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ARRESTMENT RESPONSES OF SOME PHYTOSEIID MITES TO EXTRACTS OF *OLIGONYCHUS PUNICAE, TETRANYCHUS URTICAE* AND POLLEN

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ABSTRACT

Arrestment responses of adult females of 5 species of Phytoseiidae to extracts of *Oligonychus punicae* (Hirst) or *Tetranychus urticae* (Koch) plus host leaves and of 3 of these species to pollen extracts were assessed by counting mites aggregated under filter paper discs treated either with the extract in methanol or with methanol alone (control). *Euseius hibisci* (Chant) showed positive responses to extracts of both spider mites plus host plant leaves as well as to pollen extracts, and a negative oviposition response to *O. punicae* extracts. *Amblyseius limonicus* Garman and McGregor and *Typhlodromus porresi* McMurtry showed no response to extracts of the mite species or pollen. *Neoseiulus californicus* (McGregor) and *Phytoseiulus persimilis* Athias-Henriot responded to *T. urticae* plus leaf extracts but not to those of *O. punicae. P. persimilis* also had a positive oviposition response to *T. urticae* plus leaf extracts. Possible reasons for these results are discussed in relation to current knowledge of these and other phytoseiid species.

KEY WORDS: phytoseiid, kairomone, tetranychid.

INTRODUCTION

Phytoseiid mites are known to respond to chemical cues emanating from colonies of spider mites, i.e., the mites, webbing, excreta and the infested foliage (reviewed by Sabelis and Dicke, 1985). These chemical cues aid the predators in finding their prey, and thus they contribute to the ability of the predator to mature and produce offspring. In most instances, the stronger responses were to chemical cues from prey species that are more profitable to the predator for reproduction (Hislop and Prokopy, 1981; Hoy andSmilanick, 1981; Sabelis and van de Baan, 1983; Dicke and Groeneveld, 1986; Dicke, 1988). For example, *Phytoseiulus persimilis* Athias-Henriot and *Typhlodromus occidentalis* Nesbitt responded to chemical cues from *Tetranychus* species, with which they usually are associated in nature, but weakly or not at all to *Panonychus* species, a prey with which they seldom are associated (Hoy and Smilanick, 1981; Sabelis and van de Baan, 1983). The reverse behavior occurred with *Amblyseius potentillae* Garman, *Euseius finlandicus* (Oudemans) and *Typhlodromus pyri* Scheuten, all of which are associated with *Panonychus ulmi* (Koch), but not with *Tetranychus* species (Sabelis and van de Baan, 1983; Dicke, 1988).

No studies have been done to determine if phytoseiid mites respond to cues from *Oligonychus* species, some of which are important pests of agricultural crops (Jeppson et al., 1975). *Oligonychus punicae* (Hirst) is the major phytophagous mite species on avocado in California, and in some seasons it causes severe bronzing of leaves and partial defoliation of some trees (Ebeling, 1959; McMurtry, 1985). Phytoseiid mite populations usually increase in response to *O. punicae* increases, although suppression of the spider mites probably results more from the action of the coccinellid *Stethorus picipes* Casey than from phytoseiids (McMurtry and Johnson, 1966).

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The study reported here was conducted to attempt to answer the following questions: (1) Do some avocado-inhabiting phytoseiids respond to chemical cues from *O. punicae*? (2) Do phytoseiids known to be associated with *Tetranychus* spp. but not to *Oligonychus* spp. also respond to cues emitted by an *Oligonychus* species? (3) Is there a response to extracts of pollen by *Euseius hibisci* (Chant), or by *Amblyseius limonicus* Garman and McGregor, both omnivorous species which feed on pollen (McMurtry and Scriven, 1964, 1965), compared to a species (*Typhlodromus porresi* McMurtry) which does not develop and reproduce as readily on pollen?

MATERIALS AND METHODS

Phytoseiid species and cultures

Five phytoseiid species were tested: *E. hibisci*, the most common and widespread phytoseiid on avocado in California, was cultured from mites collected from avocado in the type locality of Alamos, Sonora, Mexico; *Amblyseius limonicus*, a coastal species occurring on citrus and avocado trees, collected from avocado in Carpinteria, Santa Barbara County, California; *Typhlodromus porresi*, from avocado near Tuxtla Gutierrez, Chiapas, Mexico; *Neoseiulus californicus* (McGregor), collected from strawberry in Oxnard, Ventura County, where it is commonly associated with *Tetranychus urticae* (Koch); and *Phytoseiulus persimilis* Athias-Henriot, also collected from strawberry at Oxnard. This predator of *T. urticae* has been established in California since the early 1970s (McMurtry et al., 1978). All species were cultured in the insectary on metal tile substrates (McMurtry and Scriven, 1975). *E. hibisci* was fed pollen from flowers of the "ice plan," *Malephora crocea* Jacquin, *A. limonicus* was fed a combination of pollen and eggs and larvae of *Tetranychus pacificus* McGregor, and the other three species were fed *T. pacificus* only.

Extraction techniques

Techniques were similar to those of Moraes and McMurtry (1985). Squares (2 × 2 cm) of avocado and bean leaves for *O. punicae* and *T. urticae*, respectively, were placed on wet foam pads in stainless steel pans and infested with 200 adult female spider mites. An additional avocado and bean leaf square without mites was set up as a control. After 48 h, infested leaves containing the mites, webbing and excreta, and uninfested control leaves were cut into 2 or 3 pieces and submerged in 1 ml of methanol in centrifuge tubes. Previous studies (Hislop and Prokopy, 1981; Moraes and McMurtry, 1985) comparing several solvents indicated that methanol was efficient in extracting kairomonal components. After 4 min of extraction time, the solutions were centrifuged at 10,000 rpm for 3 min. Pollen extracts were obtained by placing 40 mg of *Malephora crocea* pollen in 1 ml of methanol for 4 min and then centrifuging as with the mite and leaf extracts. After centrifugation, the supernatants were poured off and stored in a refrigerator until used for the bioassays, usually within 2 days of extraction.

Bioassays

The technique we used (Moraes and McMurtry, 1985) only tested for arrestment responses, and was not designed to detect attraction to volatile compounds. Test arenas consisted of 4 × 4 cm pieces of avocado leaf placed upper side down on water-saturated foam pads in pans of water. Leaf pieces were bordered with strips of "cellucotton" to deter escape of the predaceous mites. Ten well-fed adult female phytoseiids were placed in each arena. There were 10 or 20 arenas (replicates) per treatment and a comparable number of controls. Filter paper discs (Whatman No. 1) 1.2 cm in diameter were placed on a glass surface and, with a microsyringe, impregnated with 20 μl of extract. Control discs were impregnated with 20 μl of methanol. Treated discs were allowed to air-dry for 40 min, then a treated and a control disc were placed in each arena in the center of 2 of its diagonally opposed quarters. The arenas were examined after 2 h and any missing mites replaced, and after 5 and 8 h the number of mites under each disc was recorded. After 24 h from the start of the experiment, the number of eggs under each disc was recorded. The Chi-square test was used to analyze the data.

RESULTS

There were significantly more adult female *E. hibisci* under discs treated with extracts of *O. punicae* or *T. urticae* plus their host plant leaves than under control discs (Table 1). The ratio on treated:control discs was only about 3:2 for *O. punicae* extracts:controls, compared to about 3:1 for *T. urticae* extracts:controls. *E. hibisci* was the only one of the 5 species showing a response to extracts of *O. punicae* plus avocado leaves. There were no significant differences in numbers of eggs laid on discs treated with *T. urticae* extract compared to controls, and *O. punicae* treated discs had significantly fewer eggs of *E. hibisci* than controls. *E. hibisci* females also showed a significant tendency to congregate under discs treated with pollen extract compared to methanol-treated control discs after 5 h but not after 8 h. Significantly more eggs were laid under discs treated with pollen extract compared to the controls.

A. limonicus showed no tendency to congregate under discs treated with extracts from either species of spider mite plus host plant leaves or from pollen, compared to control discs (Table 1). Few eggs were laid under any of the discs. *T. porresi* showed no response to *O. punicae* or to pollen extracts and laid no eggs during the experiment. Both *N. californicus* and *P. persimilis* showed a significantly greater tendency to congregate under discs treated with extracts of *T. urticae* plus bean leaves, but showed no response to extracts of *O. punicae* plus avocado leaves. Few eggs were laid by *N. californicus* on either mite/leaf extract or control discs. *P. persimilis*

TABLE 1
Phytoseiid mite females and eggs under filter paper discs treated with extracts of mites or pollen, compared to those under control discs (Mean number under treated: mean number under control discs)

		Females		Eggs
Species	Extract	5 h	8 h	24 h
E. hibisci	*O. punicae* on avocado leaf: leaf only[a]	2.9:2.0*	3.1:1.9*	0.5:1.5**
	T. urticae on bean leaf: leaf only[a]	3.0:1.0***	3.4:1.3***	2.2:1.6
	Pollen: methanol only	3.5:0.9***	1.9:2.6	2.5:0.2*
A. limonicus	O. punicae on avocado leaf: leaf only	2.9:3.5	2.6:3.8	0.2:0.1
	T. urticae on bean leaf: leaf only	1.7: 0.8	1.9:1.6	1.0:0.1
	Pollen: methanol only	2.0:4.2	2.1:3.4	0:0
T. porresi	*O. punicae* on avocado leaf: leaf only	0.9:1.3	0.8:1.0	0:0
	Pollen: methanol only	0.7:1.3	0.4:1.4	0:0
N. californicus	*O. punicae* on avocado leaf: leaf only	2.5:2.2	4.0:2.7	0:0
	T. urticae on bean leaf: leaf only	4.3:1.5***	4.8:3.0**	0.4:0.1
P. persimilis	*O. punicae* on avocado leaf: leaf only	2.2:2.1	2.7:2.0	2.6:3.5
	T. urticae on bean leaf: leaf only	2.9:1.9	3.7:1.2**	9.2:2.7**

laid considerably more eggs under the discs than the other species and significantly more under discs treated with *T. urticae* extract than under controls.

DISCUSSION

The known distribution of *E. hibisci* on avocado extends southward to Oaxaca state in southern Mexico (McMurtry et al., 1985), where avocado or related *Persea* species as well as *Oligonychus punicae* probably are indigenous. Therefore, it is plausible to hypothesize that *E. hibisci* has evolved a behavioral response to chemical cues emanating from infestations of *O. punicae*.

The fact that significantly more *E. hibisci* adults were observed under discs treated with *O. punicae* plus leaf extracts, but that the predators laid fewer eggs under those discs is not inconsistent with field and laboratory observations on this species. *E. hibisci* readily feeds and reproduces on *O. punicae*, although mite prey is less nutritious than pollen as measured by developmental and ovipositional rates (McMurtry and Scriven, 1964). As evidenced by a brown coloration in their bodies, a high percentage of predators feed on this spider mite when the latter is abundant on avocado (McMurtry and Johnson, 1966). However, the eggs of *E. hibisci* have not been observed in the spider mite colonies, which occur predominately on the upper sides of the leaves. Rather, the eggs are deposited on the undersides, and often on uninfested leaves, especially those curled downward or those having a few strands of webbing, e.g., from psocids or small spiders (McMurtry and Johnson, 1966). Thus, *E. hibisci* probably responds to different cues for selecting oviposition sites than for selecting food items. As these phytoseiids cannot search efficiently in the webbed colonies of *O. punicae* (McMurtry and Scriven, 1964; McMurtry and Johnson, 1966), a negative oviposition response to this prey would ensure that eggs are laid away from spider mite webbing, which may impede the movement of immature *E. hibisci*. This lack of propensity of *E. hibisci* to congregate and oviposit on infested leaves may be one reason for the delayed response of this phytoseiid to increases of *O. punicae* (McMurtry and Johnson, 1966).

The positive response of *E. hibisci* to extracts of *T. urticae* plus bean leaves was unexpected. We have not observed it to be associated with *Tetranychus* species in the field. Laboratory studies showed the closely related *T. cinnabarinus* (Boisduval) to be an unfavorable prey species because the predators often became trapped in the spider mite webbing (McMurtry and Scriven, 1964). Dicke et al. (1986) and Dicke (1988) pointed out that a predator may respond to an unprofitable prey when the alternative is no prey at all or a deficient diet. Another example of a phytoseiid responding to an unsuitable prey species was the positive arrestment response of *P. persimilis* to extracts of *Tetranychus evansi* Baker and Pritchard (Moraes and McMurtry, 1985). Therefore, although laboratory assessments of the responses of phytoseiids to kairomones of various prey species may be helpful in deciding which species have the most potential for biological control of tetranychid mites (Hoy and Smilanick, 1981; Dicke, 1988), the results from such experiments can be misleading.

The arrestment response of *E. hibisci* to pollen grains is consistent with results of other studies on this species, showing that pollen promotes a higher rate of reproduction than any other food tested (McMurtry and Scriven, 1964). This also seems to be the case for other *Euseius* species (McMurtry and Rodriguez, 1987). Probably most pollen feeding in avocado and citrus orchards is on airborne grains which land on the leaf surfaces (McMurtry and Johnson, 1965; Kennett et al., 1979); therefore, an attraction response from a distance as well as an arrestment response would be of benefit to foraging *E. hibisci*. Further studies should be conducted to determine if such an attraction response occurs.

Although *A. limonicus* showed no response to extracts of either species of spider mite plus host plant leaves, this species feeds and reproduces readily on *O. punicae* (McMurtry and Scriven, 1965). *A. limonicus* also shows a superior ability to suppress *O. punicae* populations compared to *E. hibisci* (McMurtry and Johnson, 1966; McMurtry and Scriven, 1971). This is another example in which data on responses to chemical cues would have been misleading had they been used as the criterion for selecting promising phytoseiids for use in biological control programs.

T. porresi, found in the region where both the avocado and probably associated *Oligonychus* species are indigenous, also develops and reproduces readily on *O. punicae*. Although *T. porresi* was not collected in association with spider mites (McMurtry, unpublished), laboratory studies showed that *O. punicae* was a favorable food source, and pollen a less favorable food (Badii et al., 1990). Still, a response to chemical cues from *O. punicae* would have been predicted. It would be of interest in future studies to determine if a Y-tube olfactometer test, designed to detect responses to volatile compounds from *O. punicae* plus leaves, would also yield negative results.

The responses of *N. californicus* and *P. persimilis* to *T. urticae* and not to *O. punicae* are consistent with previous studies and observations. *N. californicus* commonly occurs on strawberries and various weeds in association with *T. urticae*. It also occurs on grapes in the coastal region of California in association with *Eotetranychus willamettei* (McGregor), another species which occurs in dense colonies with copious webbing. *N. californicus* has not been collected on avocado with *O. punicae*. *P. persimilis* also is not known to be associated with *Oligonychus* species under natural conditions; it appears to be a specialized predator of *Tetranychus* species and has a lower reproductive potential on *Oligonychus* species (Ashihara et al., 1978). However, *P. persimilis* has shown potential for controlling *Oligonychus pratensis* (Banks) using mass releases in sorghum (Pickett and Gilstrap, 1986a). Unlike most *Oligonychus* species, *O. pratensis* colonies are typically very dense with heavy webbing, more similar to those of *Tetranychus* species (Pickett and Gilstrap, 1986b).

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