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Research Article

An examination of *Opuntia littoralis* fruit volume, sugar concentration, number of seeds and average seed mass in relation to fitness

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Abstract. Organisms cannot maximize all life functions and therefore must allocate resources to maximize reproductive fitness such that they produce the highest number of surviving offspring. The object of the experiment was to evaluate variation of fruit morphology to determine how *Opuntia littoralis* optimizes reproductive investment. The experiment focused on fruit volume, sugar concentration, number of seeds and average seed mass on two different aspects (polar-facing and equatorial-facing slopes) in Temescal Canyon Gateway Park, Pacific Palisades, California. The results revealed fruit volume was positively correlated with number of seeds, sugar concentration was positively correlated with number of seeds, and average seed mass was negatively correlated with number of seeds. The study suggests that variation in *Opuntia* fruit morphology can be explained by the principle of allocation and life history strategies rather than by microhabitat variation alone.

Introduction

The principle of allocation (Cody, 1966) suggests that natural selection results in each organism optimizing resource partitioning to maximize fitness. Resource allocation in plants such as *Opuntia littoralis* is a tenuous compromise among fecundity, survival and growth (Silvertown and Dodd, 1999). As such, a balanced fruit volume, fruit sugar concentration, number of seeds and average seed mass ensure optimal growth and reproduction. Previous experiments by Barbera et al. (1994) showed a positive correlation between seed content (number and weight) and fruit weight, while other studies have focused on fruit production and plant size (Watkinson and White, 1986). Few studies have focused on aspect as a factor in seed production or sugar concentration specifically in *O. littoralis* fruit. The objective of the experiment was to explore the relationship between fruit volume, sugar concentration, number of seeds and average seed mass of *O. littoralis* fruit found on polar-facing slopes and equatorial-facing slopes. In accordance with the principle of allocation and life history strategies it was predicted that equatorial facing slopes would have a lower fruit volume because the habitat was dryer, higher sugar concentration because of increased photosynthesis, a larger average seed mass and a smaller number of seeds, relative to polar-facing slopes.

Materials and Methods

Materials were gathered in Temescal Canyon Gateway Park in Pacific Palisades on 16

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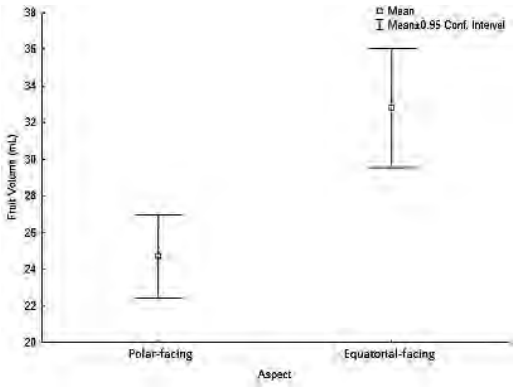

Figure 1. Mean fruit volumes of Opuntia on polar- and equatorial-facing slopes at Temescal Canyon Gateway Park. Bars denote a 95% confidence interval.

November, 2010. *O. littoralis* fruits were harvested from 50 different plants on two slopes with different aspects: a polar-facing slope and an equatorial-facing slope. The fruits were stored at approximately 5°C in Seaver Hall at Loyola Marymount University. Fruit volume was measured using water displacement in a 500 ml graduated cylinder. Sugar concentration of the *O. littoralis* fruit was determined using a portable sugar refractometer. The seeds and flesh from each fruit were removed and dehydrated in a freeze dryer for 5 days. The number of seeds was then counted and the average seed mass determined.

The distribution of fruit volume, sugar concentration, number of seeds and average seed mass was tested for normality using a Shapiro-Wilks test. Site differences in sugar concentration, number of seeds and average seed mass were tested using a Mann-Whitney U test, and site differences in fruit volume was tested using a t-test. The relationships among fruit volume, sugar concentration, number of seeds and average seed mass were evaluated using a Spearman Rank Correlation. All data analyses were conducted with the software package Statistica (v.9.1).

Results

The following variables were not normally distributed: fruit volume ($W=0.973$, $p<0.05$), sugar concentration ($W=0.939$, $p<0.05$), and average seed mass ($W=0.939$, $p<0.05$). The number of seeds across sites was normally distributed ($W=0.959$, $p>0.05$). There was no significant difference between aspects in terms of sugar concentration ($z=-0.8828$, $p>0.05$), and average seed mass ($z=-0.6015$, $p>0.05$). There was a significant difference in fruit volume ($z=-3.5604$, $p<0.05$) between sites (Figure 1). On average, the fruits on the equatorial-facing slope had an average volume of 821.5 cm^3 while the fruits on the polar-facing slope had an average of 453.5 cm^3. The number of seeds do not differ significantly between the two aspects ($t=-0.0756$, $p>0.05$). The results showed a positive correlation between fruit volume and number of seeds ($r=0.5671$, $p<0.05$), a positive correlation between sugar concentration and number of seeds ($r=0.4009$, $p<0.05$), and a negative correlation between seed mass and number of seeds ($r=-0.5098$, $p<0.05$).

Discussion

The results show that *O. littoralis* fruits growing on polar-facing slopes differ from fruits growing on equatorial-facing slopes in terms of volume but do not differ in terms of sugar concentration, number of seeds, or average seed mass. The volumes of the *O. littoralis* fruits growing on the equatorial-facing slope were, on average, much larger than the fruits growing on the polar-facing slope, perhaps because the equatorial-facing aspect is exposed to sunlight for a longer period of time (Cantlon, 1953).

The positive correlation between fruit volume and the number of seeds is supported by previous studies which state there is a positive correlation between *Opuntia ficus* fruit volume and both the number and weight of seeds (Barbera et al., 1994). The study also found a negative correlation between average seed mass and number of seeds. These results are consistent with a life history strategy in which an organism adapts aspects of its biology, to optimize size and age at reproductive maturity, by balancing the number of surviving offspring (Watkinson and White, 1986). *O. littoralis*

demonstrates a life history compromise such that seeds with greater average mass result in fruit with a smaller number of seeds. Although it was initially predicted that the site microclimate at each aspect would result in the directional evolution of *O. littoralis* life history strategies related to drought adaption, the data do not support this hypothesis.

Sugar concentration was found to be correlated with a greater number of seeds in *O. littoralis* fruit. The principle of allocation suggests that an organism cannot optimize all aspects of reproduction, growth, and development at the same time and therefore, must allocate resources accordingly. It can be proposed that *O. littoralis* allocates resources toward reproduction in a way that favors the tandem production of sugar concentration and numbers of seeds in fruit. Further studies could explore how other *O. littoralis* life functions (such as growth and defense) are affected by microclimate variation.

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