Effects of host plant species on the development of *Dysdercus cingulatus* (Heteroptera: Pyrrhocoridae)

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(Received 7 May 2003; Accepted 11 November 2003)

Abstract

The survivability and the developmental rates of *Dysdercus cingulatus* when fed various cultivated and wild host plant species were compared in the laboratory. On this basis, *Chorisia speciosa* was regarded as a better-than-adequate host plant for *D. cingulatus*. *Abelmoschus moschatus*, *A. esculentus*, *Hibiscus makinoi*, *Thespesia populnea* and *Gossypium arboreum* were adequate, *H. tiliaceus* was relatively poor, and *Abutilon indicum* was very poor. Although *D. cingulatus* developed faster when fed cultivated species than when fed wild species, host plant properties such as the weight of seeds and habit (arboreal or herbaceous) could not explain the survivability and developmental rate of *D. cingulatus* when fed the different species. Estimations of a lower threshold temperature for the development of *D. cingulatus* nymphs fed with plant species except for *A. indicum* fell within a range of 0.5 degrees (13.9 to 14.4°C). However, the estimated total effective temperature for development varied so widely among food plant species that its value for *A. indicum* was more than twice that for *Ch. speciosa*. Developmental parameters obtained here may be applied to the design of control programs for *D. cingulatus* in cotton fields adjacent to or near vegetative stands containing alternative wild host plants.

Key words: *Dysdercus cingulatus*; Malvaceae; Bombacaceae; development; alternative host plant

INTRODUCTION

Cotton is the most economically important natural fiber material in the world. One of the major obstacles hindering cotton cultivation is insect pest infestations. In particular, the cotton stainers *Dysdercus* spp. (Heteroptera: Pyrrhocoridae) cause serious damage by feeding on developing cotton balls and ripe cotton seeds and transmitting fungi that develop on the immature lint and seeds (Maxwell-Lefroy, 1908; Freeman, 1947; Van Doesburg, 1968; Fuseini and Kumar, 1975; Iwata, 1975, 1978a; Ahmad and Kahn, 1980; Ahmad and Schaefer, 1987; Yasuda, 1992). These pests are difficult to control by insecticide application because they are highly mobile and have many alternative wild host plants (Iwata, 1975, 1978a, b). For the control of these pests in cotton fields it is therefore critical to elucidate their life cycle on alternative wild host plants.

Among various *Dysdercus* species, *D. cingulatus* (Fabricius) is the most serious pest species of cot-

ton and okra plants in Southeast Asia, and is also common on Ishigaki-jima Island, the southernmost of the Southwest Islands of Japan. There exist two subspecies of *D. cingulatus* in the world; *D. cingulatus cingulatus* (Fabricius), occurring in Southeast Asia, the Oriental Region and Australia, and *D. cingulatus nigriventris* Stehlik, 1965, endemic to the Solomon Islands (Ysabel Island) (Kerzhner, 2001). All the materials treated and discussed in this study belong to ssp. *cingulatus*. The following plant species are known to be host plant species of *D. cingulatus* on Ishigaki-jima Island (Kohno, 2001; Kohno, unpublished): *Abelmoschus moschatus* Medik., the okra plant *A. esculentus* Moench, *Hibiscus tiliaceus* L., *H. rosa-sinensis* L., *H. syriacus* L., *H. mutabilis* L., *H. makinoi* Jotani et Ohba, the kenaf plant *H. cannabinus* L., *Thespesia populnea* (L.), *Abutilon indicum* (L.), *Malvastrum coromandelianum* (L.) and the cotton plant *Gossypium arboreum* L.—all of which belong to the Malvaceae family—and *Chorisia speciosa* St. Hil. and *Bombax ceiba* L. of the Bombacaceae family.

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Among these host plants, okra is herbaceous and commercially cultivated, kenaf and cotton are also herbaceous and experimentally cultivated, and *H. rosa-sinensis*, *H. syriacus*, *H. mutabilis*, *Ch. speciosa* and *B. ceiba* are exotic arboreal ornamentals cultivated on the island. *H. tiliaceus* and *Th. populnea* are common arboreal species of the island's maritime forest and are in some instances cultivated ornamentally on the island. *H. makinoi* is a common arboreal species in and around the forest near the island mountains. *A. moschatus*, *A. indicum* and *M. coromandelianum* are common herbaceous species prevailing in the open lands of the island.

The overall purpose of this study was to elucidate the relationship between life history traits of *D. cingulatus*, the most serious cotton pest species among Asian *Dysdercus*, and its host plant species. We compared the survivability and the developmental rate of this species when fed the above-mentioned Malvales species in the laboratory. We also determined the developmental rates when reared with the various wild host plant species under various temperatures. This latter data may be especially useful in Southeast Asian cotton-producing countries for predicting the occurrence of *D. cingulatus* in cotton fields adjacent to or near vegetative stands containing these wild host plant species.

MATERIALS AND METHODS

Seeds of *Abelmoschus moschatus*, *A. esculentus*, *Hibiscus tiliaceus*, *H. makinoi*, *Thespesia populnea*, *Abutilon indicum*, *Gossypium arboreum* (Malvaceae) and *Chorisia speciosa* (Bombacaceae) collected on Ishigaki-jima Island were provided for the experiment as diet for *D. cingulatus*. All the plant species listed above are commonly used as host plant by *D. cingulatus* on Ishigaki-jima Island. Among the above listed species, *A. moschatus*, *H. tiliaceus*, *Th. populnea* and *A. indicum* are wild and widely distributed in tropical and subtropical Asia (Hatusima, 1975) and overlap with cotton cultivation areas to a considerable extent. The seed weights of the above-mentioned plant species were measured for 10 seeds to analyze the relationship between the seed weight and adequacy as a diet for *D. cingulatus*. The seed weights are substituted for seed size in the discussion.

Eggs of *D. cingulatus* for the experiments were obtained from females collected from fields on Ishigaki-jima Island and kept at room temperature (ca. 25°C) under natural photoperiods until oviposition. Within 24 h after oviposition the eggs were moved to conditions of 20.0, 22.5, 25.0, 27.5, or 30.0°C and 14L–10D photoperiod and kept in a plastic container (ca. 5 cm in diameter and 1 cm in depth) with moistened filter paper until molting to the second stadium nymphs. After that each nymph was kept singly in a plastic container and provided with water and one species of host plant seeds ad libitum. Nymphs were examined every day until adult emergence and the duration of each developmental stadium was calculated. Thirty-six hatchlings were examined for each temperature and food treatment.

RESULTS

The seed weights of all host plant species tested are shown in Table 1. The seeds of *Th. populnea* were the heaviest, more than seventy times the weight of the smallest seeds of *H. makinoi* and *A. indicum*. Cultivated species (*A. esculentus*, *G. arboreum* and *Ch. speciosa*) generally exhibited greater seed weights than wild species. However, the difference was not significant ($p > 0.1$ by Mann-Whitney's *U*). The difference in seed weight between arboreal species and herbaceous species examined was not significant ($p > 0.2$ by Mann-Whitney's *U*).

Survivability during total nymphal stadia of *D. cingulatus* when fed seeds of eight plant species (Fig. 1) differed significantly among the eight food species provided ($p < 0.001$ by Pearson's χ^2), but not among the five rearing temperature regimes ($p > 0.05$ by Pearson's χ^2). The survivability of *D. cingulatus* was very low when fed *A. indicum*, low when fed *H. tiliaceus*, and intermediate when fed *A. moschatus*. All the cultivated host plants exhibited relatively high survivability for *D. cingulatus*. The survivability of *D. cingulatus* when fed *H. makinoi* and *Th. populnea* (both wild species) was also high. However, differences in nymphal survivability could not be explained by the weight of host plant seeds ($p > 0.05$ by Kendall's τ), the status of host plant as wild or cultivated ($p > 0.1$ by Mann-Whitney's *U*), or the plant habit, whether arboreal or herbaceous ($p > 0.1$ by Mann-Whitney's *U*).

Table 1. Weight of host plant seeds examined

Plant species	Weight/seed (mg)	Wild/cultivated	Arboreal/herbaceous
Malvaceae			
<i>Abelmoschus moschatus</i>	10.6	wild in openland	herbaceous
<i>A. esculentus</i>	48.7	cultivated commercially	herbaceous
<i>Hibiscus tiliaceus</i>	10.7	wild in maritime beach forest	arboreal
<i>H. makinoi</i>	3.5	wild in and around forest near mountains	arboreal
<i>Thespesia populnea</i>	256.4	wild in maritime beach forest	arboreal
<i>Abutilon indicum</i>	3.5	wild in openland	herbaceous
<i>Gossypium arboreum</i>	56.1	cultivated experimentally	herbaceous
Bombacaceae			
<i>Chorisia speciosa</i>	88.7	cultivated ornamentally	arboreal

Fig. 1. Survivability during total nymphal stadia of *D. cingulatus* under five temperature regimes between 20.0 and 30.0°C and a 14L–10D photoperiod when fed seeds of eight plant species. Identical letters above columns indicate the values of survivability are not significantly different ($p > 0.05$; Tukey's method).

Total nymphal developmental periods of *D. cingulatus* when fed seeds of eight plant species (Fig. 2) differed significantly among the eight food species provided ($p < 0.001$ by ANOVA) for all rearing temperatures. In the rearing temperature regime of 25°C, the developmental period was very long when fed *A. indicum*, long when fed *H. tiliaceus*, short when fed *Ch. speciosa*, and intermediate when fed the other five species examined. The nymphal developmental period when fed wild host plant seeds was significantly longer than when fed cultivated host plant seeds (25°C; $p < 0.001$ by *t*-test). However, neither the weight of host plant seeds ($p > 0.1$ by Kendall's τ) nor the habit of the host plant ($p > 0.1$ by Mann-Whitney's *U*) explained differences in the nymphal developmental period (25°C).

Relatively good regressions were obtained be-

tween the developmental rate for nymphs and rearing temperatures for all food plant species (Table 2). The estimated lower threshold temperatures for development of nymphs varied from 13.3 to 14.4°C, and did not differ much among food plant species. However, estimated total effective temperature for the development of nymphs differed greatly among food plant species. The value for a diet of *A. indicum* was more than twice that for a diet of *Ch. speciosa*. The developmental rate for eggs also exhibited good regression to the rearing temperatures, $y = -0.214686 + 0.0136285t$ ($r^2 = 0.98$). The lower threshold temperature for development and the total effective temperature of eggs were estimated to be 15.8°C and 73.4 day-degrees, respectively. The lower threshold temperature for development of eggs was apparently higher than for nymphs.

Fig. 2. Nymphal developmental periods of successfully emergent *Dysdercus cingulatus* under five temperature regimes between 20.0 and 30.0°C and a 14L–10D photoperiod when fed seeds of eight plant species. Vertical columns indicate mean developmental periods of each nymphal stadium, and bars indicate 95% confidence intervals of means of total nymphal developmental periods. The number in each column is the number of successfully emergent insects. Identical letters above columns indicate the values for the total nymphal developmental period at 25°C are not significantly different ($p > 0.05$; Tukey-Kramer's HSD).

Table 2. Thermal requirements for nymphal development of *Dysdercus cingulatus* estimated from data for 20, 22.5, 25, 27.5 and 30°C and 14L–10D when fed seeds of eight plant species

Food species	Regression equation	r^2	Lower threshold temperature (°C)	Total effective temperature (day-degrees)
<i>Abelmoschus moschatus</i>	$v = -0.03632 + 0.002563t$	0.964	14.2	390.2
<i>A. esculentus</i>	$v = -0.03730 + 0.002661t$	0.957	14.0	375.8
<i>Hibiscus tiliaceus</i>	$v = -0.03037 + 0.002174t$	0.979	14.0	459.9
<i>H. makinoi</i>	$v = -0.03507 + 0.002501t$	0.959	14.0	399.8
<i>Thespesia populnea</i>	$v = -0.03628 + 0.002593t$	0.984	14.0	385.6
<i>Abutilon indicum</i> ^a	$v = -0.02076 + 0.001556t$	0.997	13.3	642.8
<i>Gossypium arboreum</i>	$v = -0.03950 + 0.002850t$	0.991	13.9	350.8
<i>Chorisia speciosa</i>	$v = -0.04704 + 0.003260t$	0.976	14.4	306.7

^a From data for 22.5, 25, 27.5 and 30°C.

The plant species that exhibited higher survivability also exhibits faster development, and vice versa ($p < 0.05$ by Kendall's τ between the survivability and the total effective temperature). This implies that survivability and developmental rate of *D. cingulatus* nymphs can be used as a measure of adequacy for the development of *D. cingulatus*. On this basis, *Ch. speciosa* was judged to be a better-than-adequate host plant for *D. cingulatus*. *A. moschatus*, *A. esculentus*, *H. makinoi*, *Th. populnea* and *G. arboreum* were adequate, *H. tiliaceus* was relatively poor, and *A. indicum* was very poor.

DISCUSSION

Among the wild plant species examined, *A. moschatus*, *H. makinoi* and *Th. populnea* are judged to be adequate host plants for *D. cingulatus*. Although *H. makinoi* is endemic to the Southwest Islands of Japan including Ishigaki-jima Island (Jotani and Ohba, 1984), *A. moschatus* and *Th. populnea* are widely distributed in Southeast Asian countries (Hatusima, 1975). Since the distribution of *D. cingulatus* overlaps with these two Southeast Asian wild Malvales which are adequate food for

D. cingulatus, it is possible that these two Malvales are primitive host plant species of *D. cingulatus*.

The estimated lower threshold temperature for the nymphal development of *D. cingulatus* did not differ greatly with different diets (Table 2). If the estimate when fed *A. indicum* is excluded from consideration (based on very scarce data), all the estimates fell within the range of 0.5 degrees (13.9 to 14.4°C). It can be concluded that differences in diet affect only the developmental rate above the lower threshold temperature. The lower threshold temperature of *D. cingulatus* is relatively high among heteropterous insects inhabiting Japan (Kiritani, 1997). This can be one of the limiting factors determining the northern limit of distribution of *D. cingulatus* at Okinoerabu-jima Island (Hayashi, 2002), since adequate wild host plants, *H. makinoi*, are distributed in the more northern areas (Jotani and Ohba, 1984). However, the photoperiodic reaction of *D. cingulatus* and the phenology of *H. makinoi* need to also be considered.

Among the wild plant species examined in this study, *A. moschatus*, *H. tiliaceus*, *Th. populnea* and *A. indicum* are widely distributed in tropical and subtropical Asia (Hatusima, 1975) and overlap cotton cultivation areas to a considerable extent. Developmental parameters obtained in this study may be applied to the design of control programs for *D. cingulatus* in cotton fields adjacent to or near vegetative stands containing these alternative wild host plants by monitoring or controlling *D. cingulatus* populations on the wild alternative host plants. The phenology of these alternative host plants in cotton cultivation areas should also be considered, as *D. cingulatus* is principally a seed feeder (Van Doesburg, 1968; Ahmad and Schaefer, 1987).

ACKNOWLEDGEMENTS

We thank two anonymous reviewers for valuable comments on earlier drafts of this paper.

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