1974

A Brief Summary of Insects's Vision and Their Response to Light

Tim Matthews
Ouachita Baptist University

A BRIEF SUMMARY OF INSECTS'S VISION

AND THEIR RESPONSE TO LIGHT

SUBMITTED BY: Tim Matthews

TO: Dr. Joe Jeffers

March 23, 1974

A BRIEF SUMMARY OF INSECTS'S VISSION AND THEIR RESPONSE TO LIGHT

Insects have been studied and observed since man first walked this earth. Man's first observation was that some insects were quite palatable. One of Christ's contemporary's, John the Baptist, maintained a diet which consisted of "honey and locusts". The spittings of another insect provided nourishment for the Children of Israel during the Exodus. Even today insects are of primary importance in the ecology. It is only a small minority of the insect population that are nuisances. The vast majority of the insect population is not only beneficial to man but also to the rest of the animal kingdom and to a great degree, the plant kingdom.

One of the insects' most notable characteristics is their attraction to light. Even the most disinterrested and unobservant person has noticed, at one time or another, the swarms of moths around a street light or the mosquitoes around a campfire. This fascinating reaction of insects will be explored in this paper. Although much work has been done by such notable entomologists as R. F. Chapman, Raimon L. Beard, and John Buch, there remains a great deal to be disclosed regarding insects actions and reactions.

An insect can detect light in two possible ways: (1) specialized (light sensitive) epidermal cells, and (2) the compound eye. The response illicited from the insect due to stimulation of the epidermal cells is said to be a photochemical reaction. Some entomologists claim that this reaction is due simply to a heat response within the cell.[1] Kenneth Roeder claims that response of insects to light due to stimulation of specialized epidermal cells is negligible compared to the unit reaction of their compound eyes.[2] The compound eye seems to be the center of the insects response to light.

The compound eye is composed of many ommatidia with a retinal nerve cell at the base of each. The external portion of each ommatidium is termed a facet. The more facets the more acute the vision. For example, the common housefly has 4,000 facets in its compound eye as compared to 10,000 to 20,000 facets in an eye of the dragonfly.[3] Each ommatidium is composed of two parts (1) the distal and (2) the proximal. The distal portion is the external portion of the compound eye and regulates the reception of light into the ommatidium.[4] Frequently the distal portion of the eye is termed the dioptic apparatus. It is within the dioptic apparatus that the crystalline cone is located.

In 1920, Von Hess posed the question of whether the crystalline cone simply transmitted the light to the retinal cells or if the crystalline cone refracted the light to the necessary stimulant wavelenghts.[5] Fourteen years later Lutz and Grieswood, using two species of insects (<u>Apis</u> and <u>Sarcophaga</u>), gave Hess the answer; the crystalline cone did not refract the light but simply transmitted the necessary wavelengths to the retinula.[6] The retinula consists of seven to eight retinal cells; each cell contains a rhabdomere, which is the special sensory cell located on the central edge of the optic rod.

Because of the structure of the insect's compound eye, his vision is in the form of a mosaic. The brain receives many small images; the number of images depending on the number of ommatidia. The more ommatidia the more acute the vision. This structure of the compound eye makes the insects exceedingly sensitive to movement.[7]

In 1953, Kenneth Roeder set up an experiment to determine what causes the varying responses to stimuli within a species. His results showed that "under constant stimulation the eye becomes adapted so that the animal as a whole may no longer respond to illumination, and an increase in intensity is required to cause recurrence of a response."[8] In 1972, Raimon Beard set forth his impressive but none the less unstable theory that "DNA may be the sensitive target in some systems but may or may not be in others."[9] Beard's experiment was initially a follow-up on an experiment done by three Russian entomologists in 1971. Their results showed that both red light and white light stimulated growth, with the probability that the red light activated RNA and possibly protein synthesis.[10]

In 1972, Robert DeVoe, using intracellular recordings from visual cells in the principle and secondary eyes of the wolf spider, reported that responses of all cells to all wavelengths were graded depolarizations.[11] Obviously there are several theories regarding the actual reaction of the insect to stimuli. As expected, the reactions are not constant but variable due to differences between species, differences between sex, and the particular stage within the life cycle of the insect.

Regarding the reaction of various insects to different wave-lengths, innumerable experiments have been done. One of the most impressive experiments was done by H. Weiss in 1944. He exposed approximately 15,00 insects representing 40 species to 10 wave-lengths of equal intensities ranging from 3650 Å-7400 Å. His results showed that the "stimulating efficiency increases only slightly from 0 (no response) at 7200 Å-5750 Å, and then rises to a maximum at 4920 A.[12] In more specific experiments using the species Drosophila he observed two maximum sensitivities, one at 4870 Å (in the blue-green region) and the other at 3650 Å (in the ultra-violet region). The ultraviolet being 5.5 times more effective.[13] The species Apis also showed two maxima- at 5530 Å (yellow-green) and 3650 Å.

From these results and others it is apparent that there are usually two maxima-one in the near infrared and the stronger in the ultraviolet. D. P. Velton and R. W. Fay confirmed this reaction in 1972 showing that the Anopheles stephansi followed the theorized pattern exactly.[14] This seems to be characteristic of most insects. Respones have been illicited from wave-lengths as low as 2537 Å and as long as 9,000 Å. Most insects are comparatively sensitive to the red end of the spectrum but seldom react beyond 6,900 Å.[15]

Although nuch has been said regarding the reactions of insects to various wavelengths of light, little has been said of the other factors that play part in their responses. Among the numerous influencing factors are wind, temperature, intensity, time, stage in life cycle, sex, and species. Although earlier there had been much debate over whether or not these factors actually influenced thier responces to light, it is now commonly accepted that they do.

The most important of these factors is the intensity. In general terms the greater the intensity-the more distinct the response. In 1972, Barrett made a mathematical attempt to relate the number of insects attracted with the intensity of the light. Using a light in the near ultraviolet region, he proposed the relation that the catch index was approximately equal to 4 times the milliwatt power raised to 0.4 power.[16] Since the response increases as the intensity increases, it follows that if the intensity is adjusted it should be possible to illicit a similar response using a less reactive wavelength. A confirmation experiment was done on this hypothesis by the entomologists Graham and Hartline using the electrical response of a single visual cell, and it proved sucessful.[17]

The effect of the time on the response to light is almost insignificant. For a length of exposure less than 0.6 seconds, the response depends on intensity and wavelength alone.[18] The Anopheles gambiae usually experience a peak of activity when the light source is first turned off. However, they also experience a peak of activity at light on, if it is abrupt. According to entomologists M. D. Jones, C. M. Cubbin, and D. Marsh there is no activity peak if the intensity changes during a longer period of time.[19]

The effect of temperature on light responses seems to be greater than those of wind and time. If the temperature is lowered significantly from the standard for a particular species, its reaction to light is depressed. However, in 1970, Bert Pearson noted in his experiments on captured moths that if the temperature was raised the moths reacted to more intense light values.[20] In an earlier experiment (1969), Pearson noted that light which was the controlling activity factor varied according to the season. In the summer, light was the controlling factor; but in the autumn, temperature acted as a strong depressant. C. P. Srivastana and S. L. Petri of India also showed similar experimental results in 1971.[21]

Wind has only a slight effect on behavioral responses to light. Most insects will react to light even if in an air current, although frequently the air current will have a depressing affect on their response to light. A female moth (Rhyaceonia buoliana) shows the more common reaction-that of favoring more intense light regardless of the air steam intensity.[22]

Regarding the variance of the reactive intensity between different species, there is one classic example as shown in Yoshihiko Chiba's experiments in Japan. His experiments in 1971, involved six species of mosquitoes. The results of the experiments showed that "there exists specific light intensities for the spontaneous activity of each species and this causes the species to exhibit a specific activity pattern."[23]

In summary, insects generally tend to show the strongest reaction to ultraviolet light. Another peak of activity is usually shown in the infrared. Their responses are, of course, affected to some degree by the intensity, temperature, hunidity, and air currents.

The conclusion to this research will be an experimental attempt to confirm the insects strong reaction to ultraviolet light.

FOOTNOTES

1. Roeder, Kenneth D., editor; Insect Physiology (Chapman & Hall, Lmt., London; 1953), page 485.

2. Ibid, page 488.

3. Encyclopedia Britanicca; "Insects" (Volume 12, 1969), page 287.

4. Roeder, Kenneth, editor; Insect Physiology (Chapman & Hall, Lmt., London; 1953), page 824.

5. Hess, C. Von; "Color discrimination, bees", Naturiuessen-schaften(Volume 8), pages 927-929.

6. Lutz, F. E. and E. N. Griesweed; "Reactions to 2537 Å radiation, Drosophila", American Museum Novitates, 706, 1-14, 1934.

7. Snyder, Allan W. and Colin Pash; "Detection of Polarization & Direction by the Rhabdom", J Comp Physiol, 78 (4): 346-355, 1972.

8. Roeder, page 489.

9. Beard, Raimon L., "Lethal action of UV irradiation on insects", J Econ Entomol, 65 (3): 650-654, 1972.

10. Demkiv, O. T., R. T. Repels'Kyi, and Y. D. Fedyk, "Effect of light of various wavelengths on the morphology and physiology of the protonema of Funaria hygromethica Hedw, Ukr Bot Zh, 28 (3): 309-312, 1971.

11. DeVoe, Robert D.; "Dual sensitivities of cells in wolf spider eyes at UV and visible wavelengths of light", J Gen Physiol, 59 (3): 297-269, 1972.

12. Weiss, H. B.; "Color perception", Journ Econ Entomol, 36, 1-17, 1943.

13. Ibid, pp. 1-17.

14. Wilton, D. P. and R. W. Fay; "Response of adult Anopheles stephense to light of various wavelengths", J. Med. Entomol. 9 (4): 301-304, 1972.

15. Klots, A. and Klots E.; Living Insects of the World (Dodd, Mead & Co., New York, 1966), p. 437.

16. Barret, J. R., Jr.; "Functional association of light trap catches to emission of black light fluorescent lamps", Environ Entomol, 1 (3): 285-290, 1972.

17. Graham, C. H. and H. K. Hartline; "Spectral response, single visual sense cells", Journel Gen Physiol , 18, 917-931, 1935.

18. Roeder, page 489.

19. Jones, M. D. R., C. M. Cubbin, and D. Marsh; "Light on effects and the question of bimodality in the circadian flight activity of the mosquito Anopheles gambiae", J Exp Biol, 57 (2): 347-357, 1972.

20. Lange, R. and M. Weissinger; "Influence of Wind and light on flying direction in a wind tunnel by female moths", Oecologia (Berl), 10 (1): 69-78, 1972.

21. Persson, Bert; "Influence of light-on flight activity of noctuids in Southern Sweden", Entomol Scand, 2 (3): 215-232, 1971.

22. Srivâstava, C. P. and S. L. Petri; "Effect of temperature and humidity on the susceptibility of insects of public health importance to insecticides", Labdev J Sci Technol 9B (2): 86-93, 1971.

23. Chiba, Yoshihiko; "Species specificity in the circadian pattern of mosquitoes." Jap J Ecol, 20 (6): 237-243, 1971.

BIBLIOGRAPHY

Barret, J. R., Jr. "Functional Association of light trap catches to emission of black light fluorescent lamps." Environ Entomol, 1 (3): 285-290, 1972.

Beard, Raimon L. "Lethal action of UV irradiation on insects." J. Econ Entomol, 65 (3): 650-654, 1972.

Chiba, Yoshihiko "Species specificity in the circadian pattern of mosquitoes." Jap J Ecol, 20 (6): 237-243, 1971.

Demkiv, O. T., Repels'Kyi, and Y. D. Fedyk, "Effect of light of various wavelengths on the morphology and physiology of the protonema of Funaria hygromethica Hedw." Ukr Bot Zh, 28 (3): 309-312, 1971.

DeVoe, Robert D. "Dual sensitivities of cells in wolf spider eyes at UV and visible wavelengths of light." J Gen Physiol, 59 (3): 247-269, 1972.

Graham, C. H., and H. K. Hartline "Spectral response, single visual sense cells." Journ Gen Physiol, 18, 917-931, 1935.

Encyclopedia Britannica "Insects-senses" Chicago, 1969. Vol. 12. p. 287.

Hese, C. Von "Color discrimination, bees," Naturiuessenschaften, 8. 927-929.

Jones, M. D. R., C. M. Cubbin , and D. Marsh "Light on effects and the question of bimodality in the circadian flight activity of the mosquito Anopheles gambiae," J Exp Biol, 57 (2): 347-357, 1972.

Klots, A. and Klots E. Living Insects of the World, Dodd, Mead and Co., New York, 1966,

Lange, R. and M. Weissinger "Influence of wind and light on flying direction in a wind tunnel by female moths," Oecologia (Berl), 10 (1): 69-78, 1972.

Lutz, F. E. and E. N. Grieswood "Reactions to 2537 Å radiation, Drosophila," Amer Mus Novitates, 706, 1-14, 1934.

Persson, Bert "Influence of light-on flight activity of noctuids in Southern Sweden," Entomol Scand, 2 (3): 215-232, 1971.

Roeder, Kenneth D., editor Insect Physiology, London, Chapman and Hall Lmt., 1953.

Snyder, Allan W. and Colin Pash, "Detection of Polarization and direction by the bee rhabdom," J Comp Physiol, 78 (4): 346-355, 1972.

Srivåstava, C. P. and S. L. Petri "Effect of temperature and humidity on the susceptibility of insects of public health importance to insecticides," Labdev J Sci Technol, 9B (2): 86-93, 1971.

Wilton, D. P. and R. W. Fay "Response of adult *Anopheles stephensi* to light of various wavelengths," J Med Entomol, 9 (4): 301-304, 1972.