking lint is composed of viscose rayon fibers "verlon F21" and it provides a light, fuzzy covering over the fruit which encourages the female mites to commence feeding and ovipositing.

To provide the **Stethorus** culture with a predictable and constant supply of mite-infested fruit, it was necessary to establish a standardized routine for operating the mite culture. The culture is kept in a dark room where the temperature is maintained at 78° to 80° F. and the relative humidity at 45% to 55%. All of the mite culture operations are done on Monday, Wednesday, and Friday. The culture is divided into four groups, each consisting of one or more units. Each unit is a tray of fruit heavily infested with mites which usually has on top of it a fresh tray of fruit ready to be infested (Fig. 1). The operations conducted on each group are staggered so that no two groups have the same operations on the same day. A typical operation sequence for one group would be to place trays of DDT-linted fruit for infesting on the units Monday, remove the trays of spent fruit Friday, and add trays of untreated fruit the following Monday for infesting.

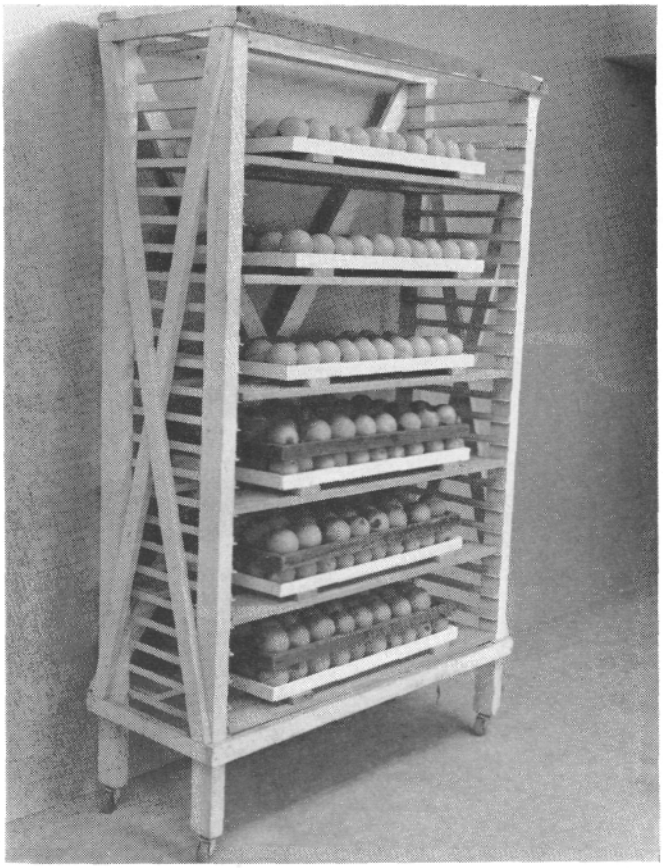

Fig. 1. A rack containing six mite units divided into two groups. One group is incubating, the other is infesting.

Each unit remains as an individual mite culture. This reduces the chance of contamination and also allows for flexibility. The following procedure represents the handling of one unit. First, a tray of DDT-treated fruit is placed on top of the tray of heavily mite-infested fruit; the mites move upward by negative geotropism onto the new fruit. Four or five days later the tray of old fruit is removed and replaced by the newly infested tray of fruit. The new culture of mites is allowed to incubate for two or three days. Then, a tray of DDT-free linted fruit is placed on top of the incubating culture. The DDT-free fruit is infested for four or five days; then it is replaced by a tray of DDT fruit, which completes one cycle. One cycle can take 11 to 14 days, depending upon the position of weekends in the cycle. The life cycle for the mite at this temperature is about 10 days. A standard flashlight is useful to determine the progress of the mite cultures. When the light is held at the proper angle, the mites and their webbing show clearly.

The **Stethorus** rearing unit (Fig. 2) is a multipurpose cabinet. The top part with sliding doors is for equipment storage, the two large cages are for rearing, and the bottom part is for tray storage. The cabinet is on casters, which allow rapid movement from room to room or to the fumigator. The cabinet is 74 inches high, 34 inches wide, and 19 inches deep. The two rearing cages are each 31 inches wide and 23 inches high. The backs of the cages are covered with organdy cloth and the front of each cage is closed with a 32

x 24-inch plywood door.

Fig. 2. Stethorus rearing unit. The upper cage contains developing predator larvae, and the closed lower cage contains an oviposition unit.

The adult female **Stethorus** can lay about 6 eggs per day and since the sex ratio is about 1:1, an oviposition unit using 500 **Stethorus** for four days theoretically could produce 6,000 eggs, a 12-fold increase. Many adverse factors operate to reduce this ratio. Cannibalism is a constant problem which can be partially reduced by supplying an overabundance of mites. Other factors, such as mechanical injury during fruit handling, starvation, and emergence mortality, contribute to lowering efficiency. A 7-fold increase is the highest obtained so far.

All **Stethorus** rearing is done at about 80° F. which is usually the highest temperature that the fruit can withstand without excessive drying and breakdown. The trays of infested DDT-free fruit are allowed to incubate for several days after removal from the mite culture, then the fruit is used in **Stethorus** oviposition units. A **Stethorus** oviposition unit uses one tray of well-infested fruit with an abundance of mite eggs and usually 600 well-fed adult **Stethorus. The Stethorus** feed on the mites and oviposit for seven days. Then the **Stethorus** adults are removed with a vacuum aspirator. After the **Stethorus** eggs hatch, additional trays of mite-infested fruit are added to the original tray when the **Stethorus** larvae begin to search actively for mites. The feeding of the

young larvae is extremely critical; the tiny larvae must have an abundant supply of mite eggs, larvae, and nymphs. The first-instar larvae are very weak and slow and usually they cannot overpower an adult mite. After the larvae reach the third instar, they can move rapidly from fruit to fruit seeking mites. Old fruit, previously treated with DDT, may, in some cases, be used at this time. Some species of **Stethorus** larvae have considerable resistance to DDT, and the emerging adults are not seriously affected by the old DDT residue. Mites should be readily available to the larvae prior to pupation or considerable mortality will result in the first few hours after emergence.

When all of the larvae in a rearing unit have pupated, the unit is moved to a room with large windows exposed to indirect sunlight. In a few days the adult **Stethorus** begin to emerge. They expand their wings, darken in color and begin feeding on mites. When all of the mites are consumed, the **Stethorus** become restless and soon fly to the windows where thin streaks of honey are provided as a supplementary food until the **Stethorus** are collected.

The **Stethorus** are collected into ½-pint ice cream cartons (Fig. 3). The aspirator used for this operation has an internal airflow valve for regulating the suction power of the aspirator. The valve is adjusted by twisting the collector tube, and the air flow is regulated to provide just enough suction to draw the **Stethorus** into the carton without injury. Excessive suction will kill the **Stethorus** by throwing them against the side of the carton.

When the **Stethorus** are to be collected for field release, they are collected 500 to a carton, provided with honey, and stored at 70° F., 60% R.H. until shipment (Fig. 3). The cartons of **Stethorus** are taken to mite-infested locations in a cooler that consists of a wooden frame enclosed by cotton quilting. The quilting is moistened, and evaporation during the trip keeps the inside of the box 15° F. to 20° F. cooler than the surrounding air.

Colonizing locations are carefully chosen to provide the **Stethorus** with a favorable environment. Moderate temperature variation, high humidity, vigorous host plants, an expanding mite infestation and leaves free from dust deposits are all conducive to **Stethorus** establishment. Freedom from competition with other mite predators is also considered.

Since the first of 1960 most of the released **Stethorus** consisted of a new species of **Stethorus** from Hawaii. Distinguishing characteristics of this species are (1) a bright red egg, (2) a larva with a light area at the posterior end of the abdomen, (3) the pupa almost black and covered with hairs of irregular lengths, and (4) the adult beetle black except for the lower two-thirds of each leg. The native mite predator **Stethorus picipes** is characterized by a light pink egg, a steel gray colored larva, a light reddish-brown pupa covered with very even hairs, and an adult which is entirely black including the legs.

Fig. 3. Collecting unit. In the upper right corner is the aspirator inserted into an organdy covered carton; in the lower right corner is a carton of Stethorus ready for shipment. The tubing connects the aspirator to a vacuum line.

This new species shows some promise of becoming established in favorable areas. All stages of development have been observed in some liberation areas. Establishment of this new **Stethorus** would mean that this species is able to compete with native mite predators and possibly be more effective in controlling mite infestations.

Additional research is being conducted in an effort to reduce the cost of rearing the mite predators. Probably the most effective means of reducing rearing cost would be the development of a cheap substitute for oranges as a base for the mites. An artificial diet on which the mite predators could feed and complete their development would be ideal. An artificial diet would permit vast numbers of **Stethorus** to be used in a periodic release program for control of outbreaks of plant-feeding mites.

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