Research article

Seed spitting and seed swallowing by wild orang-utans (*Pongo pygmaeus morio*) in Sabah, Malaysia

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ABSTRACT. Wild orang-utans (*Pongo pygmaeus morio*) studied at the "Kinabatangan Orang-utan Conservation project", Sabah, Malaysia, are mainly frugivorous. They are regularly observed to swallow large seeds (length longer than five mm) from 37 different plant genera and to spit large seeds from 27 plant genera. For three of these genera, we compared the time to first germination, the germination success, the 50% germination time and seedling mortality of seeds that were spat out, swallowed or left unprocessed by orang-utans. Our results show that mean time from planting to germination was shorter and seed germination rate was higher for seeds swallowed or spat than for seeds collected from the parent tree for two tree species (*Dracontomelon dao* and *Koordensiodendron pinnatum*, both species being part of the Anacardiaceae Family). For *D .dao*, germination success was better for seeds that were spat than swallowed, showing the potential importance of seed-cleaning and seed-spitting by orang-utans for certain tree species occurring within the natural orang-utan habitat.

Key words: *Pongo pygmaeus*, seed spitting, seed germination, Sabah
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INTRODUCTION

Seed swallowing has been documented as the most common way for seed dispersal by apes (Wrangham *et al.*, 1994; Chapman & Onderdonk, 1998; Poulsen *et al.*, 2001). The process of seed cleaning by apes (i.e. consumption and removal of the exocarp and of the flesh of the fruit that is found around the endocarp) is also said to provide better germination chances to the seeds (Lambert, 2001). Seed spitting however is commonly seen as playing a minor role for seed dispersal. At Kibale (Uganda), 82% of the fruit species eaten by chimpanzees were swallowed and defecated while seed spitting represented only 7% (Lambert & Garber, 1998). In Borneo, McConkey (2000) reported seeds of 77 species in gibbon feces (i.e. 48% of fruit species eaten) but only four types (or 2.5%) were spat by this species. Orang-utans are described as "gardeners or cultivators of much of their own provisions" in the forest (Rijkseen & Meijaard, 1999) since they have a large gut capacity with variable gut passage time, consume large quantities of fruits from a wide variety of species, and can travel long distances in nearly all types of habitats. At Tanjung Puting (Indonesia), unharmed seeds of 23 species of plants were collected in 94% of orangutan feces, but only 12 types of seeds were spat by orangutans (Galdikas, 1982). Seed-swallowing makes orang-utans efficient seed-dispersers especially for the seeds larger than one cm that are not widely dispersed by other animal species (pigeons, bats, gibbons, hornbills, etc) (Leighton, 1993; Ungar, 1993; Wunderle, 1997). This report investigates the possible role of seed-swallowing and seed-spitting by orang-utans for seed dispersal in the forests of the Lower Kinabatangan, Sabah, Malaysia.

MATERIAL AND METHODS

Eco-ethological studies of wild habituated orang-utans

In Sabah (Malaysia, Borneo), eco-ethological observations of wild orangutans have been conducted since 1998 at a 4-sq km intensive study site (E 118°17' to 118°18'40" - N 5°32'20" to 5°33'30") established in secondary mixed lowland dipterocarp and fresh water swamp forest at different stages of degradation and regeneration (Ancrenaz *et al.*, 2004). Orangutans are followed nest to nest seven days a week by a team of local research assistants. Data are collected on diet composition, activity budget, ranging pattern and social behavior. Species and plant parts eaten by focal individuals are carefully recorded, and food samples are systematically brought back to the KOCP station for further identification by professional botanists from the "Sepilok Forest Research Center" (Sandakan).

Fecal sample collection

We opportunistically collected orang-utan feces from the forest floor during orangutan follows. Feces were placed in clean plastic bags and brought back to the KOCP Field Station. Each sample was then weighed, washed through a one mm mosquito-net wire sieve, and the content was macroscopically analyzed for presence of fibers, leaves, wood, seeds, etc. The abundance of small seeds (less than five mm long) was ranked as absent, rare, common, or abundant. Large seeds (longer than five mm) were extracted, counted and identified to genus level with the assistance from botanists from the Sepilok Forest Research Center. Only large seeds were used in this study (i.e. size longer than five mm long). During observation bouts, we also collected seeds from the forest floor that the focal orang-utans spat, and ripe fruits (originating from the same trees where orangutans were observed eating fruits).

Germination experiments

In order to assess the overall impact of gut processing versus oral processing alone on seed germination characteristics, we conducted a germination experiment with large seeds (more than five mm in length) of three species of fruit that were commonly consumed by orang-utans at the KOCP study site: *Dracontomelon dao*, *Koordersiodendron pinnatum* (Anacardiaceae), and *Microcos crassifolia* (Tiliaceae). Three different types of lots were considered: intact endocarps collected from orang-utan feces, intact endocarps spat by focal orang-utans, and intact ripe fruits collected on the forest floor to obtain a control. For each lot, between one and five intact endocarps or fruits were placed in plastic polybags filled up with clean soil collected from a single location in the forest. The bags were kept in partial shade under natural day-length conditions and were watered as needed. During nine months, we calculated every ten days the germination success (cumulative number of endocarps producing seedlings/number of endocarps planted) and the number of seedlings produced by the multiple seeded endocarps of *D. dao* and *M. crassifolia*. We also determined the 50% germination time (first germination and time taken to reach 50% of the total number of germinated endocarps; see Traveset & Verdu, 2001). and occurrence of the germination plateau. Statistical analyses were carried out with a chi-square test (SSPS).

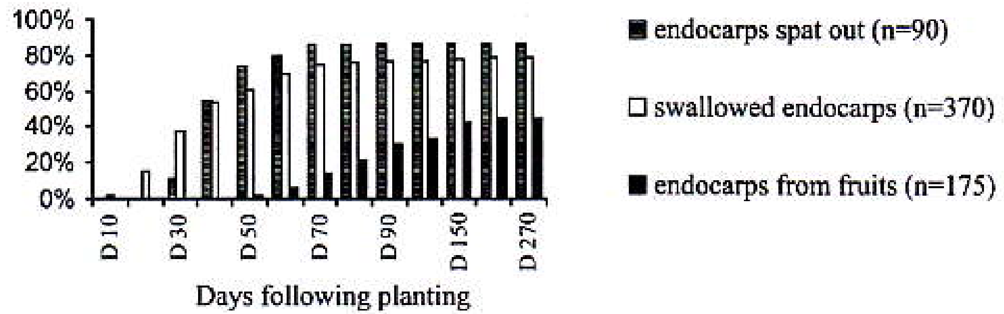
RESULTS AND DISCUSSION

We observed that orang-utans in Kinabatangan consumed fruits of 80 genera of plants and spat seeds of 27 plant genera (33.7% of genera consumed for their fruits), which is the highest rate ever documented for an ape species. During the same period, we collected 197 feces from 11 different individuals living at the KOCP study site. Fragments of seeds (husk, endocarp, exocarp) and intact seeds were found in 97.6% and 61.4% of these feces respectively. A total of 37 different genera of intact seeds (all included in the 80 genera) were identified in all feces (46% of genera consumed for their fruits), 22 genera with seeds longer than one cm. Each fecal sample contained a mean (± Standard Deviation) of one (± 1.02) genus of intact seed (range: 0-5).

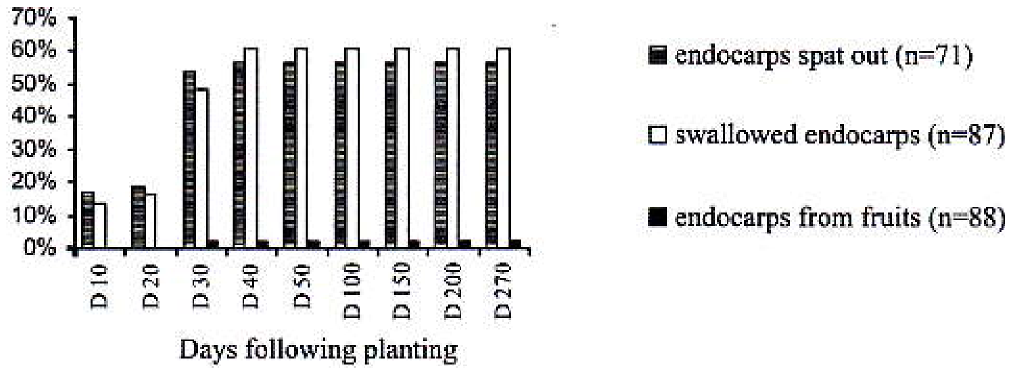
Figure 1 shows the germination success for different sets of seeds. *D. dao* and *K. pinnatum* produce multi-seeded endocarps (with the number of seeds fluctuating from one to three per single fruit). This ecological trait explains why it is possible to obtain more seedlings than the number of endocarps that was planted.

The extreme low germination recorded for fruits of *K. pinnatum* could indicate that fruits collected on the forest ground suffered from seed predation or fungus attack, or were fertilized by self-pollination. They were not suitable as a control and were not considered in our statistical analysis. These results show that it is always a problem to collect control seeds and that ideally, they should originate from mature fruits collected directly in the tree crown. According to Traveset and Verdu (2001), latency should be considered significantly different only if two treatments differed by at least four weeks since shorter periods are unlikely to be biologically meaningful. For *D. dao*, the 50% germination time of swallowed seeds occurs at 33 days, for spat seeds at 45 days and for fruits at 81 days, showing a significant delay for fruit germination compared to the two other groups. Overall, germination success at day 270 was not significantly influenced by the way seeds were processed by orang-utans: *D. dao* (78.4% for seed-spitting; 86.7% for seed-swallowing: χ^2=2.43, p>0.1); *K. pinnatum* (56.3% and 60.9%: χ^2 = 0.52, p>0.3); *M. crassifolia* (25.8% and 21.5%: χ^2 = 1.06, p>0.3). For *D. dao*, more seedlings were produced by multi-seeded endocarps spat (127.7%) than swallowed (94.6%), but this result was significantly different at p=0.1 only (χ^2 = 3.61). When combined together, endocarps of *D. dao* that were processed by orangutan produced more seedlings than fruits (101.1% against 49.7%: χ^2 = 24.1, p<0.001). Conversely, more seedlings were produced with fruits of *M. crassifolia* (130%) than with endocarps processed by orang-utans (23.9%): χ^2 = 72.96, p<0.001).

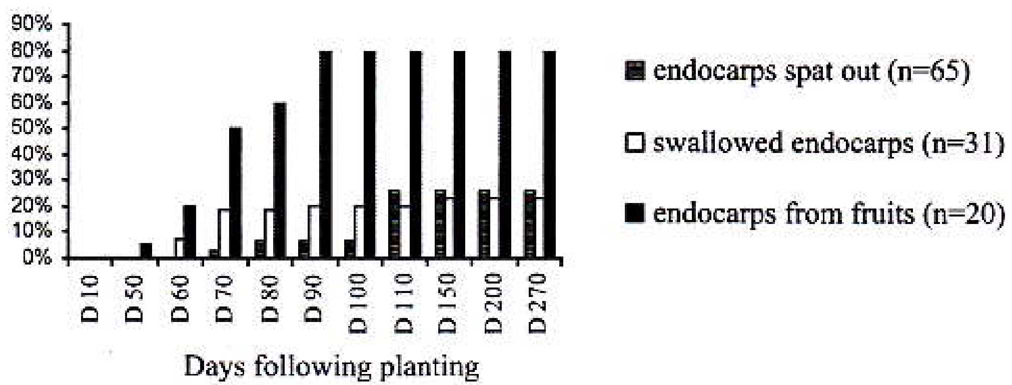
In our study, almost all orang-utan feces contained seed fragments, showing the potential seed predator role of this species for several plants. However, orang-utans swallowed whole seeds of at least 37 genera and spat seeds of 27 plant genera that were viable for germination, making them potential seed dispersers for many tree species. The highly prehensile, mobile and muscular lips of orang-utans facilitate food processing, rapid fruit flesh ingestion and seed-spitting (Galdikas, 1982) and have been functionally compared to the cheeckpouches of Cercopithecinae (Walker, 1979). Our experiment showed that spitting and swallowing had a similar effect on seed germination in three plant species regularly consumed by wild orang-utans in the lower Kinabatangan. Although



(a) *Dracontomelon dao*



(b) *Koordensiodendron pinnatum*



(c) *Microcos crssifolia*

Figure 1. Germination success for seeds spat, swallowed and unprocessed by orang-utans

seed cleaning is not clearly understood, it has been proposed to reduce seed mortality through the decrease of fungal attack in the plant-guenon relationship, *Strychnos mitis - Cercopithecus ascanius* (Lambert, 2001). Most probably, the two types of orangutan seed-handling (seed-swallowing and seed-spitting) increases the range of opportunities for seeds to be deposited in a micro-habitat suitable to seedling establishment. However, the often complex interaction between biotic and abiotic factors in influencing germination success and latencies requires that the effect of each seed disperser species is considered separately for each plant species (Garwood, 1983). Testing the fate of seeds swallowed or spit out by orang-utans was beyond the scope of this study and would require longer-term studies for determining the actual contribution of orang-utans to forest regeneration.

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