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SEED DISPERSAL OF THE GENUS *LEEA* IN FOREST PATCHES OF BATAAN, PHILIPPINES

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INTRODUCTION

The tropical forests of the Philippines have been identified as some of the most biologically diverse and threatened in the world (Myers *et al*. 2000, Laurance 2007). While most of the plant diversity in the Philippines is concentrated in the few remaining primary forests (Langenberger *et al*. 2006), a small but significant flora persists in secondary forest patches, known as *parang* (Ashton 1997, LaFrankie, pers. comm.). Animal-mediated seed dispersal is an important aspect of these ecosystems in the Philippines (Hamann & Curio 1999, Corlett & Hau 2000, Ingle 2003, Gonzalez *et al*. 2009) and elsewhere in the tropics (Janzen 1983, Whittaker & Jones 1994, Weir & Corlett 2007), especially where remnant forest patches are surrounded by degraded habitat (Ingle 2003, Weir & Corlett 2007). The microphanerophytic genus *Leea* (Leeaceae) includes two species representative of both lowland primary forest understory (Co *et al*. 2004, Langenberger *et al*. 2006) and secondary forest patches in the Philippines: *L. guineensis* (G. Don) and *L. indica* (Merr.) (Ridsdale 1974). Molina (2009) documented their pollination, and Schabacker & Curio (2000) observed one bird species (the bulbul *Hypsipetes philippinus* Forster) feeding on the fruits. The present study examines *Leea* seed dispersal in greater detail.

MATERIALS & METHODS

Leea trees were located along two intermittent streams near the Kanawan Aeta community, Morong, Bataan at 150 m elevation (14.715°N, 120.333°E). The regional climate is Type I, with maximum rainfall of about 400 mm in July, and almost none in December-April (Pajuelas 2000). Temperatures range from a monthly mean of 23.3°C in December to 28.6°C during April. Average annual relative humidity is 78% (Bustos *et al*. 1997). Fruit counts on each of twelve *Leea* trees were conducted on 13 and 23 October, 3 and 15 November, 8 and 11 December, and 15 January (2007-08, during the dry season). This quantified the rate at which dispersers were removing the fruits. Direct observations (naked eye) of probable dispersal agents were conducted during early morning (3.5 hours), midday (4.5 hours), afternoon (3 hours), and dusk (1.5 hours) for most of the trees from a distance of 25 m. The average and minimum distances between trees were about 200 m and 10 m. Birds were identified using Kennedy *et al*. (2000). Identification of animals observed at *Leea* trees by local people (Aeta) were verified by showing them pictures from guidebooks. Additional information on the local names used for particular species came from U. Ferreras (pers. comm.). *Leea* fruits are 8-mm berries with 2-3 seeds. A fluorescent dye technique was used to test how far dispersers moved the *Leea* seeds before dropping them. "Orange Yellow" No. PS32 fluorescent powder (Radiant Color, Inc.) was dissolved in acetone to a ratio of 15:100 by volume. This was sprayed onto the *Leea* infructescences. An ultraviolet lamp was used to search for defecated seeds and pulp on the forest floor (Reiter *et al*. 2006). UV monitoring was completed by 17 November 2007. To test for bat dispersal, six of the trees were sprayed just before dusk on 3 November 2007, and

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a 20-m radius around each tree was monitored before dawn the next morning. The remaining six trees were sprayed on 4 November 2007. Sixteen transects of 2 x 50m, as well as three shorter ones (due to steep terrain), were monitored with the UV lamp in dense *Lantana* spp. (Verbenaceae) thickets adjacent to the trees (a total of 1780 m^2). Secondary dispersal was examined by placing three fruit piles on sandy soil and three under vegetation, with a distance of >10 m between each pile. Both the vegetation and sandy piles had four, eight, and 16 fruits present. The piles were established at 10:00 h on 8 December 2007. Observations of all piles were conducted 8, 23, 31, 55, 70, 80, and 97 hours after establishing the piles. To test if seeds germinate more effectively after removal from pulp (Samuels & Levey 2005), 30 seeds (12 fruits) were planted in each of six pots with wire exclosures and checked after 32 days. Each pot had 12 holes of depth 2.5 cm (equivalent of one fruit per hole). The 15-cm diameter pots were filled with sandy loam soil from the study site to a depth of 10 cm. Three of the pots were placed in sun and three in shade. Both groups included three treatments: mechanically scarified seeds, normal seeds separated from fruit pulp, and intact fruits.

RESULTS

None of the 12 fruiting *Leea* trees monitored were flowering, preventing species identification. However, habitat (and a local botanist) suggested they were likely *Leea guineensis* (Ferreras, pers. comm.). Tree heights were approximately three to six meters. Thirteen infructescences with 35-420 fruits each were monitored. Total fruit count (f) declined exponentially ($r^2 = 0.9928$) over a three-month observation period (t):

$$f = 1507.9e^{(-0.0285\ t)}$$

Philippine Bulbuls (*Hypsipetes philippinus* Forster) fed on about 10-15 whole fruits twice without dropping any. The bulbuls flew in pairs and fed in the morning, spending only 10-20 seconds on each infructescence and calling loudly. Besides these, the frugivorous birds *Phapitreron leucotis* (Temminck), *Pycnonotus goiavier* (Scopoli), and *Lanius schach* (L.) were frequently seen near the *Leea* trees. We also observed small bats and the monkey *Macaca fascicularis* (Raffles); however none of the mammals was seen directly feeding on the fruits.

During the 15 days of UV-lamp monitoring, 349 fruits were removed from trees near the 19 transects (covering 1780 m^2) but no fruits or seeds were recovered using the fluorescent dye technique. Examination of fruits still on the tree revealed the dye's fluorescence to persist for several months despite exposure to weather, and the dye did not alter fruit attractiveness to dispersers because the removal rate was consistent before and after spraying. If putative dispersers defecated or regurgitated fruits uniformly within 50 m of each tree, the fruit density would have been 0.00889 fruits/m^2, and one fruit would be expected for every 113 m^2 searched. Since 1780 m^2 was searched, about 16 fruits were expected, or more if the seed shadow conformed to Willson & Traveset's canonical distribution (2001), because the density of seeds would diminish with distance from the source tree and our transects oversampled the area near each tree. During the 97-hour secondary dispersal experiment, only three fruits were removed from the six different piles. All of these were removed from the vegetation pile where n = four fruits. One fruit was removed after 23 hours, another after 55 hours, and the final one after 97 hours. Of the approximately 180 seeds in the germination experiment, only three sprouts penetrated the surface of the soil after 34 days. Two sprouts in the scarified, shade treatment reached lengths of 3.0 cm and 5.2 cm root-to-node, and one sprout in the unscarified, shade treatment (skin and pulp removed) reached a length of 4.9 cm root-to-node.

DISCUSSION

Hypsipetes philippinus alone was observed feeding on *Leea* fruits. Few fruits remained on trees or nearby to rot. Since the dye technique failed to detect propagules within a 50-m radius of source trees, dispersal may be medium to long. Further, the bulbul's mean gut passage time (GPT) for *Leea aculeata* (Blume) seeds is 9.5 minutes (Schabacker & Curio 2000). Future studies could compare *H. philippinus* to *Pycnonotus sinensis* (Gmelin) and *P. jocosus* (L.), which disperse seeds across open areas wider than 1 km from forest patches in the Hong Kong hills (Weir & Corlett 2007). The bulbul may similarly spread *Leea* trees between isolated forest patches. We found no direct evidence for mammals feeding on *Leea*, but people from the local Aeta community claim that the monkey *Macaca fascicularis* (Raffles), two civets, *Paradoxurus hermaphroditus* (Pallas) and *Viverra tangalunga* (Gray), and also small bats consume *Leea*

fruits (pers. comm.). Reiter e*t al*. (2006) suggest fruit bats such as *Ptenochirus jagori* (Peters) leave masses of seeds and pulp below roosts within 50 m of sources, making them unlikely candidates given that no such piles were found. Ingle (2003) found fewer cases of bat dispersal (relative to birds) in Mindanao. Future studies could directly test seed dispersal by bats, including *Cynopterus brachyotis* as well as *P. jagori* (Hamann & Curio 1999). Ground-dwelling mammals may nominally feed on *Leea* fruits, but according to Reiter *et al*. (2006), *P. hermaphroditus* always drops *Ficus* fruit remnants near the parent tree, which implies that we would have observed such fragments using the fluorescent dye technique. Hamann & Curio (1999) observed *M. fascicularis* feeding only in primary forests. We detected none of these. Finally, barbed calcium oxalate raphides in *Leea* may deter mammals, which would help to explain why very few fruits were removed from piles placed on the ground (Ward *et al*. 1997, Wen 2007). Methodological improvements could include the use of camera traps rather than direct observation, capturing potential dispersers and comparing fruit choice between *Leea* and other species, and comparing defecated *Leea* seed germination to whole fruits. The low germination rates might have been caused by planting the fruits at excessive depth. Finally, due to monitoring difficulties, the dye technique may be useful only when dispersal distance is short, or when fruits are large and abundant (Levey & Sargent 2000, Reiter *et al*. 2006).

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