Spectral Sensitivity of the Compound Eye of *Coccinella septempunctata* (Coleoptera: Coccinellidae)

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Ann. Entomol. Soc. Am. 83(4): 817–819 (1990)

ABSTRACT The spectral sensitivity of the compound eyes of three age groups of both sexes of *Coccinella septumpunctata* L. was measured electrophysiologically at wavelengths of 350–700 nm. Both sexes in each group show two peaks of sensitivity, one at 365 nm and a second at 500 nm. Female beetles were slightly more sensitive than male beetles, but the difference was not significant. Beetles 29–33 d old were significantly more sensitive than younger (16–24 d) or older (38–42 d) beetles.

KEY WORDS Insecta, *Coccinella septempunctata*, spectral sensitivity, vision

Coccinella septempunctata (L.) is a European predator on several species of aphids and is now established in the eastern and central parts of North America (Schaeffer et al. 1987). This study on the beetle's visual sensitivity was done to determine what colors they could detect that may be important in mating, food selection, and host plant detection.

Materials and Methods

The anatomy, number of lenses per eye, and organization of the compound eye was determined from KOH-treated head capsules and thin-sliced longitudinal and cross sections of eyes examined at 25–400×. The instrumentation and electroretinogram (ERG) techniques have been described (Agee & Park 1975, Agee & Patterson 1983, Agee 1986). The beetles were immobilized on a block of wax (Tackiwax, Chicago) (0.5 cm diameter) by placing miniature staples over the body. The legs were removed to prevent movement. The eye being tested (containing the recording electrode) was oriented in the center of the stimulating light beam and the other eye (containing the indifferent electrode) was positioned in the dark, unilluminated shadow. The compound eye was illuminated with monochromatic light at selected wavelengths from 350 to 700 nm. A stainless steel recording microelectrode was inserted into the dorsal midline of the illuminated eye to a depth of 45–55 μm, and the indifferent electrode was positioned in a similar position in the unilluminated eye (Fig. 1). The beetles were held in a lightproof, electrically shielded chamber until the eyes were fully dark-adapted (usually >60 min) before the eye response to light stimuli was tested.

Silver leads from the electrodes were connected to the input of a biological amplifier (Grass P-15) and the output of the stimulus monitor and electrophysiological response were displayed on a dual beam oscilloscope (Tektronix 5115). The light pulses (200 ms duration) were delivered at a rate of 6/s. Light stimuli were controlled by an electromagnetic shutter driven by a stimulator (Grass S-44). The monochromatic light stimuli were generated by a tungsten-iodine lamp and an UV-visible monochromator (Bausch and Lomb). The light stimuli were measured with a calibrated thermopile traceable to the National Bureau of Standards. The ERG criterion "on" response used in these tests was 200 mV at the stimulated eye to a 200-ms light stimulus. Ten males and 10 females from three age groups (16–24, 29–33, and 38–42 d) were tested for visual sensitivity. Results were analyzed with the Mann-Whitney *U* test (Sokal & Rohlf 1969).

The percentage of incident light reflected at wavelengths from 300 to 850 nm was measured using a Varian 634S spectrophotometer with a reflectance attachment. This measurement was done to determine the major reflected wavelengths that might be important in visual detection by other beetles. The elytra were removed from a living beetle and attached to a 2-cm^2 slide, making a complete block of color that was measured by the spectrophotometer.

The *C. septempunctata* used in this study were reared at the Biological Control Laboratory, USDA, APHIS–PPQ, Niles, Mich. The beetles were held in a greenhouse under natural light in cages (20 by 20 by 20 cm) and were provided a liver-based diet and water until they were tested.

Results and Discussion

The eye of *C. septempunctata* is an oval hemisphere in anterior-to-posterior orientation and comprises approximately 1,100 hexagonal and some

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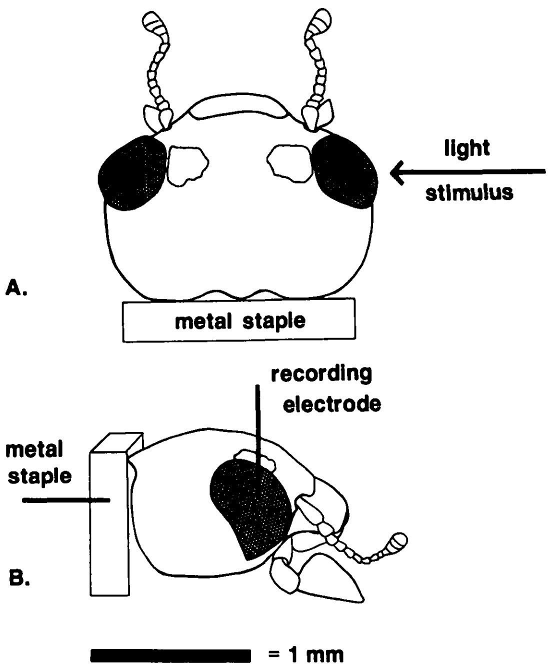

Fig. 1. (A) Diagrammatic dorsal view of restrained head of *C. septempunctata* showing the position of the compound eye as it is oriented to the light stimulus. (B) Diagrammatic lateral view of the restrained head capsule and compound eye in relation to the position of the recording electrode. Calibration bar, 1 mm in both illustrations.

modified hexagonal (nearly square) lenses and associated ommatidia (Fig. 1). A typical lens is 18–20 μm in diameter and 25–28 nm long with a hemispherical base where the lens meets the Semper cells, which are distal to the retinula cells (Holmes 1975). The external surface of the lens is flat with a slight depression where one lens contacts its neighbor. Short spines at the junctions of the lens edges are spaced about every 3–4 lenses. The

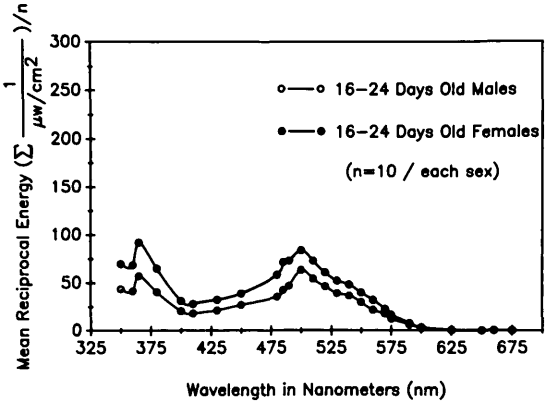

Fig. 2. Mean spectral sensitivity curve for 29-33-d-old male and female (n = 10) laboratory-reared *C. septempunctata* to light stimuli at wavelengths from 350 to 700 nm.

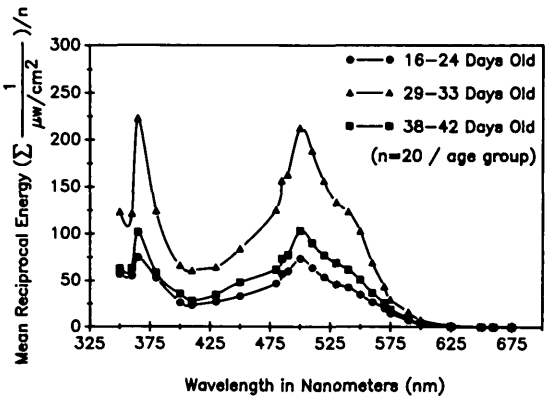

Fig. 3. Mean spectral sensitivity curve for combined male and female (n = 20) laboratory-reared *C. septempunctata* for three age groups to light stimuli at wavelengths from 350 to 700 nm.

retinula cells are surrounded by dark pigment cells that extend from the base of the lens to approximately two-thirds the distance to the base of the retinula cells (about 80 μm long). The ommatidium from the surface of the lens to the basement membrane is 120–130 μm long.

The maximal visual sensitivity of the eye occurred after the insect was held in the dark >60 min. The long dark-adaptation time for a day-flying insect is caused probably by the movement of screening pigments away from the retinula cells and the movement of the retinula cells to a more central position in the dark-adapted eye (Holmes 1975, Horridge & Giddings 1971). Another diurnal coleopteran, *Diabrotica longicornis barberia* Smith & Lawrence, required only 30 min to adapt fully to the dark (Agee et al. 1983).

The compound eye of the male and female has two peaks in the spectral sensitivity curve, one at 365 nm and a second at 500 nm. All age groups had similarly shaped curves, as did both sexes (Fig. 2). The mean sensitivity of females was consistently greater than the males in each age group; however, the difference was not statistically significant in any age group (Mann-Whitney U test; Sokal & Rohlf 1969). Both sexes of the 29–33 d age group were more sensitive at 365 and 500 nm than were age groups 16–24 d or 38–42 d ($P < 0.025$) (Fig. 3).

The finding that spectral sensitivity continued to increase for such a long period was unexpected. H.R.A. has measured the visual sensitivity of >30 species of Diptera and Lepidoptera and found that it ceases to increase 3–4 d after eclosion. Also, this is the first species found that continued to increase in visual sensitivity for 29–33 d after emergence unless there was a nutritional impairment such as was identified in the boll weevil, *Anthonomus grandis* Boheman (Agee 1986). Under ideal conditions, the visual sensitivity of field-collected *C. septempunctata* would be compared with laboratory-reared specimens; however, only laboratory-reared beetles were available for this study.

We conclude that ultraviolet (365 nm) and green (500 nm) visual stimuli are the most important wavelengths in the behavior of this insect. The spectral reflectance of the elytra reflects most effectively in the 600–850 nm range (17–30%, respectively). Therefore, it is unlikely that elytral color is important to this beetle because the eye has such a low visual sensitivity to wavelengths reflected by the elytra. However, the contrast of the black dots on the red background on the elytra may be important in species recognition.

Acknowledgment

We thank Scott Yocom for technical assistance.

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Received for publication 20 December 1988; accepted 26 February 1990.