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# Notes and records

## Preliminary observations indicate that giant tortoise ingestion improves seed germination for an endemic ebony species in Mauritius

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### Introduction

Native forest in Mauritius has been reduced to patchy degraded fragments and the extinction risk of constituent rare endemic plants is compounded by poor seed germination (Page & D'Argent, 1997; Safford, 1997; Nyhagen *et al.*, 2005). Endemic fruiting plants evolved alongside a number of ecologically important large frugivores that are now extinct, such as the dodo (*Raphus cucullatus* L.) and two species of giant tortoises (*Geochelone inepta* Günther and *Geochelone triserrata* Günther). Seed adaptations required to survive frugivore ingestion intact, such as a thickened seed coat, may in turn prevent germination if the seed is not ingested (Temple, 1977) and result in varying levels of dependency upon ingestion for germination. It is suggested that contemporary poor germination results from partial dependence on ingestion by these extinct frugivores.

The giant tortoise has been shown to be an effective disperser of viable seeds on Aldabra in the Indian Ocean (Hnatiuk, 1978) and seed germination of a tomato variety in the Galapagos is dependent on giant tortoise ingestion (Rick & Bowman, 1961). No study to date, however, has investigated whether giant tortoise ingestion influences the germination success of seeds of endemic Mauritian plant species. Preliminary experimental results are presented here on the effects of tortoise ingestion on seed germination, using the endemic Mauritian ebony *Diospyros egrettarum* Richardson and – as an analogue for the extinct Mauritian tortoises – the Aldabra giant tortoise *Geochelone gigantea* Schweigger.

### Materials and methods

Freshly fallen mature ebony fruits were collected in September 2004 on the offshore islet of Ile-aux-Aigrettes, Mauritius. Seeds from randomly selected fruits were de-pulped and used as the non-ingested control treatment. The remaining fruits were fed to a single 130-kg tortoise as the ingestion treatment and seeds collected when voided after an 18-day gut passage. A separate set of ebony seeds were collected from the dung of other tortoises that had naturally fed on ebony fruits on another part of the island and these seeds were used to check whether germination for the experimental ingestion treatment reliably approximates that of naturally ingested seeds. A secondary factor in giant tortoise seed ingestion is the deposition of dung along with the seeds. To test for the effect of dung, seeds were germinated in two alternative substrates – soil-only or a 50/50 mix of tortoise dung and soil. For each of the two substrates, 100 seeds of each of the three seed sets were sown singly in plug trays. The trays were kept under moderate shade in the Mauritian Wildlife Foundation plant nursery on Ile-aux-Aigrettes and watered daily. Germination date for each seed was defined as the first emergence of any seedling part above the soil. Statistical values on the significance of differences in germination success (% of seeds planted) and germination delay (time taken for half of the final total to germinate) were calculated using the chi-squared test and the z-test, respectively.

### Results and Discussion

The control non-ingested seeds (CE) had a 12% germination success (in both soil and dung) and a germination delay of 61 days (soil) and 77 days (dung). Ingestion treatment (TE) increased germination rate to 42% (soil) and 44% (dung) ( $P < 0.01$ ) and decreased germination delay by almost one-third ( $P < 0.01$  in soil and  $P < 0.05$  in dung) (Table 1). These results suggest that giant tortoise ingestion considerably improves germination of the ebony *D. egrettarum* seed.

Prolific amounts of ebony seeds were also found in the dung of other tortoises elsewhere on Ile-aux-Aigrettes.

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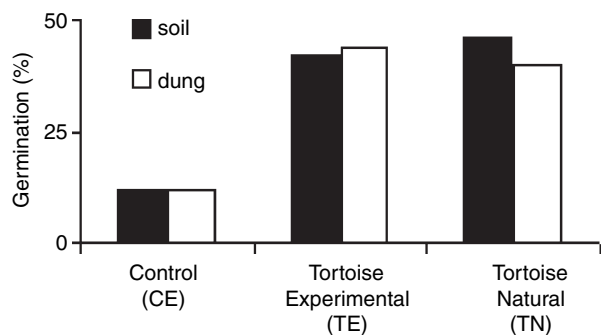
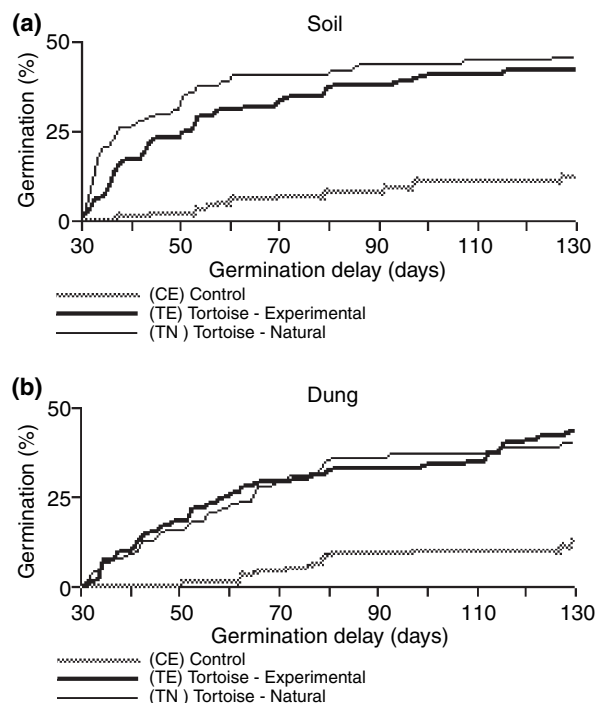
**Table 1** Seed germination and delay of different treatments in 'soil' and 'dung' substrates

|                   | Germination (%) |      | Delay (days) |      |
|-------------------|-----------------|------|--------------|------|
|                   | Soil            | Dung | Soil         | Dung |
| Control (CE)      | 12              | 12   | 61           | 77   |
| Experimental (TE) | 42              | 44   | 44           | 53   |
| Natural (TN)      | 46              | 40   | 37           | 56   |

Germination = final % of seed germinated; delay = days for 50% of final total to germinate; CE, control; TE, experimental tortoise ingestion; TN, natural tortoise ingestion.

Together with dense clusters of small ebony seedlings found at distances over 25 m away from the nearest ebony trees, this offers convincing evidence that tortoises naturally feed on ebony fruit and disperse viable seeds that give rise to seedlings in new locations. Venkatasamy *et al.* (2006) speculate that the extinct giant tortoises and other large frugivores might have played an important role in the dispersal of Mauritius' twelve endemic *Diospyros* species.

The two tortoise-ingested seed sets had equivalent germination success percentage (no statistical difference) (Fig. 1) and only small (although statistically significant,  $P < 0.05$ ) differences in germination delay (Fig. 2). This supports the experimental tortoise ingestion (TE) treatment as providing a reliable approximation for the germination characteristics of naturally occurring tortoise-ingested seeds (TN). Soil or dung substrate had no statistically significant effect on the germination success of any of the seed treatments. Longer germination delays in dung substrate (Table 1) were statistically significant for both sets of tor-

**Fig 1** Germination success (%) for control (CE), experimental tortoise ingestion (TE) and natural tortoise ingestion (TN) seeds in soil and dung**Fig 2** Cumulative germination success for control (CE), experimental tortoise ingestion (TE) and natural tortoise ingestion (TN) seeds in (a) soil and (b) dung

oise-ingested seeds ( $P < 0.05$ ) but not for the control seed treatment. It is suggested that dung may have small effects on seed germination because of the different water retention properties compared with soil.

This study has various limitations. The control treatment non-ingested seeds were manually cleaned of fruit pulp so that they matched the tortoise-ingested seed sets (cleaned of pulp by tortoise digestion) in their exposure to germination conditions – differing only in whether they had passed through a tortoise. Pulp removal, however, means that this treatment does not truly match natural germination conditions – in which ebony seeds would germinate from the decomposing remains of unconsumed fruit (Robertson *et al.*, 2006; Samuels & Levey, 2006). The main limitation of this study is the lack of replicates – a single tortoise is a small sample and no synthetic methods to break down the seed coat (such as hydrochloric acid) were tested. Replicate trials using different tortoises, different years and additional pre-germination treatments would better clarify these observations.

## Conclusion

Despite the various limitations of this preliminary trial, the magnitude of the effects shown strongly supports the suggestion that there are native plants in Mauritius that have evolved degrees of dependence on ingestion (by giant tortoises or other extinct frugivores, such as the dodo) for their seeds to germinate. More extensive research into the effects of ingestion on the germination of native Mauritian plants should be encouraged both for a greater understanding of the original ecology of the island and for improved practical efforts to conserve its threatened endemic flora.

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## References

- HNATIUK, S.H. (1978) Plant dispersal by the Aldabran giant tortoise, *Geochelone gigantea* (Schweigger). *Oecologia* **36**, 345–350.
- NYHAGEN, D.F., TURNBULL, S.D., OLESEN, J.M. & JONES, C.G. (2005) An investigation into the role of the Mauritian flying fox, *Pteropus niger*, in forest regeneration. *Biol. Conserv.* **122**, 491–497.
- PAGE, W. & D'ARGENT, G. (1997) A Vegetation Survey of Mauritius to Identify Priority Rainforest Areas for Conservation Management. Mauritian Wildlife Foundation & IUCN, Mauritius.
- RICK, C.M. & BOWMAN, R.I. (1961) Galapagos tomatoes and tortoises. *Evolution* **15**, 407–417.
- ROBERTSON, A.W., TRASS, A., LADLEY, J.J. & KELLY, D. (2006) Assessing the benefits of frugivory for seed germination: the importance of the deinhibition effect. *Funct. Ecol.* **20**, 58–66.
- SAFFORD, R.J. (1997) A survey of the occurrence of native vegetation remnants on Mauritius in 1993. *Biol. Conserv.* **80**, 181–188.
- SAMUELS, I.A. & LEVEY, D.J. (2006) Effects of gut passage on seed germination: do experiments answer the questions they ask? *Funct. Ecol.* **19**, 365–368.
- TEMPLE, S.A. (1977) Plant-animal mutualism: coevolution with dodo leads to near extinction of plant. *Science* **197**, 885–886.
- VENKATASAMY, S., KHITTOO, G., NOWBUTH, P. & VENCATASAMY, D.R. (2006) Phylogenetic relationships based on morphology among the *Diospyros* (Ebenaceae) species endemic to the Mascarene Islands. *Bot. J. Linn. Soc.* **150**, 307–313.
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