TABLE 2. ANOVA model for fuchsia reproductive success that includes defense and patch nested within defense, with defense and patch both treated as significant effects.

		Fruits/Inflorescence	
Source	df	MS	F
Defended	1	8	0.01
Patch(Defended)	3	350	0.52
Error	95	669	

DISCUSSION

There was no apparent effect of hummingbird territoriality on the reproductive success of fuchsia. It may be that fuchsia plants lack strong self-incompatibility (i.e., can reproduce with their own pollen equally well as with the pollen of another plant). Another explanation is that because there were several individual fuchsia plants within each of our patches, cross pollination among patches was not critical to the plants' reproductive success. In undefended patches, visiting birds may facilitate a similar level of cross-pollination within the patch as territorial birds in defended patches.

We cannot judge how much pollen was carried into defended patches. In defended patches, the mate of the territorial male may move among patches and facilitate some outcrossing among patches. Furthermore, volcano hummingbirds, unlike other visiting species, often poached nectar along the edges of defended patches and thus may have contributed pollen from other fuchsia patches. Perhaps their small size made them less noticeable or more tolerable to fiery-throated defenders. Visiting birds could be less important for pollination than we had hypothesized if they were frequently carrying pollen from another plant species when they arrived at a fuchsia patch.

Our hypothesis rested on the assumption that fuchsia reproduction was limited by pollinators in general and hummingbird pollinators in particular. The considerable variation in fruit production among inflorescences is consistent with pollinator limitations, but pollen addition experiments are needed to separate the effects on plant reproduction of pollen limitations vs. carbohydrate and nutrient limitations. Butterflies, bees, and frugivores regularly visited all patches, so their effect on pollination and fruit numbers were presumably the same in defended and undefended patches. However, if insects pollinate a large number of fuchsia flowers, the potential effects of hummingbird territoriality on the reproductive success of fuchsia would be less important and more difficult to detect.

Both of our defended patches were occupied by fiery-throated hummingbirds. At other times of year, volcanoes, gray-tailed mountain-gems, and magnificents may defend patches of fuchsia. To our knowledge, nothing is known about the effects of territorial behavior in these species on the reproductive success of fuchsia. Although no hummingbird species specializes on *Fuchsia arborescens* , it would be interesting to examine the effects of a specialist hummingbird's territoriality on its host species, such as the green violet-ear hummingbird (*Collibri thalassinus*) and *Centropogon*.

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THE EFFECT OF PATCH DENSITY ON THE REPRODUCTIVE SUCCESS OF *MONOCHAETUM VULCANICUM*

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Abstract. Plant aggregation patterns may influence their apparency and value to pollinators and seed predators, and in turn have consequences for plant reproduction. We hypothesized that seed set and seed predation would vary with patch density of *Monochaetum vulcanicum*. High density patches had a two-fold greater proportion of their ovules fertilized and only 25% as much as insect damage to fruits compared plants in low density patches. Increased fertilization in high density patches could be attributed to more visits by pollinators while the lower predation rates in high density patches could be explained by predator swamping. Our results suggest directional selection could favor traits that promote high density aggregations of *M. vulcanicum*.

Keywords: aggregation, Melastomataceae, *pollination potential, seed predation, seed set*

INTRODUCTION

We observed great variation in the spatial distribution of *Monochaetum vulcanicum* (Melastomaceae) in a high elevation tropical forest. In sunny, open areas these plants were found in large, high density patches, while in areas with greater canopy cover they occurred in small, low density patches. Because flowers are resources for many organisms, their aggregation patterns could influence animal populations, and in turn have consequences for plant reproduction. Pollinators should be attracted to, and spend more time in more densely aggregated, visible patches of flowers, which may result in increased seed set. However, these densely populated patches are also likely to be more apparent to potential seed predators. We predicted that a greater proportion of flower ovaries would be fertilized in high density areas, but that a greater proportion of fruits in high density patches would suffer seed predation.

METHODS

We collected melastome fruits along the trails above the Estacion Biologica de Cuerici in Cerro de la Muerte, Costa Rica, on 28 January 1998. We sampled plants in six high density patches and four low density patches. Patches with > 15 plants within a 2.5 m radius of a focal individual were considered high density, while patches with < 6 individuals in the same area were considered low density. All patches were separated by at least 20 m. Within each patch, we haphazardly selected three fruits from each of five plants. Using a dissecting microscope, we counted the proportion of fertilized and unfertilized ovaries within each fruit. To test for seed predation, we collected additional fruits (~40) from each patch, irrespective of individual plants. We opened each of these fruits and determined the proportion of fruits within each patch that contained insects or insect damage.

We used a Chi-square test to compare the proportions of fruits in low density versus high density patches that contained at least one fertilized ovule (seed). We assessed the proportion of seeds that were fertilized using a nested ANOVA that tested for (1) effects of plant density, (2) variation among patches within density classes, and (3) variation among plants within patches. Patches and plants were treated as random effects. We used a Student t-test to compare differences in seed predation between high and low density patches. All proportional data were arcsin transformed.

RESULTS

The probability of there being at least one viable seed in a fruit was significantly greater in high density melastome patches than in low density patches (80% of 90 fruits vs 60% of 57 fruits; $X^2 = 7.19$, $P < 0.001$). There was a two-fold greater proportion of fertilized ovaries in fruits within high density patches compared to low density patches (Table 1, Fig. 1). There was low but significant variation in the proportion of fertilized ovaries among plants within patches, but patches within density classes were very similar (Table 1). The probability of seed

predation was almost four-fold greater in low density patches than high density patches (Fig. 2, $t_8 = 3.47$, $P = 0.009$). Damage to fruits and seeds appeared to be chiefly due to consumption by insect larvae.

DISCUSSION

As predicted, a greater proportion of melastome ovaries was fertilized in high density patches. Reduced fertilization in low density patches could be because these patches are less apparent to pollinators. In addition, pollinators may be unwilling to visit and/or remain in patches where net energy gain will be low (Bird and Canny, 1996).

Our prediction that seed predation would be greater in higher density patches was falsified. Greater predation in low density patches could be the result of the increased probability of an individual fruit experiencing predation in patches with fewer plants from which predators can choose. Alternatively, low density plants may be located in less ideal habitats and can not afford to allocate as many resources to defense. Greater insect abundance in the areas of the low density patches could also have contributed to higher predation rates, however, our study could not account for this.

Apparently, *M. vulcanicum* in high density patches have substantially greater reproductive success than those in low density areas. Thus, there should be directional selection favoring traits that promote aggregations of plant individuals. This runs counter to the usual ideas about the importance of dispersal in tropical plants (Hartshorn, 1983). Further study could test the effect of habitat quality on reproductive success by examining abiotic factors and insect activity at different plant densities.

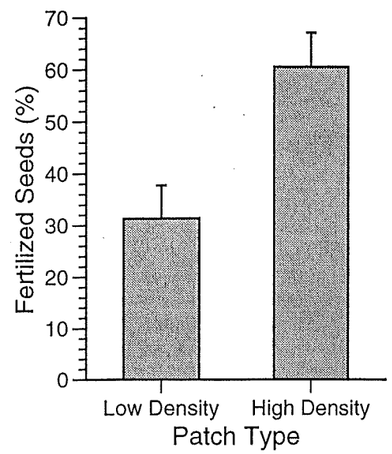

FIG. 1. Percent of fertilized seeds per fruit in each patch type. (mean ± 1 SE)

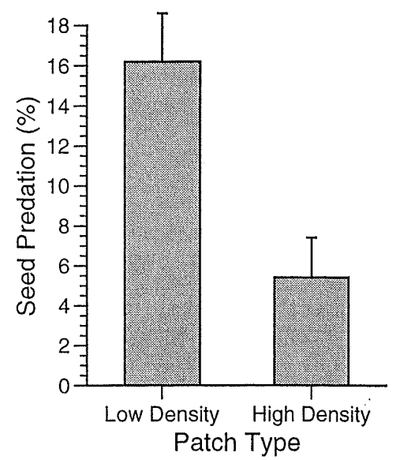

FIG. 2. Percent of fruits with insect damage. (mean ± 1 SE)

TABLE 1. A nested ANOVA testing for the effects of patch density, patches within density classes, and plants within patches on proportion of fertilized ovaries in *Monochaetum vulcanicum*.

Source	df	Mean Square	F-statistic	P-value
Density	1	1.018	11.09	0.005
Patch (Density)	8	0.096	1.34	0.26
Plant (Patch, Density)	30	0.073	1.73	0.03
Error	66	0.042		

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