PUPAL COLOR IN *PAPILIO DEMODOCUS* (PAPILIONIDAE) IN RELATION TO THE SEASON OF THE YEAR

D. F. OWEN
Department of Animal Ecology, University of Lund, Sweden

The pupae of some species of Papilionidae may be either green or brown. Green pupae match a green leafy background extremely well, indeed their pattern is suggestive of a curled green leaf, while brown pupae match a dead brown leaf. Brown pupae are rather more variable (some are light and others dark brown) than green, which suggests that the color is cryptic as brown vegetation is more variable in color than green.

The existence of two distinct phenotypes in a population is suggestive of genetic polymorphism under the control of one pair of alleles with dominance. But this is evidently not so in the pupae of Papilionidae as the number of green and brown pupae resulting from a given cross does not fit any known segregation ratio. A typical result is for almost all the pupae to be one color and one or two the other color. In *Papilio demodocus* green × green crosses have given some brown pupae and brown × brown crosses some green pupae. These results cannot be explained by the existence of a pair of alleles with dominance as either green or brown would have to be homozygous recessives and would give only one pupal color among the offspring. It therefore appears that pupal color is environmentally determined, although there may be a genetic component to the capacity to produce a pupa of a particular color.

One possibility is that green pupae tend to be produced when the larvae pupate on a green background and brown pupae when on a brown background. There is some evidence of this which will be discussed later, but in addition there is evidence of a seasonal cycle in the production of green and brown pupae.

On the assumption that green and brown pupae are environmentally determined an experiment was planned to determine if the season of the year affected the frequency of the two pupal colors. There are *a priori* reasons for supposing that green pupae would be advantageous in a tropical wet season and brown pupae in a dry season. It was possible to perform the experiment in both West Africa and East Africa at localities that are quite different in climate. The species chosen for investigation, *Papilio demodocus*, is a common African butterfly. The larvae now feed on *Citrus*, which is an introduced plant in Africa, but some larvae may still be found on the presumed original foodplants, various wild species of Rutaceae.

TABLE 1. Mean monthly rainfall (in mm) at Kampala, Uganda, and Freetown, Sierra Leone.

	J	F	M	A	M	J	J	A	S	O	N	D
Kampala	64	53	139	174	95	61	51	111	98	121	115	96
Freetown	6	1	11	60	180	382	803	849	600	290	110	28

Methods

First and second instar larvae were collected in the wild on *Citrus* and reared in small glass jars, one or two larvae to each jar. When full grown they were allowed to pupate on the side of the jar, but not on the foodplant. The jars were placed indoors and the larvae were reared under normal conditions of temperature, but a very high humidity (near 100%) was generated and maintained inside the closed jars by the larvae and the plants. Larvae were collected and reared in all months of the year. The experiment was conducted in two parts, the first at Kampala, Uganda, in 1964–65, and the second at Freetown, Sierra Leone, in 1968–69. Both these localities have an equatorial climate, but differ in that in Uganda there is some rain in all months of the year with two seasonal peaks, while at Freetown there is a very large single peak of rainfall and a rather severe dry season. The mean monthly rainfall figures (ten-year averages) are shown in Table 1. The most important ecological difference between the two localities which results from the seasonal distribution of rainfall is that Kampala is relatively green all the year round while at Freetown the dry season causes a considerable dying back of the vegetation and the environment is for several months quite brown.

In addition to the main experiment some larvae were reared in the dark in blackened jars and some were reared at high densities, but the results are ambiguous and are not discussed further.

Pupal Color and the Season of the Year

In Table 2 the pupae obtained during the experiments are divided into two groups corresponding to the six wettest and six driest months at Kampala and to the wet and dry season at Freetown. Just over 66 per cent of the pupae at Kampala were green and there is no seasonal difference. But at Freetown green pupae were significantly more frequent in the wet season and brown in the dry season ($\chi^2 = 32.4$, $P < 0.001$). In the dry season just over 39 per cent were green while in the wet season nearly twice as many were green. Since the larvae were forced to pupate on the sides of the glass jars there is no question of matching the background and it appears that there is a built-in seasonal cycle in the frequency of green

TABLE 2. Relative frequency of green and brown pupae in *Papilio demodocus* reared under controlled conditions at Kampala, Uganda, and Freetown, Sierra Leone.

	green	brown	% green
Kampala			
Six driest months (Dec.-Feb., May-Jul.)	28	14	66.7
Six wettest months (Mar.-Apr., Aug.-Nov.)	43	22	66.2
Freetown			
Dry season (Nov.-Apr.)	48	74	39.3
Wet season (May-Oct.)	89	28	76.1

and brown pupae at Freetown, which, however, does not occur at Kampala.

In November 1970 at Freetown 16 larvae were reared in a cage containing a pot of growing *Citrus*. Six pupated on the plant and all formed green pupae, while the remainder pupated on the wooden lid of the cage and produced brown pupae. The sample is rather small but the result is suggestive that pupal color is correlated with the background on which the larvae pupate.

Discussion

The results obtained suggest that the color of *Papilio demodocus* pupae is adapted to the background color on which pupation takes place, and that in an area where there is a conspicuous seasonal change in the background color there is a corresponding cycle in the frequency of green and brown pupae. Exactly how the cycle is generated is obscure. The dimorphism appears to be largely environmentally controlled but this of course does not exclude the possibility that there are genes that affect larval behavior. It is possible to postulate a switch mechanism which acts on the larva in response to the background on which it is pupating, but in addition there may at Freetown be a seasonal cycle in larval behavior such that more seek out green backgrounds in the wet season than in the dry. On the other hand there are more green backgrounds available in the wet season and thus the probability of a larva pupating on green is increased.

Further investigation is required, especially as other species of Papilionidae also produce green and brown pupae (at Freetown, *Papilio nireus* and *Graphium policenes*), while there are evidently species in which the dimorphism is absent; thus all the pupae of *Papilio dardanus* at Freetown seem to be green.

Summary

The green and brown alternative pupal colors in the butterfly, *Papilio demodocus,* appear to be environmentally determined. Larvae reared under controlled conditions in Uganda produced about two-thirds green and one third brown throughout the year, but in Sierra Leone green pupae were more frequent in the wet season and brown in the dry. The difference between the two localities is correlated with differences in the seasonal distribution of rainfall and its effect on green and brown background colors. There is some evidence that green pupae are formed on green backgrounds and brown pupae on non-green backgrounds.

THE LIFE HISTORY OF *SCHINIA LIGEAE* (NOCTUIDAE)

D. F. HARDWICK

Entomology Research Institute, Canada Department of Agriculture,
Ottawa, Ontario

Schinia ligeae (Smith, 1893, p. 331) feeds in the larval stage on the blossoms of the Mojave Aster, *Machaeranthera tortifolius* (Gray) (Figs. 2, 4). According to Munz (1963), *tortifolius* occurs on the Mojave and northern Colorado deserts of southern California and is distributed from there eastward to southwestern Utah and western Arizona.

Specimens of *Schinia ligeae* in the Canadian National Collection were taken in various localities on the northern Colorado Desert and the Mojave Desert except for one specimen taken in the Valley of Fire in southern Nevada and another at Ehrenberg, Arizona. The distribution of the moth, therefore, may well correspond with the distribution of its host plant.

Schinia ligeae is a spring-flying species and its flight is co-ordinated with the early blossom period of its host plant. Specimens examined were taken between the middle of March and the end of April.

Behaviour

Schinia ligeae is a predominantly nocturnal species and the eggs are deposited at night in the heads of the Mojave Aster. The eggs are inserted among the florets from the upper surface of the head, usually at a stage when the individual florets of the blossom have not as yet opened. On the basis of the few eggs observed throughout the incubation period, eclosion usually occurs on the fifth day after deposition. The newly hatched larva bores into an adjacent floret and feeds within it for the duration of the first stadium. The second-stadium larva feeds in the head