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Preliminary Report

Relationship between elaiosome and EFN gland size in castor bean (*Ricinus communis L.*), an exotic mymercophyte in Southern California

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Abstract. Castor bean (*Ricinus communis L.*) relies on seed dispersal by attracting ants with elaiosomes; lipid rich seed appendages, which serve as a source of food for ant larvae. Additionally, castor bean petioles and inflorescences have extra floral nectary (EFN) glands that secrete sugars that also attract ants, which in return, defend against herbivores. We propose that in order to attract ants, castor bean would have to balance allocation of energy toward plant defense and seed dispersal per the Principle of Allocation. Specifically, we hypothesized that in castor bean, an increase in elaiosome size would correspond to result in a decrease in EFN gland size. We examined proportion of elaiosome:seed (by weight) investment relative to the EFN gland size on a given castor bean plant. We found that elaiosome weight was not correlated with EFN gland area ($p = 0.1542$), and report a one to five fold range in elaiosome investment across 34 plants. We present a range of environmental factors contributing to the observed variation in elaiosome investment.

Introduction

The castor bean, native to the Ethiopian region of east Africa, has been naturalized in tropical and warm regions around the world, with an increasing abundance in the southwestern United States. Castor bean seeds contain about 60% oil, which can be utilized for industrial and medicinal purposes. Additionally, castor oil contains ricin, a toxic substance that can be detrimental upon ingestion for mammals (Lord et al., 1994). The castor bean heavily relies on a mutualism with ants for defense and seed dispersal. Sugars secreted by EFNs provide a source of food for ants, which in turn provide protection against herbivores (Rutter, 2004). The amount of extra-floral nectar

produced is directly associated with the amount of herbivory the plant experiences (Ness et al., 2009). Specifically, the EFN sugars increases due to either a biochemical process involving enzymes found in herbivores' saliva, or from mechanical damage done by the consumer (Arimura et al., 2009).

In castor bean, imperfect male and female flowers contribute to seed production. Which over time, fruiting bodies will dry out and crack open, explosively dehiscing seeds to the soil (Bianchini and Pacini, 1996). In castor bean, production of fleshy, nutritious seed appendages called elaiosomes, cause ants to carry seeds to their underground nest, resulting in secondary seed dispersal. Rich in lipids and proteins, ants feed these elaiosomes to larvae, and deposit the rest of the seed into an area called a waste cache. This disposal area is rich in nutrients from dead ant bodies, which allow seeds to successfully

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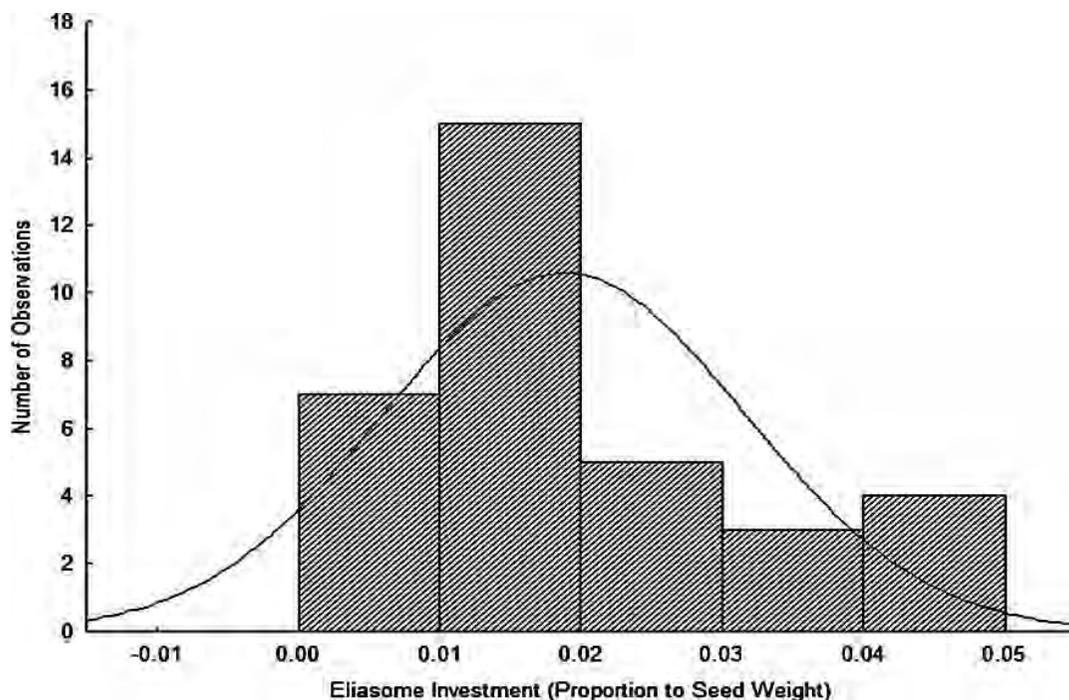


Figure 1. Histogram showing a non-parametric distribution of proportional elaiosome investments. The solid line indicates a projected normal distribution.

germinate (Gorb and Gorb, 1999b). Gorb and Gorb (1999a) examined the likelihood for a seed to be dropped by an ant while carrying it back to the nest and found that plants that produced larger seeds were characterized by a high removal rate and low drop rate by ants during dispersal. Additionally, larger seeds were more likely to successfully reach the waste cache. Our study evaluates the allocation optimization of defense and reproduction by examining EFN gland and elaiosome size, respectively, in castor bean. We hypothesized that per the Principle of Allocation, there would be a trade-off in energy investment between EFN glands and elaiosomes. An inverse relationship is predicted in which increased EFN gland size will result in decreased elaiosomes and vice versa.

Materials and Methods

This project was conducted on November 8, 2011 at a riparian woodland in Westchester, California. We collected a single dried fruit from 34 castor bean plants selected at random. Each

dried fruit contained exactly three seeds ($n=102$). At each plant, we took a digital photograph of a single EFN gland located on the top petiole near the edge of leaf lamina. We separated elaiosomes from their respective seeds and weighed both the seed and the elaiosome individually using a Mettler Microbalance (model UMX2). We calculated averages of the three elaiosome weights and the three seed weights per fruiting body. Investment of elaiosome was calculated as proportion of elaiosome investment to total seed (seed + elaiosome) weight. The surface area of a given EFN gland was determined using Sigma Scan Pro (V5).

Results and Discussion

The proportion of elaiosome investment to seed production was not normally distributed ($W=0.878$, $p=0.0012$, Figure 1). The EFN gland area was normally distributed ($W=0.952$, $p=0.1455$). Elaiosome investment was not correlated to size of EFN gland ($r=0.180$, $p=0.154$, Figure 2).

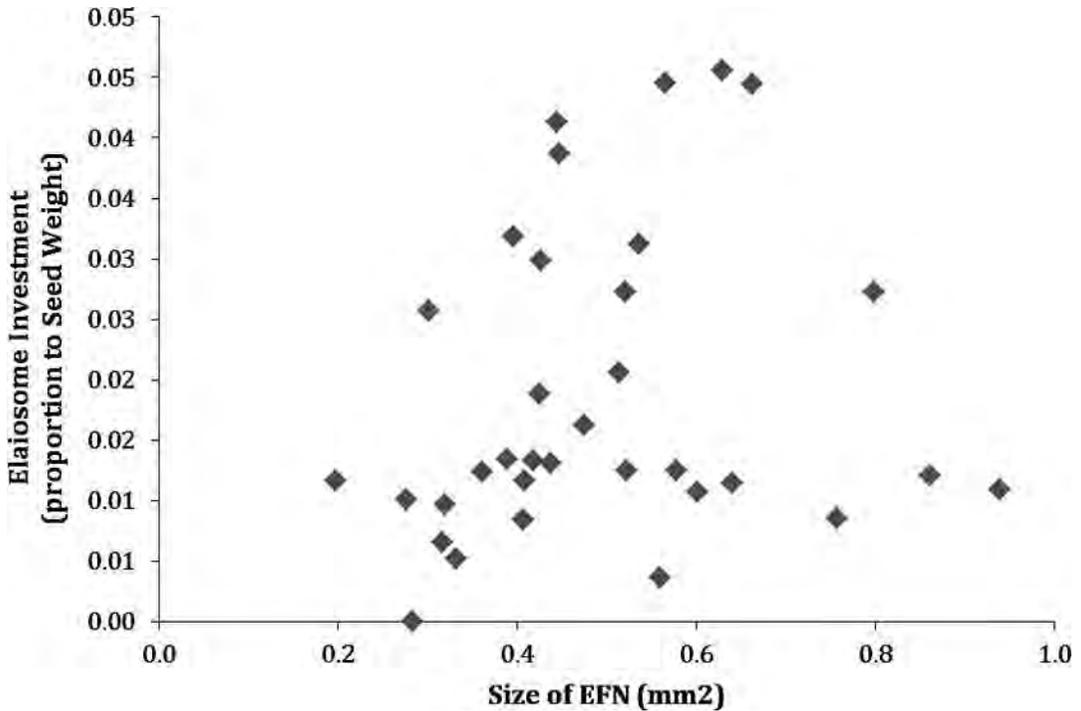


Figure 2. The relationship between elaiosome investments in total seed weight and EFN gland size.

There was no relationship between size of EFN gland and elaiosome in castor bean. This suggests changes in EFN gland size did not reflect compromise in elaiosome investment. Elaiosomes exhibited a positive skew in seed investment (Figure 1). Approximately two-thirds (65%) of seeds had a <1% elaiosome investment in total seed mass. The remaining third (35%) of seeds contained elaiosomes comprising 4-5% of total seed mass. While variation in elaiosome investments was not explained by EFN gland size, there may exist other environmental factors, such as herbivory that may account for the observed pattern. As an exotic species, castor bean typically experiences low herbivory rates due to decreased native predators (Schutzenhofer and Knight, 2007). This suggests that plants can invest more greatly into other life functions, such as reproduction. Conversely, elaiosome investment may be subject to distance from ant colonies. Beattie (1985) found that plants farther from ant colonies would have greater elaiosome investments, suggesting that

larger elaiosomes will incentivize ants to travel greater distances when foraging.

In North American forests, *Aphaenogaster* were significantly more likely to collect ant-adapted seeds than are ten other ant genera found in these forests (Ness et al., 2009), suggesting that specific ant species may be adapted to utilize certain myrmecocherous seeds. Although ants respond positively to seeds with elaiosomes, the response remains unchanged among varying myrmecocherous guilds and is not affected by ant size (Garrido et al., 2002). This suggests that several exotic ant species may contribute to castor bean seed dispersal. However, further investigation is needed to characterize the intriguing range of elaiosome investment in castor bean.

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