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# FOOD PLANT SPECIFICITY AND BIOLOGY OF *ITAME VARADARIA* (WALKER) (GEOMETRIDAE), A NORTH AMERICAN MOTH INTRODUCED INTO AUSTRALIA TO CONTROL THE WEED *BACCHARIS HALIMIFOLIA* L.

W. A. PALMER

North American Field Station, Queensland Department of Lands,
2801 Arrowhead Circle, Temple, Texas 76502

**ABSTRACT.** *Itame varadaria* (Walker) is an infrequently encountered ectophagous, foliage feeding geometrid that occurs from South Carolina to Texas on *Baccharis halimifolia* L. Laboratory studies indicated that the moth completes its development in about 28 days, that there are five larval instars, and that females have an average potential fecundity of 165 eggs. In Texas there are at least three generations per year and there was no evidence of diapause. The moth was reared through a number of generations in the laboratory using cut foliage as a food source. Food plant specificity studies were conducted both in Texas and Australia. Moths were not specific in their oviposition preference under cage conditions but larvae developed only on four species of *Baccharis*. *Itame varadaria* is therefore sufficiently stenophagous for use as a biocontrol agent and approval was granted for its release in Australia.

**Additional key words:** Texas, Queensland, Asteraceae, fecundity.

The woody shrub *Baccharis halimifolia* L. (Asteraceae: Astereae: Baccharinae), introduced from North America, is a serious weed in Queensland, Australia (Stanley & Ross 1986, Palmer 1987). The Queensland Department of Lands, through the Alan Fletcher Research Station (AFRS), therefore initiated a long-range research program in 1962 to find biological control agents in the New World for release in Australia. This ultimately led to the establishment of the North American Field Station (NAFS) at Temple, Texas, in 1982.

The insect fauna on *B. halimifolia* has been described by Palmer (1987) and Palmer & Bennett (1988). A rather rare geometrid, *Itame varadaria* (Walker) was listed in both these studies and was identified as a possibly monophagous insect that should be investigated further as a biological control agent.

This paper describes the experimental and field observations undertaken to investigate the biology, phenology, and food plant specificity of this moth prior to its release in Australia.

## LIFE HISTORY

Eggs were green with a slightly flattened ovoid shape and sculptured exochorion. Mean length and width of the eggs were 0.74 mm (SE = ±0.02; n = 6) and 0.40 mm (±0.02; n = 6) respectively. They were attached to the leaf margin along the longitudinal axis of the egg and

TABLE 1. Life history of *I. varadaria* when reared at 28°C.

| Stage | Head capsule width mm (±SE; No. obs.) | Larval length range in mm | Development time days | Feeding damage |
|---|---|---|---|---|
| Egg | — | — | 4 | — |
| 1st Instar | 0.25 (0.01; 11) | 2.2–3.3 | 3 | pinholes |
| 2nd Instar | 0.44 (0.01; 12) | 3.0–6.0 | 3 | pinholes |
| 3rd Instar | 0.71 (0.03; 5) | 7.0–8.5 | 1 | from margin |
| 4th Instar | 1.1 (0.01; 24) | 6.0–12.0 | 3 | from margin |
| 5th Instar | 1.76 (0.04; 22) | 10.0–21.0 | 6 | whole leaf |
| Pupa | — | — | 8 | — |

were usually oviposited singly or in groups of two or three, rarely in larger clusters.

Larvae developed through five instars before pupation. A cohort of larvae was kept at 28°C in the laboratory and observed daily. First and second instars chewed tiny holes 0.5–1.0 mm in diameter through the epidermis to feed on underlying parenchyma tissue. Later instars fed from the leaf margin inwards. Fifth instars consumed about a leaf a day. Measurements of head capsule width and larval length were made daily on a selection of 4–6 larvae from the cohort and these are given in Table 1 together with the time spent in each development stage. The insect completed its life cycle in approximately 28 days.

The mean head capsule widths for the five instars were consistent with the "Brooks-Dyar" rule (cf. Daly 1985). Relatively constant growth ratios of 0.57, 0.62, 0.65 and 0.63 can be calculated to describe the width of head capsules as a proportion of the width of the following instar.

Pupae were very difficult to sex and it was found more reliable to wait for the emergence of the adult to determine sex. Mean weights were 40 mg (±2; n = 6) and 55 mg (±2; n = 10), for male and female pupae respectively.

Four single pair matings were made by confining pairs of moths in 10 oz. paper cups with moistened raisins. After the death of the female, the eggs in the container were counted, the female dissected and eggs remaining in the abdomen counted. The two counts were added to give an estimate of the total potential fecundity. Mean total potential fecundity was 165 eggs (±20; n = 4). Some 31% of the total egg count remained in the insects' abdomens.

## PHENOLOGY AND RANGE

*I. varadaria* occurs from South Carolina (Ferguson 1973) to Florida (Palmer & Bennett 1988) and along the Gulf Coast to Houston, Texas (Palmer 1987). Its only known larval food plant is *B. halimifolia*. Fer-

guson (1973) noted at least two broods a year with the moths of the spring generation being slightly larger, darker, and less brightly marked than the summer ones.

An area to the west of Beaumont, Texas, was periodically surveyed throughout 1986 and 1987 by sweeping the bushes with a heavy duty net to recover larvae. Larvae were recovered as early as March and were also seen as late as early December. It therefore appeared that there could be up to 6 or 8 generations a year and certainly at least 3 generations per year.

Larvae were never very abundant and numbers showed little variation with season; an hour's sweeping rarely resulted in the capture of more than half a dozen larvae. At such low densities the insect was not adversely affecting the plant.

Because only a few larvae were captured and these by sweeping, no natural enemies were observed nor parasites reared from the immatures.

## REARING

A colony was maintained in a laboratory kept at 25–28°C and 40–60% RH for more than four generations with the following procedure. Batches of 10–15 unsexed pupae were placed in 10 oz. paper cups. Emerging moths were offered soaked raisins (or a sugar-water wick) and a piece of fine polyester netting (approx. 20–30 $cm^2$). Moths successfully mated in the cups and then laid most eggs on the netting but some on the cup itself.

Neonate larvae were transferred to bouquets of foliage held in 1 oz. soufflé cups. The foliage of both *B. halimifolia* and *B. neglecta* Britton (a species growing near the NAFS) were equally acceptable. The larvae were transferred to fresh bouquets of foliage twice a week. On completing their growth, fifth instars usually wandered from the foliage before becoming prepupae. Naked pupae were collected from the cage floor and sometimes from the foliage.

An alternative method of rearing was also successful. Moths were released into large cages containing potted plants held in an airconditioned greenhouse. Providing care was taken to replace plants if they were defoliated, this system required little work and pupae or adults could be recovered from the cage regularly.

## FOOD PLANT SPECIFICITY TESTING

**Oviposition preference.** In an experiment with two replicates, mesh cages (62 × 45 × 45 cm) were set up, each containing ten asteraceous species in gallon pots. Three sugar-water wicks were placed in each cage before the release of twelve unsexed moths from the laboratory

TABLE 2. Mean number of eggs oviposited by moths on various species of plants in a multiple choice experiment replicated twice.

| Plant species | Eggs (±SE) |
|---|---|
| *Baccharis neglecta* Britton | 20.0 (±8) |
| *Ageratum houstonianum* Mill. | 0.0 |
| *Aster novae-angliae* L. | 3.0 (±1) |
| *Bellis perennis* L. | 1.0 (±1) |
| *Callistephus chinensis* (L.) | 0.0 |
| *Chrysanthemum morifolium* Rem. | 0.0 |
| *Conyza canadensis* L. | 0.0 |
| *Dahlia pinnata* Cav. | 0.0 |
| *Parthenium hysterophorus* L. | 11.0 (±10) |
| *Solidago altissima* L. | 0.5 (±0.5) |
| Cage walls | many (>10) |

colony. Four and seven days later, all plants and the cages were very carefully examined using a lighted magnifier and any eggs counted.

Although most eggs were laid on *B. neglecta,* some were also found on other species and on the wire netting of the cages (Table 2). Under these laboratory conditions the insect was not specific in its oviposition behavior. This is not an uncommon finding when Lepidoptera are held in close confinement.

**Survival of neonate larvae on cut foliage.** These tests, which constituted the most comprehensive component of the food plant testing, were conducted at both the NAFS in Texas and at the AFRS in Australia because many of the plant species were available on only one continent. However, the same procedure was used at both locations. The insect was tested against 6 species of *Baccharis,* 13 genera in the Astereae tribe, 26 genera in 10 other tribes of the Asteraceae and a further 24 genera in 18 other plant families. In all, a total of 72 plant species (Table 3) was tested. Not all plants could be tested simultaneously so they were tested in batches of about 20 plants. *B. halimifolia* was always included as a control with each batch. The plants were randomly selected for each batch but eventually each species was tested at least three times by the following method. Except for a few cases, foliage was taken from different potted plants for each replication.

Five unfed, neonate, laboratory reared larvae were placed in a glass vial with a leaf of one plant species. The vials were observed daily and wilted leaves replaced. Survival was assessed after 72 h and again after 144 h.

Larvae survived for 144 h only on 4 species of *Baccharis.* Mean survival on *B. halimifolia, B. neglecta, B. pilularis* D.C., and *B. sarothroides* Gray were 70%, 80%, 100% and 50%, respectively, and significant feeding was observed in each case. Almost all larvae on plants

TABLE 3. The plant list against which neonate larvae were tested in a cut foliage, no-choice experiment. Species selected for additional experiments are also indicated (*†).

Anacardiaceae: *Mangifera indica* L.
Apiaceae: *Apium graveolens* L.
Asteraceae: **Tribe Astereae:** *Aster novae-angliae* L.*†, *A. novi-belgii* L., *Baccharis bigelovii* Gray, *B. glutinosa* Pers., *B. halimifolia* L.*†, *B. neglecta* Britton†, *B. pilularis* D.C., *B. sarothroides* Gray, *Bellis perennis* L.†, *Brachyscome multifida* D.C.*†, *Callistephus chinensis* (L.) Nees*†, *Calotis cuneata* (F. Muell. ex Benth.) G. L. Davis*†, *Chrysothamnus nauseosus* (Pall.) Britt., *Conyza canadensis* L.†, *C. sumatrensis* (Retz.) E. H. Walker*, *Gutierrezia microcephala* (D.C.) Gray, *Isocoma wrightii* (Gray) Rydb., *Olearia subspicata* (Hook.) Benth.*†, *Solidago altissima* L.†, *Vittadinia sulcata* N. T. Burbidge*†. **Tribe Heliantheae:** *Cosmos bipinnatus* Cav.*†, *Dahlia pinnata* Cav., *D. variabilis* Desf.†, *Eclipta prostrata* (L.) L.*†, *Gaillardia aristata* Pursh†, *Glossogyne tenuifolium* (Labill.) Cass.†, *Helianthus annuus* L.†, *Iva frutescens* L., *Wedelia spilanthoides* F. Muell.†, *Zinnia angustifolia* H.B.K.*†. **Tribe Inuleae**: *Cassinia laevis* R. Br.*†, *Gnaphalium sphaericum* Willd.†, *Helichrysum bracteatum* (Vent.) Andr*†. **Tribe Senecioneae:** *Emilia sonchifolia* (L.) D.C.†, *Flaveria australasica* Hook†, *Senecio lautus* G. Foster ex Willd†. **Tribe Anthemideae:** *Artemsia frigida* Willd., *Chrysanthemum carinatum* Schousb.†, *C. morifolium* Remat, *Cotula australis* (Spreng.) Hook. F.*†. **Tribe Eupatorieae:** *Adenostemma lavenia* (L.) Kuntze†. **Tribe Vernonieae:** *Vernonia cinerea* (L.) Less*†. **Tribe Lactuceae:** *Cichorium intybus* L., *Lactuca sativa* L. **Tribe Cynareae:** *Carthamus tinctorius* L.†, *Cynara scolymus* L.†. **Tribe Calenduleae:** *Calendula officinalis* L.†. **Tribe Tageteae:** *Tagetes lucida* Cav.
Brassicaceae: *Brassica oleracea* L.
Caricaceae: *Carica papaya* L.
Chenopodiaceae: *Beta vulgaris* L.
Cucurbitaceae: *Cucurbita maxima* Duch.*
Fabaceae: *Arachis hypogaea* L.*, *Medicago sativa* L., *Phaseolus vulgaris* L.
Liliaceae: *Allium cepa* L.*
Malvaceae: *Gossypium hirsutum* L.*
Myrtaceae: *Eucalyptus* sp.
Passifloraceae: *Passiflora edulis* Sims.
Poaceae: *Triticum aestivum* L., *Saccharum officinarum* L., *Sorghum vulgare* L., *Zea mays* L.
Proteaceae: *Macadamia integrifolia* Maid & Betche.
Rosaceae: *Fragaria vesca* L.
Rubiaceae: *Coffea arabica* L.
Rutaceae: *Citrus sinensis* (L.)
Solanaceae: *Solanum tuberosum* L., *Lycopersicon lycopersicum* L.
Vitaceae: *Vitis vinifera* L.

* Potted plants tested against nenonate larvae.
† Cut foliage tested against third instar larvae.

other than these four species were dead after 72 h and little evidence of feeding was observed. The exceptions were two larvae on *Cassinia laevis* R. Br. where a little feeding was seen, and one larva each on *Calotis cuneata* (F. Muell. ex Benth.) and *Olearia subspicata* (Hook) Benth. where no evidence of feeding was present.

**Survival of neonate larvae on potted plants.** To ascertain whether larvae responded similarly on growing plants as they did on cut foliage, neonate larvae were exposed to twenty plant species (Table 3). Two potted plants of each selected species were available and these were

placed in an air-conditioned glasshouse. Ten neonate larvae were placed on the foliage of each plant and a fine mesh bag placed over them to confine them to a limited portion of the plant so that they could be more easily observed and protected from marauding ants. The plants were examined after 4 days and surviving larvae noted.

After 4 days 100% survival and substantial feeding were noted on both *B. halimifolia* plants but no live larvae were found on any other plant. Feeding marks were noted only on one *Cassinia laevis* plant.

**Late instar survival on cut foliage.** This experiment was conducted to determine if late instar larvae have a wider food plant range than neonate larvae. Neonate larvae were reared on *B. halimifolia* foliage for 10 days at 22°C at which time they were third instars. Five larvae were transferred to foliage of each of 25 species of Asteraceae (Table 3), cuttings of which had been placed in small bottles of water. These cuttings were replaced after three and six days. The experiment was evaluated on the 7th day and live larvae noted.

Survival of larvae on *B. halimifolia* and *B. neglecta* averaged 80% and 100% respectively and extensive feeding occurred. No feeding occurred on any other plant. Soon after their placement on the cuttings, most larvae on plants other than *Baccharis* left the foliage and were subsequently found on the bottom of the containers; most larvae had died by the fifth day and all were dead by the seventh.

## DISCUSSION

*Itame varadaria* was tested very comprehensively against a wide range of plant species with particular emphasis being given to closely related species in the Asteraceae. It was evident that the larval food plant range of this insect is confined to certain species of *Baccharis*. The four species on which *I. varadaria* could be reared (viz., *B. halimifolia*, *B. neglecta*, *B. pilularis*, and *B. sarothroides*) must be phytochemically very similar as other highly stenophagous species tested at the NAFS have had the same host range [e.g., *Prochoerodes truxaliata* (Guenee) reported by Palmer and Tilden (1987)]. *Itame varadaria* is considered to pose no threat to existing flora in Australia.

Of the four plant species acceptable to *I. varadaria* larvae in the laboratory, only *B. halimifolia* grows within the geographic range of this moth. Therefore, environmental factors unsuitable to *I. varadaria* probably explain why *B. neglecta*, *B. sarothroides*, and *B. pilularis* are not natural larval food plants. However, two other species, *B. glomeruliflora* Pers. and *B. angustifolia* Michx., which are closely related to *B. halimifolia* and *B. neglecta*, respectively, do occur within the insect's range and it would not be surprising if they are someday reported as food plants.

There was good agreement between the three feeding tests. Cut foliage experiments are the simplest in design and have the advantage that the insects are kept under maximum supervision. However the question is sometimes raised that the insects may respond differently on growing plants than on cut foliage. Similarly, while the insect can not become established on a plant species if neonate larvae cannot feed on it, there is sometimes concern, particularly with mobile species, that late instar larvae might move onto non-target plants. In this case there was no evidence that late instars had a broader food plant range. The technique of using neonate larvae exposed to cut foliage accurately determined the food plant range for this insect.

Although *I. varadaria* is not abundant in its native habitat, it has a number of useful characteristics that might make it an effective agent. It has a relatively short life cycle, is quite fecund, is easily reared in the laboratory, occurs in areas with similar climates to southeastern Queensland, and apparently has no diapause mechanism. Its success will probably depend on the predation rate in its new environment.

## RELEASE IN AUSTRALIA

Permission to release *I. varadaria* in Queensland was granted in December 1988 by the Australian Quarantine and Inspection Service and the Australian National Parks and Wildlife Service, which administer the Quarantine Act of 1908 and the Wildlife Protection Act of 1982, respectively. The insect was then moved out of quarantine facilities at the AFRS and a mass rearing program commenced.

It is anticipated that the first field releases will be made in spring of 1989. Moths will be released at a number of sites in southeast Queensland over the following twelve months. In some situations the moths will be released into cages covering *B. halimifolia* bushes to give some measure of protection against predators to the establishing colony.

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## LITERATURE CITED

DALY, H. V. 1985. Insect morphometrics. Ann. Rev. Entomol. 30:415–438.

FERGUSON, D. C. 1973. The identity of *Macaria inapta* Walker and *Itame varadaria* (Walker) (Geometridae). J. Lepid. Soc. 27:288–290.

PALMER, W. A. 1987. The phytophagous insect fauna associated with *Baccharis halimifolia* L. and *B. neglecta* Britton in Texas, Louisiana and northern Mexico. Proc. Entomol. Soc. Wash. 89:185–199.

PALMER, W. A. & F. D. BENNETT. 1988. The phytophagous insect fauna associated with *Baccharis halimifolia* L. in the eastern United States. Proc. Entomol. Soc. Wash. 90:216–228.

——— & J. W. TILDEN. 1987. Host specificity and biology of *Prochoerodes truxaliata* (Guenee) (Geometridae), a potential biocontrol agent for the rangeland weed *Baccharis halimifolia* L. in Australia. J. Lepid. Soc. 41:199–208.

STANLEY, T. D. & E. M. ROSS. 1986. Flora of southeastern Queensland. Vol. 2. Queensland Department of Primary Industries, Brisbane. Misc. Publ. QM84007. 623 pp.

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