Selection for protection in an ant-plant mutualism: host sanctions, host modularity, and the principal-agent game

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Appendix: Parameter estimates for the net benefit of patrolling

The dry mass of a female alate is 4.20 *mg* ± 0.19 (mean ± s.e.), and that of a male alate is 2.30 *mg* ± 0.04. We use these masses to convert alate counts (Yu et al. 2004b) to biomass. To convert alate *larvae* counts to alate *adult* weights, we used the female population numerical sex ratio of 0.53 (D. Yu, unpublished data) and assigned that proportion of larvae to females and the remainder to males. We then regressed total alate biomass M against colony size (as indexed by domatia number D, Yu & Pierce 1998). The best-fit equation was $M^{1/2} = 0.215D$ ($F_{1,57}$=34.2, p<0.001, R^2=0.38), where we omit the intercept as it was not significantly different from zero (p=0.31, *i.e.*, no reproduction at zero colony size). Log (y +1)-transforming or not transforming the response variable resulted in worse-behaved residuals and worse fit (see also below).

The marginal instantaneous increase in alate biomass is the derivative with respect to colony size, $dM/dD = 2(0.215)^2 D = 0.09D$. Thus, per-domatium alate biomass production increases with colony size D. (Note that any function in which dM/dD increases with D will produce the same qualitative results.)

The number of alate generations produced over the lifetime of a domatium, G, is L/T_D, the ratio of domatium lifetime to alate development time. We used the one-year (thus, censored) survivorship curve of the control (non-clipped) domatia from the *Four new leaves* experiment (Fig. 4) and calculated the mean age at death under a Weibull distribution, which yielded an estimate of L = 51 months (Crawley 2002). For T_D, reported literature values suggest alate development times of 1.5 months (Schmidt 1974 cited in Hölldobler & Wilson 1990; Smith & Whitman 1992). We conservatively use a range of 1.5 - 3 months to allow for the possibility of a pause between alate generations. G thus takes the values 34 and 17.

The effect of host sanctions S on domatia survivorship and growth was only statistically significant for the highest simulated level of herbivory (removal of *Four new leaves).* At that level, most domatia died (Fig. 4), and the remainder failed to grow more than a tiny amount (Fig. 5). In short, when leaves are heavily eaten, attached domatia are rendered unavailable or too small for housing alates (Fig. 1b). However, unprotected new leaves suffer only a 22% (6 of 27 shoots) chance of herbivory at that level (Fig. 3, Results) before they lignify and can defend themselves via toughness. Thus, we set $S = 1.0 * 0.22$, the expected value of domatia volume loss, including mortality, (i.e., total loss), weighted by the risk of heavy herbivory.

Note: If we use a straight-line biomass response, $M = \beta D$, the marginal benefit (dM/dD) is a constant: 5.8 *mg*. Plugging in the other values reveals that the net marginal benefit B is positive for all $D > 0$. However, a straight-line regression assumes unrealistically that reproductive allocation does not increase with colony size.