

THE VISUAL WORLD OF THE COLORADO POTATO BEETLE

L.J. van der Ent¹ and J.H. Visser²

¹Department of Entomology, Wageningen Agricultural University, P.O. Box 8031, 6700 EH Wageningen, The Netherlands;

²Research Institute for Plant Protection (IPO), P.O. Box 9060, 6700 GW Wageningen, The Netherlands.

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Summary. The visual capabilities of the Colorado potato beetle were studied. A locomotion compensator was used to record behavioural responses. The beetles were highly attracted by a yellow paper stripe compared to a grey field. Individual objects were discriminated by Colorado potato beetles on their size and larger ones are preferred. Resolving power of Colorado potato beetles was about 2°. Field crops of 30 cms high can be detected by the beetle at eight meters or less. The beetles made no choice between two equally-sized stimuli until the stimuli became separated more than 90° apart. The orientation based upon visual discrimination of plant characteristics on a distance will increase the probability of host-plant finding by the beetle.

INTRODUCTION

Human beings do have a well developed visual system which is important to cope with every day life. The present question is how insects depend on vision. The Colorado potato beetle *Leptinotarsa decemlineata* Say, a pest species on potatoes, is able to locate food as well as conspecifics for vital processes such as growth and reproduction. At present it is difficult for us human beings to understand how the beetle's perceptual world is like during host-plant finding. For this reason we studied several aspects of the visual world of the Colorado potato beetle.

MATERIAL AND METHODS

Beetles

Newly-emerged female Colorado potato beetles were obtained from the laboratory stock culture and isolated in petri dishes lined with wet filter paper. Prior to the experiments the beetles were fed for four hours on pieces of potato leaves and subsequently starved for at least 16 hours. At the time of the experiments all females were about one day old. The

beetles were reared and tested under long-day (16/8) light conditions.

Locomotion compensator

The experiments were conducted on a locomotion compensator as described previously (Thiery & Visser, 1986). Light intensity was set at 1300 Lux by means of two high-frequency illumination units (1750Hz). A white paper arena (diameter of 48 cms, height of 24 cms) was placed around the top of the locomotion compensator and visual objects were attached at the inside wall. Yellow ochre paper was used as a stimulus because of its attractiveness to the beetles. After each test the stimulus was moved +90° to abandon effects of orientation other than visual. Behavioural responses of the beetles were studied by recording their walking tracks on the locomotion compensator for successive treatments. Mann-Whitney *U* tests (two-tailed) are used for making statistical analyses (Siegel, 1956).

RESULTS AND DISCUSSION

Color vision

In preliminary experiments, it has been found that Colorado potato beetles were attracted by grey and black objects displayed on a white background. In the next experiment color attraction of Colorado potato beetles, *i.e.* spectral sensitivity in competition with contrast sensitivity, was examined. Two equal bright stimuli in terms of photographic contrast, a color neutral one (grey) and the yellow ochre paper, were matched. Results are shown in figure 1.

No significant decrease in directional response was found for beetles exposed to a yellow ochre stripe on a background being grey instead of white. The cosine of the walking direction was found to be significantly decreased ($P < 0.0001$) for beetles walking to a grey field in absence of the yellow stripe. In this latter treatment the beetles showed orientation towards the edges of the grey field which caused the distribution of orientation angles show a dip at 0° (fig.1).

From these results it is obvious that Colorado potato beetles are attracted by color rather than by contrast. Spectral sensitivity of Colorado potato beetles has previously been examined by measuring ERG-potentials (Mischke, 1981). Two maxima in responses were found at 360 nm (ultraviolet) and 510 nm (green). Stüben (1972) showed that Colorado potato beetles were able to distinguish between colors of the same light-intensity and preferred yellow. It is likely that color vision assists Colorado potato beetles in finding their host plants.

Resolving power

The size of an object at a certain distance or the distance to an object of a certain size determines the ability of Colorado potato beetles to perceive the visual information. The dimensions of a visual stimulus are characterized by the angle of perception of the object by the beetle's

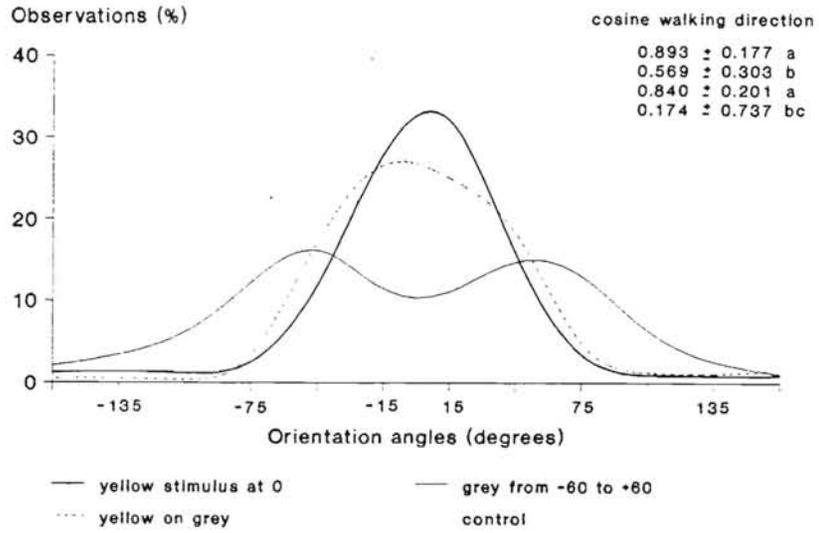


Fig. 1. Orientation of 20 beetles in 10 minutes each to: (1) yellow stripe at 0°, (2) grey field covering -60° to +60°, (3) yellow stripe on grey field, and (4) control. Seconds spent at orientation angles as % observations. Cosines of directions (mean and SD) from top downwards: experiments (1)-(4). Different letters indicate $P \leq 0.05$.

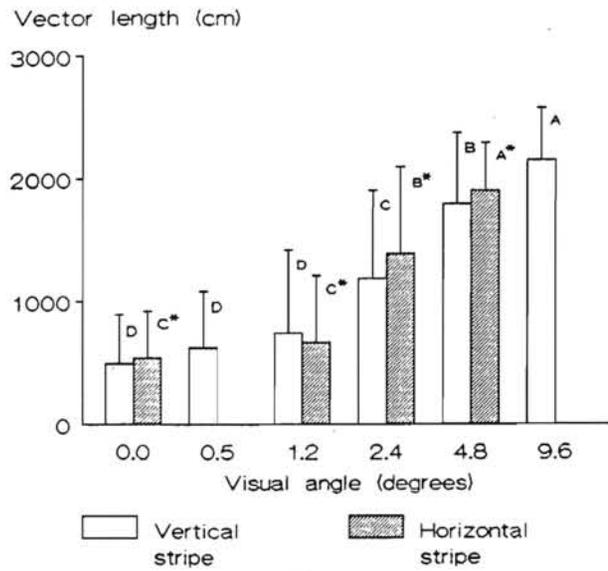


Fig. 2. Displacement from the origin (vector length) of 20 beetles in 5 minutes each to yellow stripes. Dimensions of stripes are expressed as visual angles in the beetle's eye. SDs shown half. Different letters indicate $P \leq 0.05$.

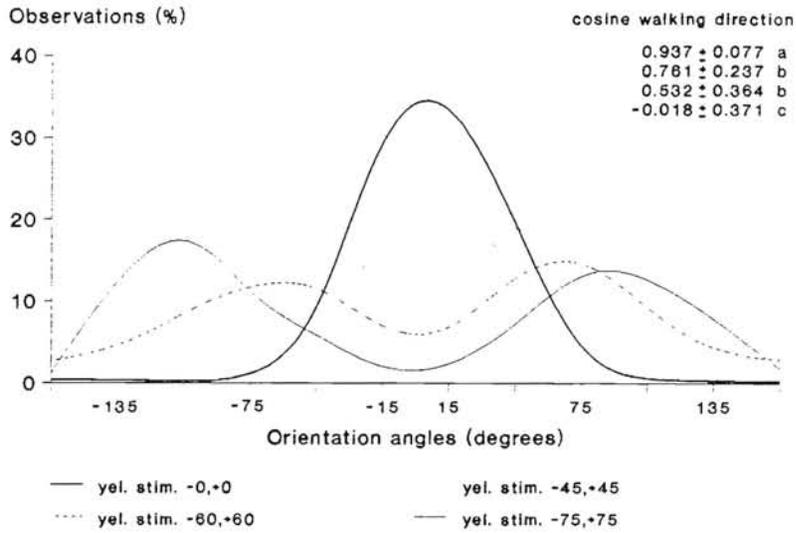


Fig. 3. Orientation of 20 beetles to 2 yellow stripes. Position of stripes: (1) -0/+0, (2) -45/+45, (3) -60/+60, and (4) -75/+75. Cosines of walking directions (mean and SD) from top downwards: experiments (1)-(4). See further fig. 1.

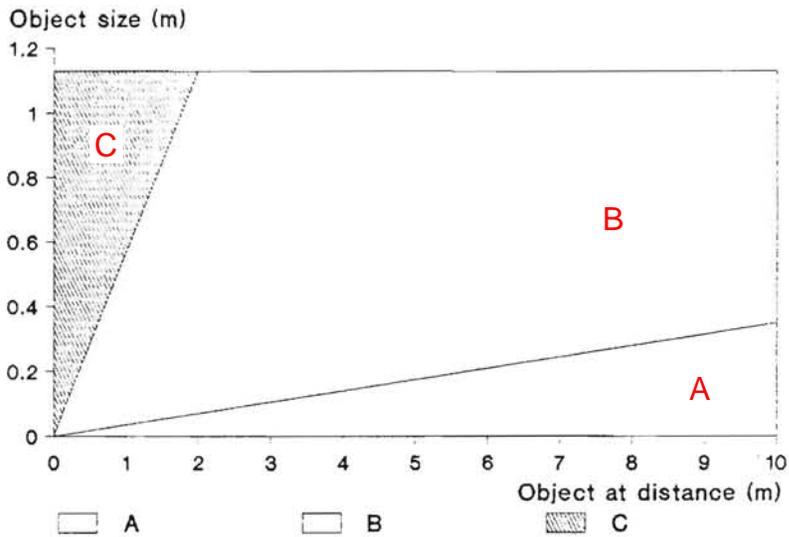


Fig. 4. Depending on the size of an object and the distance: (A) object is too small for perception by the beetle, (B) perception and discrimination in size are possible, and (C) perception is possible, discrimination in size is not possible.

compound eye. The minimum angle of perception to evoke a directional response, which thus is related to the minimum size of an object at a certain distance, is called resolving power. The resolving power of Colorado potato beetles was examined by displaying vertically or horizontally a yellow ochre stripe and decreasing the size of the stripe in successive treatments. Results are shown in figure 2.

The smaller the object the more difficulties the beetles encountered to respond to that stimulus. When the vertical or horizontal dimensions of the yellow ochre stripe became 1.2° or less the objects became too small for perception by the beetles. In this case the net displacement was not significantly different from the control.

The resolving power of Colorado potato beetles appeared to be about 2° . This value has been found for several other insects as well, for example *Musca* (Kirschfeld, 1973) and *Lymantria dispar* (Preiss & Kramer, 1984).

Visual interference

In field situations Colorado potato beetles are usually confronted with more than one object. The beetles do have to make choices. Competition between two unequally-sized stimuli resulted in preference for the largest stimulus (unpubl., L.J. van der Ent). In the present experiment two equally-sized yellow ochre stimuli were given and the distance between these objects was enlarged in successive treatments. Results are shown in figure 3.

On enlarging the distance between both stimuli Colorado potato beetles were observed to walk zigzag instead of rectilinear. Obviously, the beetles were switching between both yellow ochre stripes for direction keeping, especially when both stimuli were displayed at -45° and $+45^\circ$. The directional response at this latter treatment was significantly lower compared to the $\pm 0^\circ$ and $\pm 15^\circ$ treatments ($P=0.0036$ and $P=0.0008$, respectively). The cosines of orientation angles at the $\pm 15^\circ$ and $\pm 30^\circ$ treatments were not statistically different from the $\pm 0^\circ$ treatment. In the two last treatments the beetles showed attraction to one stimulus at the time. Half of the beetles walked to the stimulus displayed left and the other half to the stimulus at the right side. The distribution of orientation angles, thus, showed a dip at 0° (fig.3). In the absence of stimuli, the control experiment, the cosine of the orientation angle was -0.052 ± 0.694 (mean and SD).

This so called 'moment of decision' at 90° distance is also reported for the Gypsy moth *Lymantria dispar* (Preiss & Kramer, 1984). However in their experiment Gypsy moths were exposed to a single stripe or field. Exposure of the beetles to a grey field covering -60° to $+60^\circ$ (fig.1) or yellow stimuli exposed at -60° and $+60^\circ$ (fig.3) resulted in similar distributions of orientation angles.

Host-plant finding

In the present research Colorado potato beetles were able to discriminate a yellow stripe from a grey background. The beetles responded to a single

object if the angle of perception of such object was at least 2°. The minimum angle of perception to discriminate between two equally-sized objects appeared to be 90°. Figure 4 illustrates further the visual capabilities of Colorado potato beetles. From the data in figure 2, it is calculated that a 30 cms-high potato crop, can be seen by the beetle at 8 meters distance or less. However, it should be realized that laboratory conditions differ from the outside world and, thus, may have affected the visual perception as recorded in the present study. On the other hand, field-reared beetles do have more sensitive eyes (unpubl., J.H. Visser). Moreover, the spatial distribution of food resources will be more complex than assumed in the present research. In addition to visual orientation, olfactory stimuli are perceived by the beetles (Thiery & Visser, 1986). The interplay of both sensory modalities will affect host-plant finding in complex and yet unknown ways. Nevertheless, it is obvious that Colorado potato beetles are capable to perceive the surrounding world and on perception of visual characteristics increase their probability of encountering host-plants.

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ERRATUM

Bad printing caused lines in Figures 1 and 3 to disappear. Therefore Figure 1 (top) and Figure 3 (bottom) are duplicated.

