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Naive *Fopius arisanus* females respond mainly to achromatic cues

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Abstract

Parasitoids rely on a variety of visual and olfactory cues to locate exploitable resources. Their perception of colors is based on achromatic and chromatic information, though very few studies clearly distinguish the influence of both. We present here the results of field-cage experiments about the color perception of *Fopius arisanus* (Hymenoptera: Braconidae: Opiinae), an egg-pupal parasitoid of various fruit fly species (Diptera: Tephritidae). The tested insects were naive, fed and mated females. In all experiments, the wasps preferred the colors with the lower total reflectance in a spectrum of wavelengths above 450–500 nm. We conclude that *F. arisanus* females are not sensitive to the UV–blue part of the spectrum. Inversely we could not provide evidence that they are able of any hue discrimination, though the absence of response might indicate a lack of preference of naive females. Visual stimuli are predominant for *F. arisanus* females in close range landing site selection and even overrode the olfactory stimuli. The lack of innate preferences for chromatic cues is consistent with previous observations made on the specificity and the olfactory response of *F. arisanus* and may be related to the low innate specialization of this parasitoid. Its preference for dark colors matches the behavior of some polyphagous Tephritidae. It may reflect an innate attraction towards contrasted objects, as fruits appear within the foliage.

Keywords: Color perception; Achromatic contrast; Reflectance; Hue; Opiine parasitoid

1. Introduction

Parasitoids rely on a large array of cues to locate resources which are indispensable for their survival and reproduction. These resources include food, shelters, mates and oviposition sites. Previous studies of parasitoid perception were largely concentrated on elicitation by chemical cues while visual stimuli received far less attention. The latter have yet been shown to be a major information source for parasitoids. They may for example be associated either to host or food when these two resources are spatially separated, making the parasitoid's response dependent on its feeding state (Wäckers, 1994). Moreover, some parasitoids have been reported to learn associatively these visual cues and therefore modify their behavior according to their experience (Wäckers and Lewis, 1994). The response to color is therefore an essential factor of parasitoid's foraging behavior, and thus a key feature in a biological control program.

Colors may be defined by their hue (the main reflected wavelength) and their reflectance (percent of light reflected). As a result, the response of the insect to a given color may be triggered by chromatic (true color vision) or achromatic cues. Peitsch et al. (1992) and Chittka et al. (1993) demonstrated that most apocritan Hymenoptera show a maximal sensitivity in the UV, blue and green parts of the wavelength spectrum, though the sensitivity of photoreceptors appears variable among species. In some cases, a chromatic distinction by parasitoids has been suggested (Fischer et al., 2003a), but often this perception could not be clearly separated from the effect of achromatic cues (Messing and Jang, 1992; Schmidt et al., 1993). Indeed, the perception of contrast is known to be fundamental for the Hymenoptera: this has been mainly investigated for pollinators (Giurfa and Lehrer, 2001; Menzel and Schmida, 1993), but also for parasitoids (Fischer et al., 2003b).

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However, for this latter group, very few studies have been published up to now.

Fopius arisanus (Sonan) (Hymenoptera: Braconidae) is an egg-pupal parasitoid of fruit flies (Diptera: Tephritidae) which was introduced in Hawaii in 1946 to control populations of *Ceratitis capitata* (Wiedemann) and *Bactrocera dorsalis* (Hendel). It was later introduced in various other parts of the world (Rousse et al., 2005). Following its introduction in La Réunion Island in 2003, we conducted studies on its specificity (Rousse et al., 2006) and its response to host and host habitat infochemicals (Rousse et al., 2007). Here are presented our results on the response of naive *F. arisanus* females to colors, to document any innate use of chromatic and/or achromatic cues by this parasitoid. These different studies aim to characterize the innate behavior of one of the most effective biological control agent used against fruit flies pests in tropical areas. The knowledge of this behavior in laboratory helps us to assess its extent in the field, defining its optimal environment and thus predicting its natural distribution post-release.

2. Materials and methods

2.1. Insects

A colony of *F. arisanus* had been established in December 2003 in the Entomology Laboratory of the CIRAD Réunion from a batch of parasitized pupae of *B. dorsalis* obtained from USDA-ARS Hawaii (E.J. Harris). Emerging adults were subsequently offered *B. zonata* eggs for female oviposition. The main colony has been reared for 26 generations in a $110 \times 60 \times 60$ cm plastic screened cage at 25 ± 2 °C, $70 \pm 20\%$ RH and 12L: 12D. The adults were given free access to water on a moistened sponge and to a mixture of honey/agar 15 % (1:1).

2.2. General procedure

All experiments were carried out in field cages (2.5 m high $\times$ 3 m diameter, Synthetic Industries, Gainesville, USA). Three potted and fruitless mango trees (height 1.5–2 m) were placed on one side of the cage, behind a metallic rod placed 1.5 m above ground. The rod was placed perpendicularly to the axis given by the sun direction. The observer sat in front of the rod, with the sun on his back. The targets proposed to the parasitoids were hung on the rod at regular distances. Two hundred females of *F. arisanus* (naive, 6–10d old) were released in the cage 15 mn before the start of the experiment, i.e., before hanging the targets. Each experiment lasted 36 m. Every 3 m, the observer recorded the number of wasps that had landed on each target and removed them from the experiment. Every 9 m, the position of targets along the rod was randomly permuted to minimize any potential position effect. Each experiment was replicated three times.

2.3. Colored targets

The targets were plastic balls (6 cm diameter) or traps (Tephritrap®, Sorygar, Spain) painted with two layers of spray or classical paint (Mauvilac Industries Ltd., Les Pailles, Mauritius). The reflectance of the targets was measured on a 350–650 wavelength spectrum with a FieldSpec Full Range spectroradiometer (Analytical Spectral Devices, Boulder, CO, USA) calibrated by a blank reference. The spectral sensitivity of photoreceptors of *F. arisanus* is unknown but this range contains the peaks of sensitivity reported for Hymenoptera by Peitsch et al. (1992).

2.4. Color preferences

In this first experiment, we exposed a panel of different colors to *F. arisanus* females to distinguish any potential visual discrimination. The six offered colors were white, yellow, red, blue, dark green and black. They were chosen to represent a large panel of distinct hues and reflectance spread along the analyzed spectral range. The spectral characteristics of these colors are shown in Fig. 1.

2.5. Reflectance preferences

Three experiments were carried out to determine the response of *F. arisanus* females to a gradient of light reflectance without any hue differences. In the first one, black and white paints were combined at ratios B1:W0, B2:W1, B1:W1, B1:W2 and B0:W1 to obtain a scale of grey shades (Fig. 2a). In the second and third ones, we combined respectively blue and green paints with black or white paints to obtain a scale of reflectances for these two hues. These hues were chosen to correspond to two areas of high visual sensitivity frequently present in Hymenoptera (Peitsch et al., 1992). Each of these scales was composed by three painted spheres: the unmodified paint, the paint to which was added a same volume of white paint and the paint to which was added half of the same volume of black paint (Fig. 2b and c).

2.6. Hue preferences

Are females of *F. arisanus* able to discriminate between two distinct hues regardless of the reflectance? We used three different pairs of blue and green spheres of varying relative reflectance to determine if the parasitoid females responded first to chromatic or achromatic information. The first pair (light blue/dark green, Fig. 3a) offered an achromatic contrast in the whole spectrum. The second pair (medium blue/medium green, Fig. 3b) offered an achromatic contrast up to 500–550 nm and similar reflectances above this area. The third pair (dark blue/light green, Fig. 3c) offered an achromatic contrast above 500 nm and similar reflectances below.