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BY

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INTRODUCTION

There are over 140 species of insects and mites that are known to be pests in greenhouses (Pritchard, 1949). In recent years, the major pest species involved--such as aphids, mealybugs, scales, and spider mites--have generally been controlled by insecticides and acaricides. However, it is becoming increasingly clear that the strategy of unilateral reliance on chemical control will not be the final solution to the problem. In this regard, there are four major problems attendant to chemical control: (1) development of resistance to chemicals in target pest species; (2) the dwindling supply of useful, registered insecticides and acaricides; (3) the damaging (or detrimental) effect of these chemicals on nontarget species resulting in secondary pest outbreaks; and (4) phytotoxic reactions by treated plants. On the other hand, unilateral reliance on biological control should not be viewed as a sound strategy because biological control alone does not always give adequate protection.

A solution to this problem lies in the utilization of integrated control--or what is now called integrated pest management (IPM). This is a management system in which ecologically suitable and economically rewarding control tactics are employed to maintain pest populations at tolerable levels. With respect to the current situation in many commercial greenhouses, there is a critical need for integrating biological control agents with existing cultural and chemical control methods.

The purpose of this bulletin is to synthesize information relevant to biological control of one of the major plant pests found in greenhouses worldwide. This pest is the twospotted spider mite, *Tetranychus urticae* Koch. Its most effective control agent (at present) is the predatory mite, *Phytoseiulus persimilis* Athias-Henriot. The twospotted spider mite is a suitable subject for an IPM program in which biological control plays a major role and may even be employed by itself for extended periods of time. Biological control programs are currently available for the control of greenhouse whitefly, but many of the remaining pest species--particularly aphids, leafminers, mealybugs, scales, and various species of Lepidoptera--will require additional research. With adequate support, the necessary information for these species and their biological control agents should be forthcoming.

The emphasis in this bulletin will be on information--not implementation. There are two reasons why we have chosen this approach. First, during 12 years of research on biological control of pests in greenhouses in Florida, California, and New York, we have detected a strong interest, on the part of growers and others, in the use of biological control. However, information about the available biological control agents was

either lacking or too difficult for those interested in the topic to obtain and eventually utilize. Second, because of the great diversity of plant species (and cultivars) grown in greenhouses, the wide variety of cultural practices used, and the differing environmental conditions encountered, it is virtually impossible to develop a set of guidelines for implementing biological control which would cover every conceivable situation. Instead, growers who are interested in using biological control agents should be able to draw upon the information contained herein and develop their own systems. In fact, this approach is already being practiced.

Biological control can be defined as the action of natural enemies which maintains a host's (or pest) population density at a level lower than would occur in the absence of the enemies. There are three classes of natural enemies of insects and mites: predators, parasites (or parasitoids), and pathogens. A predator is an insect (sometimes mite, spider, etc.) whose immature form (larva or nymph) develops at the expense of more than one host individual. The adult form can be either predacious or free-living. Common examples of predators include lady beetles, big-eyed bugs, lacewing larvae, and ground beetles. Parasites, on the other hand, are insects whose immature form (larva) develops in or on only one host individual. The adult of the parasite is usually free-living, feeding, for example, on nectar or insect body fluids. Parasites are usually either certain flies (Diptera) or small wasps (Hymenoptera) and can be considered "specialized predators." Finally, pathogens are those micro-organisms whose interactions with the host induce a disease (often lethal) in the insect. Such pathogens include fungi, bacteria, protozoa and viruses. Nematodes are often included in this category.

The fundamental premise for biological control of a plant-feeding (phytophagous) insect can be summarized as follows: in the native home (or region of origin) of a given phytophagous insect, there should exist a natural enemy or complex of natural enemies which maintains (or is capable of maintaining) the population density of the insect at comparatively low levels. Essentially, the same applies for plant-feeding arthropods such as spider mites. This action is called natural biological control and is the reason why so many of our phytophagous insects, including several potential pest species, are relatively rare and/or innocuous. Plant-feeding insects which are introduced into a new country without their effective natural enemies often reach outbreak proportions and are thus subjects for classical biological control, that is, importation of the appropriate natural enemies from the native home of the pest. Also, natural enemies from areas other than the native home of the pest species, but which are preadapted to exploit the pest, can be of considerable value in classical biological control.

The effectiveness of a given natural enemy under greenhouse conditions may not always coincide with its performance outside of the greenhouse. Natural enemies which are generally ineffective under field conditions may be relatively effective in the greenhouse and vice versa. For example, the parasite *Encarsia formosa* Gahan is effective against greenhouse whitefly in the greenhouse; however, the same species is generally ineffective in many field situations especially where temperature extremes either favor the pest or cause direct mortality of the parasites. The underlying reasons for the differential performances of other natural enemies are not always known. However, it is clear that certain greenhouse conditions may be quite favorable for one species of natural enemy, but not for another.

It is our view that, for biological control to be employed successfully in the greenhouse, a proper attitude on the part of grower is necessary. Indeed, colleagues in New York have also noted the importance of this aspect (see Tauber, 1977; Tauber and Helgesen, 1978). Some philosophical commitment to biological control, including commitment to the integration of biological and chemical control, is also necessary. A certain amount of patience and a firm resolve for making biological control work is generally needed. In our experience, one of the foremost obstacles to the implementation of biological control in the greenhouse is a negative attitude.

THE TWOSPOTTED SPIDER MITE

The twospotted spider mite, *Tetranychus urticae* Koch, is the major spider mite pest of ornamental plants and vegetable crops grown in greenhouses. Furthermore, this ubiquitous spider mite is a serious pest of numerous ornamental plants in home landscapes, and is of considerable importance as a pest of food and fiber crops throughout the world. The literature on spider mites in general, and the twospotted spider mite in particular, is voluminous; however, much of the pertinent information (including references) has been summarized by Huffaker *et al.*, (1969, 1970), McMurtry *et al.*, (1970), van de Vrie *et al.*, (1972), Jeppson *et al.*, (1975) and Hussey and Huffaker (1976).

TAXONOMY

Contrary to popular belief, mites (including spider mites) are not insects. Although both insects and mites belong to the Phylum Arthropoda (because of their jointed appendages and exoskeletons), there are major differences between the groups. Adult mites characteristically possess 4 pairs of legs compared to 3 pairs in insects (larval mites do however possess 3 pairs of legs). Virtually all adult insects have 1 or 2 pairs of wings. However, neither of these features is found in adult mites. Whereas mites belong to the Class Arachnida which also

contains the spiders, insects belong to the Class Insecta. All mites occupy the Subclass Acari (=Acarina).

The twospotted spider mite is a member of the family Tetranychidae which contains many harmful species of plant-feeding mites. There has been considerable confusion concerning the nomenclature (i.e., scientific name) of the twospotted spider mite. In the past, acarologists and applied entomologists commonly referred to the spider mites in question as Tetranychus bimaculatus Harvey or T. telarius (Linnaeus). Boudreaux (1956) examined the so-called "twospotted spider mite complex" and demonstrated that more than one species was involved. In this case, the major species were the twospotted spider mite, Tetranychus urticae Koch and the carmine spider mite, T. cinnabarinus (Boisduval) (Boudreaux, 1956; Boudreaux and Dosse, 1963; Jeppson et al., 1975). Common names such as red mite, red spider mite, glasshouse spider mite, twospotted spider mite, and common spinning mite generally referred to the species complex; the same is true for the approximately 60 synonyms (i.e., scientific names) in the literature, the most common ones being T. telarius (Linn.) and T. bimaculatus Harvey (Boudreaux and Dosse, 1963; Jeppson et al., 1975).

DEVELOPMENTAL BIOLOGY

In both male and female twospotted spider mites, development proceeds through the following stages: egg, larva, protonymph, deutonymph, and adult. The larval, protonymphal, and deutonymphal stages are further divided into feeding (active) and quiescent (resting) stages. The quiescent stages are referred to as nymphochrysalis (=protochrysalis), deutochrysalis, and teliochrysalis for larval, protonymphal, and deutonymphal stages, respectively. Thus, development of the twospotted spider mite can be summarized as follows: egg, larva (including nymphochrysalis), protonymph (including deutochrysalis), deutonymph (including teliochrysalis), and adult (Laing, 1969; van de Vrie et al., 1972).

Females normally lay eggs (oviposit) on the undersides of leaves. According to Cagle (1949), the spherical egg is about 0.14 mm in diameter (Figure 1). The newly deposited egg is clear, but turns opaque and glassy as incubation progresses. Just before hatching, the egg is strawcolored and the carmine "eyespots" of the embryo become visible (Cagle, 1949). The larva (Figure 2) has 3 pairs of legs (hexapod). At the time of hatching, it is colorless, except for the carmine eye spots. After feeding, its color changes to pale green, brownish green or very dark green and two dark spots appear in the mid-portion of the body (Cagle, 1949). At the end of the feeding stage, the larva attaches to the substrate (i.e., leaf), becomes quiescent (nymphochrysalis), and is later transformed into a protonymph. The protonymph has 4 pairs of legs (octapod) and is somewhat larger than the larva. Its color is usually pale green to dark green and the two spots are larger and more

Figure 1. Eggs (lower portion) and adult male (upper) of the twospotted spider mite.

Figure 2. Egg and larva of the twospotted spider mite (left) and egg of P. persimilis (right).

pronounced than in the larva (Cagle, 1949). At the end of the feeding stage, the protonymph attaches to the substrate, enters the quiescent stage (deutochrysalis), and is later transformed into a deutonymph (Figure 3). The octapod deutonymph is generally larger than the protonymph (Figure 4), although similar in color pattern. At this stage, the males can usually be distinguished from the females because of the smaller size and wedge-shaped posterior of the former (Cagle, 1949; Laing, 1969). Following cessation of feeding, the deutonymph attaches to the substrate (Figure 5) and becomes quiescent (teliochrysalis). The octapod adult (Figure 6) eventually emerges from the teliochrysalis.

Developmental time of the twospotted spider mite will generally vary with conditions such as temperature, humidity, host plant, leaf age, etc. However, temperature is the most important factor that influences the rate at which mites develop. The lower threshold for development is about 12°C (53.6°F), whereas maximum upper limit to the development is about 40°C (104°F) (Jeppson et al. 1975). Laing (1969) maintained the mites on strawberry leaflets at an average hourly temperature of 20.3°C (68.5°F) and relative humidity fluctuating from 55% to 98%. Under these conditions, the mites developed from egg to adult in an average of 16.5 days. Shih et al. (1976) cultured the mites on lima beans at 27±1°C (81°F) and 90±5% relative humidity. In this case, mites developed from egg to adult in an average of 7.6 days. Sabelis (1981) determined the developmental time required for an egg to develop to a female capable of laying eggs. In his studies, he reared the mites on detached rose leaves under two alternating day/night temperature regimes. The regimens studied were 25-35°C (77-95°F) and 10-20°C (50-68°F) for which he determined the developmental times to be 8.3 and 28.2 days, respectively. Additional aspects of developmental time are summarized in Table 1.

REPRODUCTIVE BIOLOGY

In a given colony of twospotted spider mites, both adult males and females can usually be found; however, females are normally about three times more abundant than males. Cagle (1949) provided an account of the characteristics of males and females. The male is much smaller and is considerably more active. The body is narrow and distinctly pointed posteriorly (Figure 5). The color of the male varies from pale to dark green, brownish, or at times, orange. The body of the female is oval-shaped and rounded posteriorly (Figure 6). Color of the females varies from light yellow or green to dark green, straw color, brown, black and various shades of orange. There are generally two large black spots one on either side of the body, hence the common name. However, there can be considerable variation in the expression of this particular character.

Figure 3. Quiescent nymphs of twospotted spider mite.

Figure 4. Deutonymph (left) and mature female (right) of twospotted spider mite.

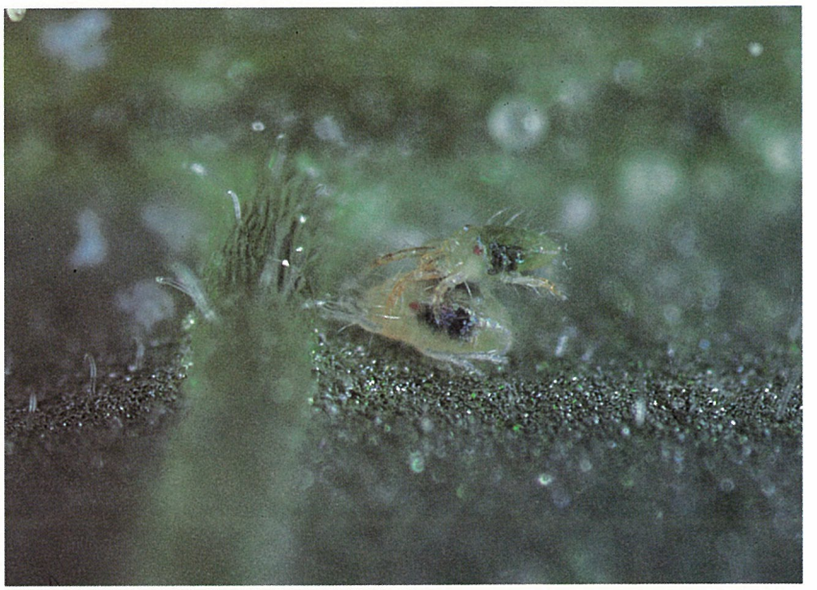

Figure 5. Male twospotted spider mite "guarding" quiescent female deutonymph.

Figure 6. Mature female/twospotted spider mite.

Generally, adult males can be found in close association with quiescent female deutonymphs (Figure 5). Evidence indicates that the quiescent female deutonymph releases a sex pheromone which attracts the male and keeps him in close proximity (Cone et al., 1971a, 1971b; Penman and Cone, 1972, 1974). The male usually remains in the immediate vicinity of the quiescent deutonymph and mates with the emergent female. When more than one male attempts to "guard" a developing female, fighting among the males often occurs; usually, larger males win these encounters (Potter et al., 1976a, 1976b). Such fights involve pushing and grappling with the forelegs, jousting with the mouth parts and entangling the opponent with silk.

The life span of the adult female is divided into the preovipositional period and the ovipositional period, the former being the time between emergence from the teliochrysalis to the deposition of the first egg. Apparently, the preovipositional period (9% of the time required to develop from egg to egg) can last less than 0.5 day and as long as 3 days depending on temperature. The period during which eggs are deposited (ovipositional period) can last from 10 days at 35°C (95°F) to 40 days at 15°C (59°F) (Sabelis 1981). An individual female can deposit over 100 eggs in her lifetime (Shih et al., 1976; Carey and Bradley 1982). The total number of eggs laid/female and the eggs laid/female/day can, however, vary with age, temperature, species of host plant, relative humidity, nutrition of host plant, exposure to pesticides, etc. (Watson, 1964; van de Vrie et al., 1972 Karban and Carey, 1984). Temperature and age of the female are especially important determinants of egg production (fecundity). However, Sabelis (1981) determined that fecundity was affected very little at temperatures between 20-35°C (68-95°F). In his study, peak oviposition, (161 eggs/female) occurred at a temperature of 25°C (77°F), with the maximum rate (12 eggs/female/day at 25°C (77°F)) occurring 2 days after the first eggs are laid. The effect of temperature is particularly evident in greenhouses, where spider mite populations often develop rapidly soon after the onset of summer temperatures.

Sex determination in twospotted spider mites (as in many other spider mites) is arrhenotokous. That is, females develop from fertilized eggs and have the normal two sets of chromosomes (diploid); on the other hand, males develop from unfertilized eggs and have only one set of chromosomes (haploid). Unmated females give rise only to males; mated females can produce either female or male progeny. According to Helle (1967), a single mating will suffice to provide a female with enough sperm to produce diploid eggs for her entire ovipositional period.

The phenomenon of arrhenotoky is of importance not only from an academic standpoint, but also from a practical one. Because the male has only one set of chromosomes, new genetic

features (arising from mutations) will be immediately expressed. Through natural selection, these characteristics can be added quickly to the population (Helle and Overmeer, 1973). Therefore, the potential for development of genetic resistance to insecticides and miticides in the twospotted spider mite is greatly enhanced by this method of reproduction. Because of the high reproductive rate and fast generation time and the intense selection pressure brought on by chemical control of this pest in the greenhouse, resistance may develop in a comparatively short time.

DISPERSAL AND DIAPAUSE

The dispersal ability of T. urticae in greenhouses is an important factor to consider in the control of this pest. Hussey and Parr (1963) indicated that twospotted spider mites dispersed in the following ways: migration of newly emerged (presumably mated) females to oviposition sites; dispersal from infested plants, simply by dropping off; and movements over soil surface in accordance with the plane of polarized light. There is direct evidence that the mites are able to suspend themselves on silken threads and thus be carried along by air currents. Mites can also be dispersed on the clothing of greenhouse personnel or through the movement of infested plant material. Despite the dispersal ability of the mites, it is not uncommon to find infestations in one portion of the greenhouse throughout the season, and perhaps even from season to season. Patchy infestations in the greenhouse are characteristic of twospotted spider mites. In greenhouses where ornamental plants are grown, patches are often found at the ends of benches near the walls and away from center aisles. The cause of these patches may be associated with poor spray coverage in these hard to reach areas.

Under certain conditions, twospotted spider mites can overwinter as diapausing (mated) females. The diapause is presumably induced by photoperiod (i.e., shortened day length), low temperatures, and unfavorable food supply (see Parr and Hussey, 1966; Jeppson et al., 1975). These diapausing females are yellowish-orange and hibernate in protected places (e.g., cracks, crevices). They neither feed nor reproduce while in diapause. The diapause normally terminates in the spring when favorable environmental conditions return. In Florida, populations of twospotted spider mites cycle throughout the year, although sometimes at reduced rates of development during winter months. However, it is possible that a small portion of the population enters diapause during the winter months.

PEST STATUS

Twospotted spider mites feed on many species of plants and are a major pest of vegetables, ornamentals, fruit trees, hops, cotton, and strawberries (van de Vrie et al., 1972). At present, it is safe to assume that most of the major spider

mite problems in greenhouses will involve twospotted spider mite.

The larva, protonymph, deutonymph, and adult feed mainly on the undersides of the leaves. When feeding, the body of the mite is tipped upward such that the 3rd and 4th pairs of legs are off the leaf surface and the mite is supported by the 1st and 2nd pairs of legs (Jeppson et al., 1975). Feeding is accomplished in the following manner: a pair of needle-like stylets penetrates the plants' parenchyma cells, the contents of which are then drawn into the body of the mite by a "pharyngeal pump". According to Laing (1969), protonymphs and deutonymphs spend about half their developmental times feeding and half in the resting or quiescent stage; the larvae spend slightly more time feeding than resting.

Damage to the plants is effected in several ways. First, feeding causes the destruction or disappearance of chloroplasts which then leads to basic physiological changes in the plant. Stomatal closure can be a primary host-plant response, and in such cases, uptake of CO_2 decreases resulting in a marked reduction in transpiration and photosynthesis (Sances et al., 1979a, 1979b). These effects can occur at spider mite densities that are too low to cause visible damage. Reduction of photosynthetic area by spider mite feeding is permanent and can only be compensated for by production of new foliage. Methods have been developed to quantify the amount of feeding and therefore damage for both cucumber and tomato (Hussey and Parr 1963, French et al. 1976, Anonymous 1976a, Anonymous 1976b). Both methods utilize a leaf damage index (LDI) using the following 0-5 scale: 0 = no damage; 1 = incipient damage with one or two 1-5 mm diameter feeding patches or 5% of the leaf area damaged; 2 = more and larger patches than 1 and with 15% of the area affected; 3 = denser speckling with 30% of the area damaged; 4 = about 60% of the leaf area damaged; and 5 = over 80% of the leaf area damaged with the leaf being chlorotic (French et al. 1976). When the mean LDI reaches 2.0 on tomato, 33% of the leaf area is damaged and loss in yield can be expected (Anonymous 1976b). Loss in yield for cucumbers occurs when the mean LDI reaches 1.9 which corresponds to 30% of the leaf area damaged (Hussey and Parr 1963). Secondly, it is likely (but not firmly established) that the mites actually inject phytotoxic substances into the plant when feeding (see Avery and Briggs 1968; Jeppson et al. 1975; Liesering, 1960). Finally, the stippling or speckling of the upper leaf surface, plus the webbing produced by protonymphs, deutonymphs, and adults, leads to aesthetic injury, particularly in the case of ornamental plants.

The factors which determine the abundance or density of spider mites have been discussed in considerable detail by Huffaker et al. (1969, 1970), McMurtry et al. (1970), and van de Vrie et al. (1972). With respect to outbreaks of spider mites, particularly since World War II, there are two central

"hypotheses" or tentative explanations to account for these events. The first is that the upsurge of spider mites is due to improved cultural practices, such as pruning, fertilization, and pesticide use. For example, outbreaks of spider mites can be induced by certain fertilization practices or by certain pesticides, regardless of natural enemies. Apparently, these cultural practices increase the nutritive value of the plant and thus enable greater reproductive activity on the part of the spider mites. The second explanation is simply that widespread use of broad-spectrum insecticides destroy or greatly hamper natural enemies of spider mites and thereby allow pest outbreaks to occur. There is reason to believe that both mechanisms can act in concert in inducing spider mite outbreaks.

Most of the pertinent information in the literature concerns the influence of pesticides on outbreaks of spider mites under field conditions. According to van de Vrie et al. (1972), increases in abundance of twospotted spider mites have been observed following use of certain agricultural chemicals in many different crops. Although the causes of such increases in greenhouses have not been determined, it would be a sound practice to minimize the use of insecticides and miticides in the greenhouse since outbreaks of twospotted spider mites in the field are often correlated with pesticide usage.

Probably the most common scenario for outbreaks of twospotted spider mites in greenhouses is as follows: the spider mites are accidentally introduced into the greenhouse without any of their effective natural enemies; if host plants and physical factors (e.g., temperature) are suitable, the population "explodes". Common sources of inoculum include infested plants carried into the greenhouse, spider mites (especially mated females) which cling to the clothing of greenhouse workers and weeds growing outside the greenhouse.

However, chemical controls used to control other pests (e.g., mealybugs or greenhouse whitefly) can destroy natural enemies which have been introduced into the greenhouses (see below) and thus, engender serious outbreaks of twospotted spider mites. Thus, insecticides, miticides, and fungicides should be used judiciously when natural enemies are present in order to minimize unnecessary problems with twospotted spider mites.

BIOLOGICAL CONTROL

Many different natural enemies are associated with spider mites under field conditions. These enemies are either predators or pathogens; there are no known parasites (parasitoids) of spider mites (McMurtry et al., 1970).

In greenhouses, there are two categories of predacious species that feed on twospotted spider mites: those which

occur naturally and those which are artificially introduced. The predacious phytoseiid mite Phytoseiulus persimilis Athias-Henriot, is the major species used to control twospotted spider mites in greenhouses. However, Metaseiulus occidentalis (Nesbitt), another predatory mite, has been evaluated for the control of mites on greenhouse grown roses with some success (Field and Hoy, 1984). Pathogens occur naturally under certain field conditions and appear to be an important regulator of spider mite populations. Hirsutella thompsonii Fisher has been proposed as a possible microbial control for twospotted spider mites in greenhouses but has only been effective in the laboratory (Gardner et al., 1982). For this reason, P. persimilis will be the only natural enemy treated in this section.

PHYTOSEIULUS PERSIMILIS

This predacious mite was accidentally introduced into Germany from Chili in 1958 (Dosse, 1958). From Germany, it was subsequently shipped to other parts of the world, including California (McMurtry et al., 1978) and Florida (Hamlen, 1980). P. persimilis has also become established in southern California (Mcmurtry et al., 1978). It has also been collected in the field in northern California. According to Kennett and Caltagirone (1968), there are two synonyms for P. persimilis: Phytoseiulus riegeli Dosse and Phytoseiulus tardi (Lombardini).

During the early 1960's, research on this species was conducted in Great Britain, Holland, Canada, and the United States. Since these initial studies, the ability of this predator to control twospotted spider mites has been demonstrated on many plants, including cucumber (Gould, 1970, 1971), tomato (French et al., 1976), ornamental ivy (Gould and Light, 1971), rose (Simmonds, 1972; Boys and Burbutis, 1972), lima bean (Force, 1967), dahlia (Harris, 1971), strawberry (Laing and Huffaker, 1969), and dieffenbachia and schefflera (Hamlen and Linquist, 1981). Although these studies were conducted under greenhouse conditions (or in growth chambers), there is evidence that P. persimilis can be an effective natural enemy in commercial strawberry plantings (McMurtry et al., 1978) and on ornamentals in commercial interior plantings (Lindquist, 1981). Whether the effectiveness of this predator in these environments will be comparable to its performance under greenhouse conditions remains to be seen.

DEVELOPMENT AND REPRODUCTIVE BIOLOGY

The developmental stage of P. persimilis is similar to that of the twospotted spider mite, i.e., egg, larva, protonymph, deutonymph and adult, and has been studied in detail by many authors (Laing, 1968: Sabelis, 1981; Shaw, 1982). However, the three quiescent periods are absent. The oval eggs are laid in close proximity to a food source. They are light orange and translucent when first deposited, but with

age, they darken (Figure 7). The eggs of the predator can be distinguished from those of the prey's by the color as well as the shape (Figure 8).

The hexapod larva (Figure 9) apparently does not feed and remains inactive unless disturbed. The first feeding stage--the octapod protonymph--emerges from the larval exoskeleton and begins to search for food almost immediately. Feeding and searching continues, with intermittent periods of inactivity presumably due to satiation. The next developmental stage, the octapod deutonymph feeds throughout most of its development. The deutonymph later molts, giving rise to the adult; the adult is about the same size as the mature prey mite and is red (Figure 10). Feeding begins soon after molting (Figures 11, 12).

Mating usually occurs within a few hours after molting. Multiple matings are common even though the sex ratio is approximately 4 females to 1 male (Laing, 1968). A female that has mated once can lay eggs throughout her life span; whereas an unmated female will not reproduce (Amano and Chant 1978a, 1978b); Laing, 1968; Schulten et al., 1978). The system of reproduction and sex determination is termed "parahaploidy" (Helle et al.,1978; Hoy, 1982). In this system, both males and females arise from diploid eggs having 8 chromosomes. However, males retain only one complement of 4 chromosomes (haploid) because of the loss or heterochromatization of one half of the chromosomes.

Laing (1968) studied the life history and developed life tables for P. persimilis and T. urticae. His studies were conducted in growth chambers in which the temperature fluctuated between 18-35°C (65-95°F). The time spent in each developmental stage was recorded and various aspects of the reproductive biology were studied.

Under these experimental conditions, Laing (1968) determined that P. persimilis would develop from egg to adult in an average of 7.45 days; this is approximately half the time required for development of the twospotted spider mites under similar conditions. For a detailed comparison of its developmental times, at three different temperatures, for various life stages of T. urticae and P. persimilis, see Table 1. Furthermore, the mean generation time (T) was 17.32 days (compared to 24 for the prey), during which the predator population increased 44X (compared to 31X in the prey) (Table 2). Finally, the maximum rate of increase (r_{max}) for the predator was higher than that for the prey (Table 2). Given these statistics, it is not surprising that P. persimilis is one of the most effective natural enemies of twospotted spider mites known. In fact, at times it can be too effective--i.e., it can often eradicate the prey in the greenhouse (see later section).

Figure 7. Eggs of P. persimilis.

Figure 8. Egg of twospotted spider mite (left) and egg of P. persimilis (right).

Figure 9. Larva of P. persimilis.

Figure 10. Adult of P. persimilis.

Figure 11. Adult of P. persimilis feeding on egg of twospotted spider mite.

Figure 12. Adult of P. persimilis feeding on immature twospotted spider mite.

Table 1. Developmental times (days) for Tetranychus urticae and its predator, Phytoseiulus persimilis.*

Temp. °C	Developmental stage** Egg	Larva	PN	DN	PO	Total
			T. urticae			
15	14.3	6.7	5.3	6.6	3.5	36.3
20	6.7	2.8	2.3	3.1	1.7	16.6
30	2.8	1.3	1.2	1.4	0.6	7.3
			P. persimilis			
15	8.6	3.0	3.9	4.1	5.6	25.2
20	3.1	1.1	1.4	1.6	1.9	9.1
30	1.7	0.6	0.8	0.8	1.1	5.0

*Data obtained on roses in growth chambers (Sabelis, 1981).

**Key to symbols: PN = protonymph; DN = deutonymph; and PO = length of time before an adult female begins to oviposit.

The rate of oviposition does not depend on the age of the female, but on the number of eggs previously laid. Eggs will be laid at a rate dependent on conditions until the maximum number is reached or until the female dies from "old age" at about 50 days (Sabelis, 1981). The most important conditions that influence the rate of oviposition are temperature, humidity, and prey density.

INFLUENCE OF TEMPERATURE AND RELATIVE HUMIDITY

Temperature has been shown to affect prey consumption, generation time, oviposition, and longevity of P. persimilis (Pruszynski, 1976; Plotnikov and Sadkowskij, 1972; Sabelis, 1981; Shaw, 1982; Laing, 1968; McClanahan, 1968; Takafuji and Chant, 1976). The ultimate outcome of the predator-prey interaction is also influenced by temperature (Force, 1967). The number of deutonymphs eaten by the most voracious stage (the young ovipositioning female) generally increases as the temperature increases. For example, at a relative humidity of 75%, the average consumption of spider mite deutonymphs by a single female was 8.8 at 17°C (62.6°F) compared to 13.5 at 26°C (78.8°F) (Pruszynski, 1976). Pruszynski also demonstrated that consumption of prey increased as the relative humidity decreased and the temperature increased. The author also cited

Table 2. Reproductive biology of the twospotted spider mite and its predator, Phytoseiulus persimilis.

Parameter	Average value at 20.3°C (68.5°F): Twospotted spider mite*	Phytoseiulus persimilis**
Preoviposition period (days)	2.1	3.0
Oviposition period (days)	15.7	22.3
Longevity (days)	17.8	29.6
Eggs laid per female	37.9	53.5
Eggs per female per day	2.4	2.4
Sex ratio (♀♀:♂♂)	2.9:1	4.1:1
r_{max}***	0.143	0.219
R_o	30.93	44.36
T	24.0	17.32

*Data from Laing (1969).

**Data from Laing (1968).

***Key to symbols: R_{max} = Intrinsic rate of increase or the number of individuals produced per female per day. R_o = The number of daughters that replace an average female in the course of one generation; and T = Mean generation time (days).

a Russian study (Plotnikov and Sadkowskij, 1972) in which spider mite eggs were offered as the prey item. The same trend seemed to occur, i.e., as temperature increased, so did the consumption of eggs. Pruszynski stated that P. persimilis is more sensitive than the prey to temperatures above 30°C (86°F) and that the predator would stop feeding at about 35°C (95°F). The number of eggs and the rate at which they are consumed is also affected by the predator's ability to effectively search for food (see later section).

The rate at which P. persimilis develops is a function of temperature and is described by a straight line over the range of temperatures between 15-30°C (59-86°F) (Sabelis, 1981); as temperature increases, the time needed to develop decreases (Table 1). However, developmental times in the literature are

quite variable and are possibly dependent on the strain studied.

Fecundity (number of eggs laid per female) is also influenced by temperature. The temperature at which the maximum reproduction (75 eggs) occurs is approximately 26°C (79°F); the optimum range for reproduction is 17-28°C (63-82°F) (McClanahan, 1968; Sabelis, 1981). At constant temperatures outside this range, females lay fewer eggs. The rate of oviposition, as stated earlier, does not depend on the age of the female, but on the number of eggs previously laid until the maximum number is reached.

The effect of temperature on the overall predator-prey interaction was studied by Force (1967). He used constant temperatures of 15°C (59°F), 20°C (68°F), 25°C (77°F), and 30°C (86°F) and obtained excellent control of twospotted spider mites at 20°C; however, at 30°C, P. persimilis was unable to affect control. At 15°C and 25°C, the prey was controlled, but not as dramatically as at 20°C. One problem with this study was the artificial condition of constant temperatures. However, the important points to note are that an optimum temperature apparently does exist and that extreme temperatures can have detrimental effects on the ability of the predator to control the pest population. Despite the temperature limitations, some effort has been made toward developing "heat tolerant" strains (Voroshilov, 1979).

Developmental time can also be affected by relative humidity. A slight increase in the predator's developmental time was observed when the humidity was increased from 40% to 70% (Begljarow, 1967; Ustchekow and Begljarow, 1968; and Stenseth, 1979). Begljarow (1967) noted that development almost stopped at humidities of 25% to 35%. Pralavorio and Almaguel-Rojas (1980) reported that relative humidities below 70% resulted in a significant reduction in the ability of immature predators to molt from one stage to another.

Humidity also exerted an influence on survival of predator eggs at temperatures above 21°C (70°F). At 27°C (81°F) and 40% relative humidity, only 7.5% of the eggs tested in one study hatched compared to 99.7% at the same temperature, but at 80% relative humidity. At 21°C (70°F), there was only a 10% reduction in hatching when eggs were held at the 40% RH compared to those held at 80% (Stenseth 1979). Begljarow (1967) showed that when eggs were held at a relative humidity of 50%, they appeared to shrivel at all temperatures between 13°C (55°F) and 37°C (99°F); while at 60% RH, hatching was successful at temperatures below 30°C (86°F). Sabelis (1981) suggests that the critical relative humidity is 50% and therefore has little influence because the relative humidity in greenhouses rarely falls to levels where predators would be affected significantly.

The searching behavior and activity of P. persimilis can also vary in response to relative humidity. Mori and Chant (1966a, 1966b) investigated the influence of relative humidity on the behavior and activity of this mite and concluded that relative humidity was an important factor limiting the number of prey consumed per predator. In these studies, predator activity and the number of prey consumed per predator increased as relative humidity decreased (i.e., from 100% to 33%). This activity response due to humidity combined with recent evidence (see Sabelis and van der Baan, 1983) that phytoseiid mites, including P. persimilis, are able to use odors (i.e., kairomones) associated with mite infested plants to locate their prey at a distance, further increases the predator's chances of finding and consuming twospotted spider mites.

FEEDING HABITS

All developmental stages of the twospotted spider mite are eaten by the adult female P. persimilis. The predator's larval stage does not feed, but the protonymph and deutonymph will feed on the egg, larva, and protonymph stages of spider mites (Takafuji and Chant, 1976). The number of each stage eaten depends on the density of prey and predator, temperature, humidity, stage of predator feeding and which prey stages are available for it to feed upon (Shaw, 1983).

Phytoseiulus persimilis depends almost entirely on animals as food (Ashihara et al. 1978, Chant 1961, and Dosse 1958). Ashihara et al. (1978) reported that this predator fed, reproduced, and completed development only on mites in the subfamily Tetranychinae. However, Chant (1961) observed P. persimilis feeding on young thrips. P. persimilis is also cannibalistic when no other food (i.e., spider mites) is available (Dosse, 1958; Laing, 1968). Free-standing water (for the predator to drink) will, in the absence of food, increase survival by 23% (Mori and Chant, 1961b; Ashihara, et al., 1978). Adult females, when fed on honey or a 10% sucrose solution, can survive at least four times longer compared to females being fed on water alone (Ashihara et al., 1978). However, neither sucrose nor free water would promote reproduction. Ashihara et al. (1978) determined that females would not reproduce on a diet of honey, but if they were removed from the honey diet after 35 days and fed spider mite eggs they could achieve their normal reproductive potential.

DISPERSAL AND SEARCHING

When compared with five other predatory mites, P. persimilis was rated as having high dispersal powers, and its distribution and that of its prey were highly correlated (McMurtry, 1982). The ability of P. persimilis to disperse and find new colonies of prey depends on the physical characteristics of the environment (Takafuji, 1977), prey

distribution and density, predator density, and the duration of infestation or the amount of the spider mite webbing present.

One important environmental characteristic is the density of plants within the greenhouse. For example, when infested plants are dense enough for their leaves to touch, the predator can disperse readily. When the plants have little physical continuity, the predator's ability to disperse can be reduced by about 70% (Takafuji, 1977).

The density of both predator and prey may play a part in the rate at which predators leave an infested plant in search of new sources of food. Young female predators increase the rate at which they depart from a colony as their density increases and that of the prey decreases (Sabelis, 1981; Eveleigh and Chant, 1982). When prey density is low relative to number of predators present, the adult predators begin to disperse in search of new food sources. On the other hand, nymphs of P. persimilis have a much lower capacity--and tendency--to disperse than do the adults and, as a result, they remain behind and feed on whatever food is left before they begin to disperse (Takafuji, 1977). This behavioral characteristic can be a contributing factor to the extinction of prey. Also, the elimination or extinction of the prey in the greenhouse is made possible because P. persimilis has a much greater dispersal potential than its prey (Nachman, 1981). In cases where little or no spider mite damage can be tolerated, such as on ornamental plants, this is a desirable situation. Because some damage can be tolerated in cucumber and tomato crops, it would be desirable to have a stable interaction between the predator and prey over an extended period of time.

The webbing produced by twospotted spider mites aids the searching predator in finding its prey. When webbing is contacted, the predator intensifies its search in the immediate area. The webbing appears to act as an arrestant for dispersing predators. In one study, females were able to find prey twice as fast when webbing was present compared to when webbing was absent (Schmidt, 1976). Schmidt (1976) also reported that spider mite eggs had a similar effect, but to a lesser degree. Kairomones (chemical odors discussed earlier) may be responsible for this nonrandom searching behavior.

METHOD OF RELEASE

The most critical phase in the implementation of any biological control program is the release phase (French et al., 1976; Gould, 1970; Markkula and Tiittanen, 1976). Thus proper timing of predatory mite release is essential to achieve adequate control of the twospotted spider mite. Many of the past failures can be attributed to the detection of natural spider mite infestations too late to utilize biological control successfully (Stenseth, 1980). In these cases, insufficient

numbers of predatory mites were released to control an established and rapidly increasing mite population. Consequently, predators were unable to reduce mite numbers fast enough to prevent economic injury.

Release methods have been developed in order to increase the probability of successfully controlling T. urticae with P. persimilis. One release method, termed "Pest-in-First", requires the prey to be released in a uniform pattern before releasing the predator. At the appropriate time, the predator is subsequently released. A specific predator-prey ratio can therefore be established early in the season; the predator also becomes established throughout the greenhouse before mites naturally infest the crop (Markkula and Tiittanen, 1976). A similar technique is the introduction of predator and prey at the same time. This is accomplished by purchasing a mixture of both species from a commercial insectary. In the Netherlands, predators are packed in plastic bottles which contain wheat bran and spider mites. These bottles are sealed with a screw cap equipped with a gauze covered hole for ventilation. This technique, like the "Pest-in-first" method, allows the establishment of specific predator to prey ratios. Thus, balanced control can be attained throughout the greenhouse (Ravensberg et al., 1983).

The rational behind both of the above techniques is to establish the predator evenly throughout the greenhouse early in the season before the crop becomes naturally infested. This is important where a large portion of the spider mite population enters diapause. Experience has shown that spider mites leave the sites where they diapause and infest the crop as soon as environmental conditions become suitable. Because a large and unpredictable number of mites may enter a crop over a short period of time, severe damage can occur before the problem is noted. These techniques will allow growers the opportunity to establish predators early in the season which will provide a buffer against the immigrating mite population, and thus reduce the potential for damage.

In climates such as Florida, the mass influx of mites, as a result of diapause termination, is seldom seen. Mite infestations occur throughout the year and begin as small isolated patches. Therefore, release techniques designed to release predators when natural infestations are first found are better suited to these conditions (French et al. 1976). Sufficient numbers of predators are released to create a desirable predator-prey ratio, e.g., 1:10 on cucumbers (Markkula and Tiittanen 1976) or 1:6-1:25 on ornamental foliage plants (Hamlen and Lindquist 1981). When distinct patches of prey can be identified, predators should be released on every plant within the patch. Predators should also be released on plants around the outer edge of the infestation in order to establish a barrier that should slow or prevent the spread of the prey. If prey are found, but no distinct patches can be

identified, P. persimilis should be released on every fifth plant (Anonymous 1976a). The number of predators to release is dictated more by economics and their availability than any other factor. In situations where the mite population has reached high densities, the cost and logistics for releasing adequate numbers of predatory mites is usually prohibitive. In these cases, conventional chemical control should be employed to reduce the possibility of economic damage.

Many acaricides disrupt the predator-prey interaction even to the extent that acaricides must be applied during the remainder of the growing season. However, studies have shown that this problem can be avoided if either fenbutatin-oxide (Lindquist et al., 1980) or insecticidal soap (Osborne and Petitt, unpublished data) is used as the acaricide. Both studies have demonstrated that a single application of either material used in conjunction with an earlier release of predators gave better control than when either method was used alone.

Once the predators have been released in the greenhouse, some additional conditions should be taken into account. Insecticides, miticides and even certain fungicides can be detrimental to P. persimilis and should be used judiciously. Whenever possible, selective chemicals should be used (see section on Common Problems). As stated earlier, the performance of the predator is conditioned by temperature and relative humidity and to consider this aspect could easily lead to failure of the control program. Sometimes the predator may simply exterminate (eradicate) the prey from the greenhouse; thus, careful monitoring of the mites is required in order to (1) detect such eradication and (2) determine when new introductions of twospotted spider mite occur so that another release of the predator can be made at the proper time.

COMMON PROBLEMS

In this section, we will summarize some of the most common problems encountered during implementation of biological control for twospotted spider mite in the greenhouses. These are (1) improper timing of the release of P. persimilis; (2) impatience on the part of the grower; (3) lack of adequate pest suppression achieved by the control agent; and (4) cultural or chemical practices which adversely affect the natural enemy.

The need for releasing predators at the proper time has already been mentioned, but will be repeated because of its overall importance. To effectively use biological control, the grower must initiate the program when the pests are at relatively low levels. In this regard, we have observed that many growers opt for biological control when it is too late, i.e., after a major pest problem has developed and is on the verge of destroying the crop. Clearly, growers must use some

forethought and plan to initiate a control program when the pests are first found. This requires careful monitoring of the greenhouse crop(s). Growers must also realize that, unlike effective chemical control, biological control does not produce instant results. This may be true even when massive numbers of natural enemies are released in the greenhouse. Nonetheless, releasing predators at the proper time (and in adequate numbers) will shorten the period before control is attained and improve considerably the likelihood that biology control will be successful.

Impatience on the part of the grower can often lead to failure of a biological control program. Such impatience usually results in the resumption of the chemical control program before there is any need to do so. The basic cause of this is probably a lack of appropriate experience with biological control. It must be remembered that mite populations--regardless of whether predator or pest--require time to develop and increase. On the other hand, "too much patience" can also lead to problems. For example, in certain instances P. persimilis may fail to establish, and long delays before taking corrective action may allow the mite population to build up to very high densities. This problem can be minimized by closely monitoring the pest population which is critical to any pest control program. A monitoring program should be designed to identify potential problems. It should also be sensitive enough to provide the grower with enough warning to allow time for remedial actions. This lead time is important and is determined by grower-defined measurer such as the relative densities of predators and prey and the presence of other pests. The level at which other control measures should be initiated must be determined prior to implementing a biological control program.

As an example, Hassen (1983) developed a program for cucumbers. Forty cucumber plants in each of three different greenhouses were chosen at random. These 40 plants were ca. 3, 6, and 20% of the total number of plants in each of the greenhouses. Each plant was examined weekly for the presence or absence of any stage of T. urticae or P. persimilis. At the same time, these plants were observed for other potential problems. If such a program is to be useful, the grower should look for areas where damage is about to exceed a critical damage threshold (Anonymous 1976a). Secondly, the grower should look for "hot spots" where predators are scarce. The remedial actions that could be taken would depend on what was found. Hot spots could be controlled with a selective pesticide such as soap, fenbutatin oxide, or oil. If the potential for severe damage exists the grower would have to consider treating the entire crop.

Another problem is that natural enemies may not control their hosts at all times or under all conditions. Many failures can be attributed to improper environmental conditions

within the greenhouse. As we have explained previously, P. persimilis is adapted to certain temperature regimes, outside of which their performance is reduced measurably. Certain cultural practices can also be devastating to a biological control program. One practice that can cause problems is the movement of plants in and out of the greenhouse. Obviously, when the plants one is trying to protect are held in the greenhouse for only a short period of time, biological control agents will often have a minor impact on the pest population. Another common problem is the movement of plants from one greenhouse to another, or when plants are brought in from out-of-doors. These plants are seldom inspected for the presence of pests and, invariably, there will be one plant that is infested with some kind of pest. Furthermore, these pests generally enter the greenhouse undetected and without their effective natural enemies. Subsequently, they multiply unchecked. There are methods to control a few of the occasional pest species without the disruption of the biological control program. However, in many cases pesticides may have to be used, which may then kill or severely disrupt a P. persimilis population. These disturbances can be minimized through sanitation and careful inspection of all plant materials before they are brought into the greenhouse.

Plants contaminated with occasional pests may be present in the greenhouse when the grower, in preparation for a biological control program, discontinues the use of broad-spectrum pesticides. These pests are then free to multiply, unchecked, and usually require chemical control which, again, jeopardizes the survival of existing biological control agents. Perhaps the most effective way of eliminating this problem is to treat the greenhouse with the appropriate pesticide prior to releasing the predator.

This leads us to the quickest and most common way of causing a biological control program to fail, that is, the application of nonselective pesticides. As we have emphasized, P. persimilis is very susceptible to many chemicals (Table 3). However, there appears to be some discrepancy as to the susceptibility of P. persimilis to specific pesticides. Some of the confusion is probably due to differences between strains. Efforts are being made toward identifying and/or developing strains resistant to various pesticides (Schulten et al., 1976; Schulten, 1980). Resistance or tolerance to diazinon, demeton-S-methyl, malathion, mevinphos, fenbutatin-oxide, tetradifon, cyhexatin, azinphosmethyl, carbaryl, methidathion, pirimicarb, pyrazophos, and triforine has been reported (Woets and van Lenteren, 1983). Because important differences exist among strains, growers are advised to consult with their suppliers as to the sensitivity of their specific predators.

Table 3. Safety of commonly used pesticides to Phytoseiulus persimilis eggs and adults*.

Chemical	Method of application	Eggs	Adults
	Insecticides and Acaricides		
Acephate	HV**	-***	H
Aldicarb	GRANULES	-	H
Bacillus thuringiensis	HV	S	S
Carbaryl	HV	-	H
Cyhexatin	HV	-	H
Diazinon	HV	-	H
Diazinon	DRENCH	-	S
Diazinon	ULV	-	S
Dicofol	HV	-	H
Dienochlor	HV	I	H
Dimethoate	HV	H	H
Dimethoate	Drench	H	-
Endosulfan	HV	-	H
Fenbutatin-oxide	HV	-	S
Insecticidal Soap	HV	S	H
Kinoprene	HV	S	S
Lindane	HV	H	H
Lindane	DRENCH	-	I
Lindane	SMOKE	S	H
Malathion	HV	H	H
Methomyl	HV	-	H
Nicotine	HV	-	I
Nicotine	SMOKE	S	S
Oxamyl	GRANULES	S	S
Oxamyl	HV	-	H
Oxydemeton-methyl	HV	-	H
Oxythioquinox	HV	H	H
Oxythioquinox	SMOKE	H	H
Parathion	HV	H	H
Parathion	DRENCH	H	H
Parathion	SMOKE	H	H
Permethrin	HV	-	H
Permethrin	FOG	-	H
Pirimicarb	HV	S	S
Pyrethrin	HV	H	H
Propargite	HV	H	-
Resmethrin	HV	H	H
Rotenone	HV	-	H
Tetradifon	HV	S	S

(continued)

Table 3. Safety of commonly used pesticides to Phytoseiulus persimilis eggs and adults* (continued).

Chemical	Method of application	Eggs	Adults
	Fungicides		
Benomyl	HV	H	H
Benomyl	DRENCH	I	I
Captafol	HV	S	S
Captan	HV	S	S
Chlorothalonil	HV	S	S
Dinocap	HV	-	S
Iprodione	HV	S	S
Mancozeb	HV	-	S
Maneb	HV	-	S
Metalaxyl	HV	-	H
Thiophanate-Methyl	HV	H	S
Thiram	HV	I	S
Triforine	HV	S	S
Vinclozolin	HV	-	S
Zineb	HV	-	S

*These data were compiled from Hassen and Oomen 1985, Ledieu 1985, and Steiner and Elliott 1983.

**HV = High volume and ULV = Ultra low volume.

***Key to symbols: S = Safe; I = Intermediate; H = Harmful; and - = Unknown.

OBTAINING NATURAL ENEMIES

Natural enemies for use in the greenhouse can be obtained from commercial insectaries. A number of such companies sell biological control agents. The problem for the grower is finding these companies. There are a few ways in which this can be accomplished. The first would be to contact the Florida Cooperative Extension Service. Offices are located within each county, with the main entomology office located at the University of Florida in Gainesville. There are a few publications that list companies that sell biological control agents (Hickman, 1984; Olkowski and Redmond, 1983). Interested individuals might also consult recent books dealing with organic methods of pest control as many of these will list sources of biological control agents.

Once an individual obtains P. persimilis, it is also possible to maintain a colony without much difficulty. There are various advantages to the grower in doing so: (1) it would provide a constant supply of the predators; (2) they would be readily available; and (3) it might be less expensive to propagate the predators than to periodically purchase them from commercial sources, especially if growers form a cooperative to maintain such a colony.

The efficient production of P. persimilis depends on the availability of three isolated areas: (1) an area for growing plants (usually Henderson bush lima beans) without any pests present; (2) an area for maintaining pure colonies of the pest; and (3) an area for raising the predators. In this manner, noninfested plants can be placed in the pest colony. After a sufficient infestation is obtained, they can then be transfered to the final location where the infested plants are exposed to the predators. Although it is possible to maintain pests and predators in one place, this practice is not usually conducive to mass production. If this method is necessary (e.g., because of space shortage), the movement of mites among areas can be reduced by placing the plants on platforms which rest over containers of water. A surfactant or detergent should be added to the water to reduce the surface tension. In this way, both predator and prey mites which drop off the plants will fall into the water and die. A second recommendation is to locate the plants containing the predator colony "down wind" from the prey colony to minimize contamination by air currents.

The method of rearing P. persimilis at the Agricultural Research and Education Center in Apopka is quite simple. First we sow bean seeds into a commercially prepared soil mix which is contained within a 15x30x33 cm plastic dish washing tub. These tubs are kept in a greenhouse until the first true leaves are fully expanded. At this time they are moved into a room maintained at 25°C and lighted with four, 4-tube, 40 W Cool White fluorescent light fixtures. Infested leaves from about 10 plants are placed on the beans in one tub. The beans in this tub are grown until a heavy mite population develops. Each tub is then placed in close contact to a tub that is infested with predators. The appropriate time to harvest the predators depends on when the two populations reach the desirable ratio. This ratio (predator:prey) could be any where from 1:0 (no prey) to 1:50 depending on need. Harvesting predators is the next step. This is accomplished in a number of ways. We place leaves cut from one tub into paper bags, fold the top over about four times, and staple the bags shut. This prevents the accumulation of excess moisture as the foliage dries, and it allows the predators to feed on the remaining spider mites. Leaves are then removed from the bag as needed and placed throughout the crop. After most of the leaves have been removed, the bag is then placed in close proximity to the most heavily infested plants. Another method of harvesting predators is to place leaves in a plastic bucket

which is sealed with a lid. A large hole should be cut into the lid and covered with nylon organdy to allow ventilation. After 24 to 48 hours predators can be found running around the lid and upper portion of the bucket. These individuals can be dislodged directly onto plants within the greenhouse or they can be collected for later use with a simple suction device such as an aspirator or with a soft camel-hair brush. Parr (1968) has shown that predators and prey can be stored. He placed 5 predators plus 15 prey in a tube and stored them at 8.3°C for 3 weeks to 4 months with ca. 60% survival regardless of the period of storage.

Additional aspects of culturing the twospotted spider mite and its predator can be found in the following: Anonymous (1975), Gilstrap (1977), Hoy et al., (1982), Kamburov (1966), McMurtry and Scriven (1965), Scopes (1968), Scriven and McMurtry (1971), Theaker and Tonks (1977).

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