DIFFERENTIAL GROWTH AMONG LARVAE OF *CITHERONIA REGALIS* (SATURNIIDAE) ON THREE GENERA OF FOODPLANTS

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ABSTRACT. Larvae of *Citheronia regalis* reared under similar outdoor conditions grow both larger and more rapidly on persimmon than on either sweetgum or sumac. We suggest that the relationship of *C. regalis* to persimmon is one of long standing, originally established in the Neotropics, whereas both sweetgum and sumac may have been exploited secondarily, as the moth entered temperate regions in more recent times.

Many species of Lepidoptera are polyphagous in the larval stage. For these larvae there often exists a spectrum of foodplant suitability, including "preferred" and "acceptable" types of host plants. Such preferences have a biochemical basis through which larvae respond to chemosensory cues. During the course of evolution, the longer an herbivorous insect and a particular plant species have been associated, the more compatible the two are likely to have become, both biochemically and nutritionally, as each species influences the evolution of the other (Brower & Brower, 1964; Ehrlich & Raven, 1965).

Larvae of *Citheronia regalis* Fabricius feed on a wide variety of deciduous trees and shrubs, including as preferred foodplants: black walnut (*Juglans nigra* Linnaeus), butternut (*J. cinerea* L.), hickories and pecan (*Carya* spp.), persimmon (*Diospyros virginiana* L.), sweetgum (*Liquidambar styraciflua* L.), as well as mountain, smooth, staghorn, and wing-rib sumac (*Rhus* spp.). Alternate foodplants include ashes (*Fraxinus* spp.), blackgum (*Nyssa sylvatica* Marsh), oak (*Quercus* spp.), sycamore (*Platanus occidentalis* L.), willow (*Salix* spp.), lilac (*Syringa vulgaris*), and even cotton and sea-island cotton (*Gossypium* spp.), according to Holland (1903), Villiard (1969), and Ferguson (1971). This paper reports differential growth and development times of *C. regalis* reared on persimmon, sweetgum, and wing-rib sumac (*Rhus capallina* L.). Furthermore, we will suggest possible reasons why *C. regalis* larvae exhibit differential growth rates on these three foodplant genera.

Materials and Methods

Rearing was done out-of-doors on a farm in Eldora (Cape May Co.), New Jersey by C.B.W. during the summer of 1977. Equal numbers of
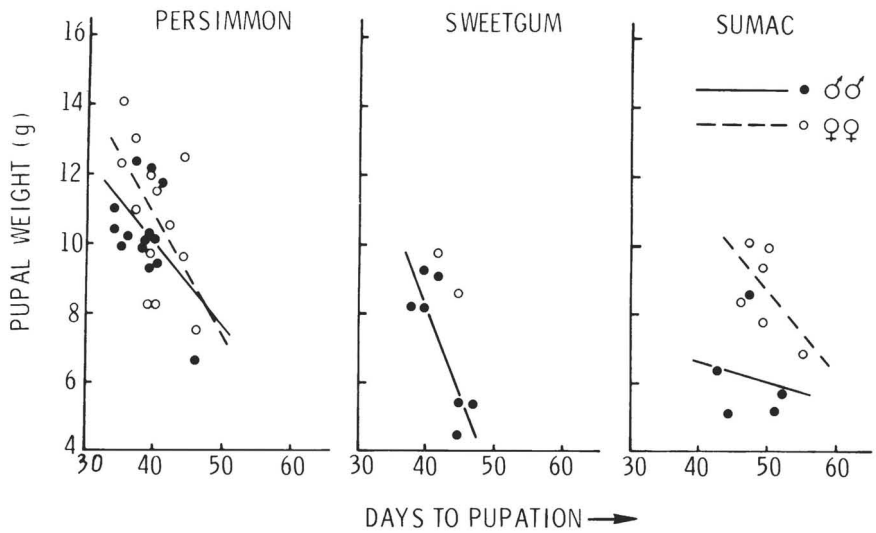
FIG. 1. Linear regression of pupal weight vs. larval development time for *Citheronia regalis* on three foodplants. Solid circles are data for males; open circles denote females. The overall slope is −0.28 (P < 0.001). Slopes of individual lines (except Sweetgum ♀♀ and Sumac ♂♂) also are significant (P < 0.001).

eggs from two females were placed in fine-mesh cloth nets on branches of the three host plants. Locations facing the same direction and having the same temporal exposure to sunlight were chosen. Larvae were reared communally until third instar, at which time they were

TABLE 1. Effects of foodplant and sex on pupal weights (g) of *Citheronia regalis* larvae, with 2-way ANOVA Test and mean pair comparisons. (Sample sizes are given in brackets.)

| | | FOODPLANT | | |
		Persimmon (PR)	Sweetgum (SG)	Sumac (SM)
Pupal weight (x̄ ± S.E.)	♂♂	10.4 ± 0.38 [14]	7.2 ± 0.77 [7]	6.3 ± 0.64 [5]
	♀♀	10.9 ± 0.57 [13]	9.3 ± 0.60 [2]	8.9 ± 0.53 [6]

ANOVA of pupal weights[1]
(food plant and sex are fixed):

Source of variation	df	Mean Square	F-statistic	P
Between foodplants	2	45.2	15.9	<0.005
Between sexes	1	16.9	5.8	<0.01
Interaction	2	4.8	1.6	>0.10 (NS)
Within subclasses	41	2.9	—	—

If the means (x̄) are ordered from largest to smallest, Duncan's multiple range tests show that the following means do not differ significantly from each other (P > 0.05): PR♀♀, PR♂♂, SG♀♀ do not differ significantly; PR♂♂, SG♀♀, SM♀♀, SG♂♂ do not differ significantly; SG♂♂ and SM♂♂ do not differ significantly.

TABLE 2. Effects of foodplant and sex on development time (days) of *Citheronia regalis* larvae with 2-way ANOVA test and mean pair comparisons. (Sample sizes are given in brackets).

| | | FOODPLANT | | |
		Persimmon (PR)	Sweetgum (SG)	Sumac (SM)
Development time	♀♀	38.3 ± 0.83 [14]	42.4 ± 1.25 [7]	48.2 ± 1.93 [5]
(x̄ ± S.E.)	♂♂	39.8 ± 0.96 [13]	43.5 ± 1.50 [2]	50.3 ± 1.28 [6]

ANOVA of development times (foodplant and sex are fixed): Source of variation	df	Mean Squares	F-statistic	P
Between foodplants	2	415.6	36.7	<0.005
Between sexes	1	27.6	2.4	≈0.10 (NS)
Interaction	2	0.5	0.04	>0.25 (NS)
Within subclasses	41	11.3	—	—

Duncan's Multiple range tests show that the means (sexes combined) differ significantly from each other: PR < SG < SM (P < 0.05).

reared singly or in pairs, depending on their size. Further rearing was done inside heavy cloth bags (pillow cases) covering terminal branches. During the fifth instar all larvae were inspected daily to determine the date each ceased feeding, and when each began to crawl around inside its cloth bag. Larvae were then brought indoors and were allowed to pupate in individual plastic boxes. The sex and pupal weight of each were determined on the day after the larval–pupal ecdysis.

RESULTS

Although initially equal numbers of eggs were placed on the three foodplants, the number of larvae which actually began to feed after hatching on each plant type was not recorded. When the larvae were transferred at third instar, there were 31 feeding on persimmon, 10 on sweetgum, and 13 on sumac. Thus, following the third instar, the *C. regalis* larvae exhibited approximately equal survival rates through pupation; these rates ranged from 85% on sumac to 90% on sweetgum, with 87% survival on persimmon.

Our data have been analyzed using two-way analysis of variance, with foodplant and sex fixed. In Table 1 the effects of foodplant and sex on pupal weight both are significant, but the interaction term is not. The Duncan's Multiple Range Tests on data in Table 1 indicate which of the group means differ significantly from one another. Table 2 shows that only foodplant affects development time, with neither sex nor the interaction term being significant. Fig. 1 presents a linear regression analysis of pupal weight vs. larval development time on each of the three foodplants. An inverse relation-

ship between pupal weight and development time is shown by these graphs. Clearly, the *C. regalis* larvae grew more rapidly on persimmon than on either sweetgum or sumac. Larval growth was retarded 4–5 days on sweetgum, and 10–11 days on sumac, as compared to persimmon.

DISCUSSION AND CONCLUSIONS

These results suggest that persimmon may be a more favorable foodplant for *C. regalis* in the northeastern United States than are either sweetgum or sumac. Larvae fed on the two latter plants not only exhibited a smaller final size, but they also required a longer feeding period. Yet *C. regalis* is know to oviposit on all three host plants in Eldora, New Jersey, and its larvae often have been found feeding in the wild on them. The local population probably exploits numerous other deciduous hostplants as well; both black walnut and mockernut hickory (*Carya tomentosa* Nuttall) are common species on the wooded areas nearby.

The geographic distribution of *C. regalis* closely matches the range of persimmon, whereas its other foodplants (except for sweetgum) have less extensive (mainly temperate) ranges (Fowells, 1965). We may now ask what reasons account for persimmon's optimal qualities as a foodplant for *C. regalis*? Possibly, this represents a relationship of long standing, whereas the contact between *C. regalis* and both sweetgum and sumac may have occurred more recently.

Citheronia has its generic focus in Central and South America, and persimmon, likewise, is a member of a predominantly tropical family, the ebonies (Ebenaceae). All of the other preferred foodplants of *C. regalis* are members of principally temperate zone families, either the Juglandaceae (walnuts and hickories), the Hamamelidaceae (sweetgum), or the Ancardiaceae (sumacs). These foodplants also are shared by *Actias luna* Linnaeus, another temperate member of predominantly Asiatic and tropical saturnid groups. Furthermore, the closest taxonomic relatives of *C. regalis* common in temperate regions (*C. sepulcralis* Grote and Robinson and *Eacles imperialis* Drury) are both pine feeders and have exploited very different plant species.

Although our data are by no means sufficient to prove our hypothesis we suspect that *C. regalis* and persimmon may have established their relationship long ago in the tropics, and that the two only recently invaded the North American temperate zone as biological consorts. The spread of *C. regalis* to mainly temperate plants such as sweetgum and sumac, then, may represent more recent relationships which are still evolving. Further comparative foodplant studies of *C.*

regalis and its other host plant species are warranted to test this hypothesis.

ACKNOWLEDGMENTS

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DOUBLY OVERWINTERING *CITHERONIA REGALIS* FABRICIUS (LEPIDOPTERA: SATURNIIDAE)

In 1975 I reared 94 larvae of *Citheronia regalis* Fabricius which overwintered successfully. Among these were 50 males and 44 females. In 1976, many eclosed, but 18 males and 5 females remained dormant. This represents 36% of the males and 10% of the females, or 24.5% of the total sample.

Later, in 1977 I secured two matings between doubly overwintered moths. From ova of those females, I reared 41 larvae, the pupae of which were still viable in the spring of 1978. I could now observe whether or not the tendency of these pupae to remain in diapause over their first summer had been reinforced by the selective matings of their doubly-overwintered parents.

The pupae consisted of 20 males and 21 females. Five of these died before emergence. Among these, two males and one female developed but failed to eclose, while one male and one female showed no signs of metamorphosis. The five dead pupae were excluded from the data.

Of the remaining 17 males, 15 emerged in 1978, with only two (11.8%) remaining in diapause. Of the 19 females, 16 emerged, and only three (15.8%) remained in diapause. Thus of the total population 13.9% remained in diapause.

These observations do not support the hypothesis that double overwintering is under simple genetic control. I could not discern any other determining conditions for the phenomenon, though double overwintering must obviously have survival value for the species by carrying it through occasional catastrophic years.

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