

Processing and Analysis of Biological Data

Report on regression/ANOVA

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Introduction

The development of insect larvae can be influenced not only by the plants they feed on but also by the experiences of their mothers. For example, the choice of host plant by a female butterfly may affect the growth and development of her offspring through maternal effects such as nutrient provisioning or oviposition decisions. In this study, female butterflies reared on two different host plants were allowed to lay eggs on the same two plants, creating a combination of maternal and larval host environments. We measured larval developmental time, adult weight, and growth rate to explore how both the larval and maternal host plants influence offspring performance, and whether these factors interact to affect key life traits of their growth and development.

Methods

To investigate how maternal host plant and larval host plant influenced larval performance, we analyzed larval developmental time, adult weight, and growth rate using two-way analyses of variance (ANOVA). For each response variable, we included maternal host plant, larval host plant, and their interaction as fixed effects to test whether the effect of the larval host depended on the mother's rearing host.

The dataset was derived from a factorial experiment in which females were reared on either *Barbarea* or *Berteroia* and their offspring were then reared on the same two host species, generating four maternal - larval host combinations. For descriptive comparison, means and associated standard errors (mean \pm SE) were calculated for each host plant combination, and mean developmental time was visualized in a plot to illustrate potential interaction patterns between maternal and larval host use. All analyses and visualizations were carried out in R.

Results

Larval developmental time varied according to both maternal and larval host plant (Figure 1). Larvae reared on *Barbarea* developed faster than those reared on *Berteroia*, and offspring coming from mothers reared on *Barbarea* also showed slightly shorter development times overall (Table 2). Mean developmental time ranged from 21.7 ± 0.12 days for larvae whose mothers and themselves developed on *Barbarea*, to 31.0 ± 0.26 days for larvae from *Berteroia* reared mothers reared on *Berteroia* (Table 1).

A two-way ANOVA confirmed significant effects of both host plants on larval development time, with an interaction between maternal and larval host plants (Table 2). The most determined factor of the larval development was the larval host plant ($SS \approx 2682$ and $F\text{-value} = 765.21, p < 0.0001$) (Table 2), with larvae reared on *Barbarea* developing faster (21.7 ± 0.12 for maternal *Barbarea* and 23.51 ± 0.24 for maternal *Berteroia*) than those reared on *Berteroia* (27 ± 0.32 for maternal *Barbarea* and 31.02 ± 0.26 for maternal *Berteroia*) (Table 1).

Maternal host plant also influenced development time ($SS \approx 623.6$ and $F\text{-value} = 177.90, p < 0.0001$) (Table 2) with offspring of *Barbarea* reared mothers developing slightly faster overall (21.7 ± 0.12 days on *Barbarea* and 27 ± 0.32 days on *Berteroia*) than those of *Berteroia* reared mothers (23.51 ± 0.24 days on *Barbarea* and 31.02 ± 0.26 days on *Berteroia*) (Table 1).

The interaction between maternal and larval host plants was significant ($F\text{-value} = 23.04, p < 0.0001$) (Table 2) indicating that the effect of larval host plant depended on the maternal environment. However, the interaction explained less of the total variation in development time than the main effects of larval and maternal host plants, as shown by its smaller sum of squares ($SS \approx 80.799$) (Table 2).

The developmental difference between larval hosts was larger among offspring of *Berteroia* reared mothers ($31.00 - 23.50 = 7.50$ days) (Table 1) than among offspring of *Barbarea* reared mothers ($27.00 - 21.70 = 5.30$ days) (Table 1). This pattern is reflected in Figure 1, where the lines connecting mean development times for the two larval hosts are non parallel, indicating an interaction between maternal and larval host plants. To be more specific, the slope of the line for *Berteroia* reared mothers is steeper than that for *Barbarea* reared mothers, showing that the effect of the larval host on development time is stronger in the *Berteroia* maternal environment. In contrast, the gentler slope for *Barbarea* reared mothers indicates a smaller difference between larval hosts in this maternal environment.

Table 1: Effects of Host Plants on Larval Development Time

Mean Values and Standard Errors by Maternal and Larval Host Plants

Maternal Host	Larval Host	Mean Development Time (days)	SE (days)
Barbarea	Barbarea	21.70	0.12
Barbarea	Berteroia	27.00	0.32
Berteroia	Barbarea	23.51	0.24
Berteroia	Berteroia	31.02	0.26

Table 1: Mean values and standard errors (SE) of larval development time (days) shown by maternal and larval host plant combination

Table 2: Two-Way ANOVA Results

Effects of Maternal and Larval Host on Development Time

Cases	Df	Sum of Squares	Mean Square	F value	p value
Maternal Host	1	623.60507	623.605072	177.89515	8.092252e-32
Larval Host	1	2682.41324	2682.413242	765.20913	1.895975e-82
Interaction (Maternal Host : Larval Host)	1	80.79942	80.799418	23.04956	2.561159e-06
Residuals	283	992.04638	3.505464	NA	NA

Table 2: Summary of the two-way ANOVA results for the effects of maternal and larval host plants on larval development time

Larval Development Time by Maternal and Larval Host Plant

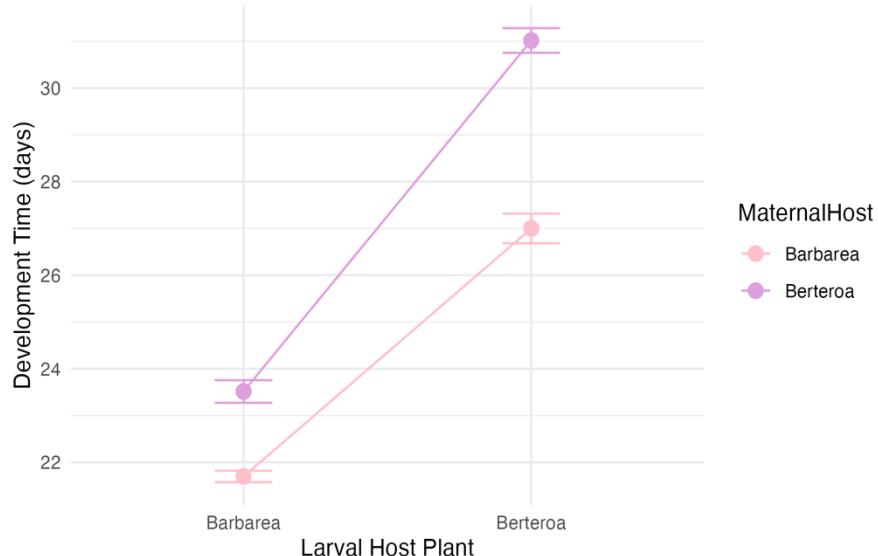


Figure 1: Larval developmental time depending on larval and maternal host plant. Error bars indicate standard error (SE)

Discussion

The study demonstrates that both maternal and larval host plants significantly influence offspring development in butterflies, and that these effects interact in shaping larval performance. The larval host plant had the strongest impact on development time, with larvae reared on *Barbarea* consistently developing faster than those reared on *Berteroia*. This is probably due to the quality and nutritional content of the larval host plant directly determine growth rates and developmental timing. Faster development on *Barbarea* suggests that it may provide higher nutritional quality resources compared to *Berteroia*.

Maternal host plant also influenced how quickly offspring developed, although this effect was smaller than the impact of the larval host plant. In general, offspring of mothers reared on *Barbarea* developed a bit faster than those from *Berteroia* reared mothers, no matter which plant they fed on as larvae. This suggests that mothers can affect their offspring's development through factors such as the nutrients they provide to their eggs or where they choose to lay them.

The interaction between maternal and larval host plants shows that the effect of the larval host depends on the mother's host plant. Although the larval host had the strongest overall influence, the size of that effect changed with the maternal environment. Offspring from *Berteroia* reared mothers showed a much bigger difference in development time between the two larval hosts, meaning they were more affected by the plant they fed on. In contrast, offspring from *Barbarea* reared mothers showed a smaller difference, suggesting that a better maternal environment may help buffer larvae against poor food quality.

In summary, the results show that both the plant larvae feed on and the plant their mothers experienced affect how quickly they develop. The larval host plant had the strongest impact, highlighting the importance of food quality during growth. However, the maternal effect and the interaction between the two environments show that both past and present conditions shape offspring development.

R Code

The code for this exercise is available at the provided link, inside the report1 folder and named “*butterflies_chatzantoni.R*”

<https://github.com/marianikichatz/BIOS15/tree/ad8e6335eaf93a18d65eb94d3996fa33db75291e/report1>