
Elephants as seed dispersal agents in Arabuko-Sokoke Forest, Kenya

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Abstract

Seed dispersal by elephants (*Loxodonta africana*) in Arabuko-Sokoke Forest was studied by examining their dung piles for seeds or fruit remains and from seedlings that germinated from dung. Seeds were recovered from 64.5% of the elephant dung piles examined between August 1996 and October 1997. Seeds of 42 plant species were distinguishable in elephant dung. At least 52 plant species germinated naturally from elephant dung in Arabuko-Sokoke Forest. Seedlings of 84 plant species germinated from irrigated elephant dung. Our study showed that elephants are important seed dispersal agents in this ecosystem. Since cultivated crops comprise part of the elephant diet here, this constitutes a source of conflict with the local community.

Résumé

On a étudié la dispersion des graines par les éléphants (*Loxodonta africana*) dans la Forêt d'Arabuko-Sokoke, en examinant les restes de graines et de fruits dans les crottes et les jeunes plants qui y germaient. On a trouvé des graines dans 64,5% des crottes d'éléphants examinées entre août 1996 et octobre 1997. On a pu identifier des semences de 47 espèces végétales dans les crottes. Au moins 52 espèces végétales ont germé dans les crottes d'éléphants dans la forêt d'Arabuko-Sokoke. On a pu faire pousser des plants de 84 espèces en arrosant des crottes d'éléphants. Notre étude montre que les éléphants sont des agents importants pour la dispersion des semences dans cet écosystème. Etant donné que les plantes cultivées composent une partie du menu des éléphants, ceci constitue une source de conflit avec la communauté locale.

Introduction

Fruits form an important component of elephant (*Loxodonta africana* Blumenbach 1797) diet in forest environments (Wing and Buss 1970; Short 1983; Tchamba and Seme 1993; White et al. 1993; White 1994) and have a marked influence on their ranging patterns (Short 1983). Consequently, seeds of many plant species are found in elephant dung (Merz 1981; Tchamba and Seme 1993; White et al. 1993). Pas-

sage of seeds through an animal's gut increases the speed and probability of germination (Estrada and Coates-Estrada 1984; Idani 1986; Chapman et al. 1992; Wrangham et al. 1994). The quantity of seeds in elephant dung can reveal the importance of cultivated crops in elephants' diet (Tchamba and Seme 1993). Fruits are important in elephant diet in Arabuko-Sokoke Forest, and elephants may be playing an important role as seed dispersal agents in the forest.

Materials and methods

Study area

Arabuko-Sokoke Forest (fig. 1) is in Kilifi and Malindi Districts, Coast Province, Kenya at 3° 50' to 3° 10' S and 39° 50' to 40° E. It lies along the Mombasa–Malindi highway between Kilifi and Malindi towns and has an area of approximately 400 km² including forest plantations. The forest experiences two rainy seasons, the long rains (late March to June) and the short rains (October to December), with the annual mean rainfall ranging from 900 mm to 1100 mm. The driest period is between January and March. Monthly average temperatures range from 27° C to 30° C (Fairclough et al. 1995). The vegetation of the forest can be classified into three broad categories: *Brachystegia*, *Cynometra* and mixed forests (fig. 1). In addition, forest plantations cover 800 hectares. The forest supports a diverse fauna (Britton and Zimmerman 1979; Dreves 1992; Chira unpubl.; Fairclough et al. 1995).

Recovery of seeds from elephant dung

From August 1996 to October 1997, 736 elephant dung piles were examined for seeds and fruit fragments. Samples ranged from 27 to 85 dung piles per month.

Germination of seeds from elephant dung

Natural germination of seedlings in elephant dung. Seedlings that naturally germinated in 176 ele-

phant dung piles were recorded in November 1996 and May 1997.

Germination experiments. From November 1996 to October 1997, 30 fresh elephant dung piles per month (33 in January and February 1997) were taken to the Kenya Forestry Research Institute tree nursery at Gede Forest Station. They were sown on individual plots and watered daily. The sample plots were inspected every week for about three months and the seedlings that germinated identified.

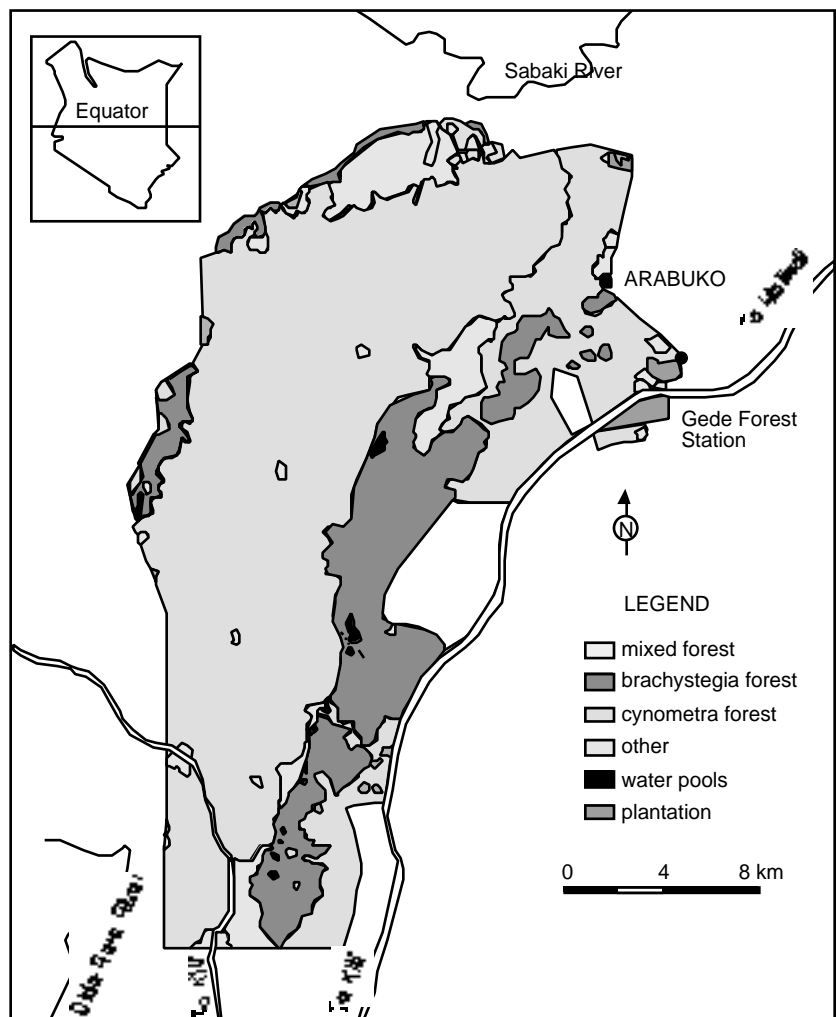


Figure 1. Map of Arabuko-Sokoke Forest showing vegetation types. Inset indicates the position of Arabuko-Sokoke Forest in Kenya.

Results

Prevalence and species diversity of seeds in elephant dung

Seeds were recovered from 64.5% ($n = 736$) of the elephant dung piles examined between August 1996 and October 1997. Seeds of 42 plant species were distinguishable in the dung (table 1). Plant species whose seeds occurred in dung frequently over the months were those of *Balanites wilsoniana* (11 months), *Grewia holstii* (7 months) and *Landolphia kirkii* (6 months). Fruit use was low from March to May 1997. In May 1997, none of the dung piles had fruit remains or seeds. Several cultivated crops constituted part of elephant diet in this period; these included maize (*Zea mays*), mango (*Mangifera indica*), cowpea (*Vigna unguiculata*) and cashewnut (*Anacardium occidentale*).

Germination of seeds from elephant dung

At least 52 species germinated naturally from the elephant dung in Arabuko-Sokoke Forest (table 2). How-

ever, some of the seedlings could not be identified to species level because they were damaged before they were big enough to be positively identified. Seeds of *Kedrostis leloja* germinated 22%, *Grewia holstii* 20%, *Rytigynia* spp. 19% and *Carica papaya* 11%. Cultivated crops that germinated naturally from the elephant dung were papaya, watermelon and pigeonpea (*Cajanus cajan*); under improved nursery conditions, 84 plant species germinated (table 3). The number of species that germinated was lowest from February 1997 to July 1997 and again in October 1997. Seedlings of cultivated crops that germinated included guava (*Psidium guajava*), papaya (*Carica papaya*), mango, cashewnut, maize, watermelon (*Citrullus lanatus*) and cowpea.

Discussion

In our study, seeds or fruit remains were recovered in 64.5% ($n = 736$) of all the dung piles examined. Other studies show a similar situation. For example, 82% ($n = 311$) of the dung piles examined at Lopé Reserve, Gabon, contained fruit remains (White et al. 1993). In that study, elephants fed on fruits of 72 plant

Table 1. Frequency at which seeds were recovered from elephant dung from August 1996 to October 1997 in Arabuko-Sokoke Forest ($n = 736$ dung piles)

Plant species	Dung piles with seeds (%)	Plant species	Dung piles with seeds (%)
<i>Grewia holstii</i>	19.6	<i>Strychnos panganensis</i>	0.7
<i>Balanites wilsoniana</i>	13.7	<i>Tephrosia pumila</i>	0.5
<i>Mangifera indica</i> *	13.7	<i>Lecaniodiscus fraxinifolius</i>	0.5
<i>Landolphia kirkii</i>	7.1	<i>Vitex ferruginea</i>	0.3
<i>Psychotria amboniana</i>	5.6	<i>Salacia</i> spp.	0.3
<i>Manilkara sulcata</i>	4.3	<i>Cajanus cajan</i> *	0.3
<i>Zea mays</i> *	3.9	<i>Commelina</i> spp.	0.3
<i>Croton pseudopulchellus</i>	3.5	<i>Crotalaria laburnifolia</i>	0.1
<i>Uvaria acuminata</i>	3.0	<i>Dichrostachys cinerea</i>	0.1
<i>Rytigynia</i> spp.	3.0	<i>Grewia stuhlmannii</i>	0.1
<i>Strychnos spinosa</i>	1.8	<i>Carica papaya</i> *	0.1
<i>Grewia plagiophylla</i>	1.8	<i>Strychnos madagascariensis</i>	0.1
<i>Anacardium occidentale</i> *	1.8	<i>Heinsia crinata</i>	0.1
<i>Monanthes fornicata</i>	1.6	<i>Brachystegia spicaeformis</i>	0.1
<i>Vigna unguiculata</i> *	1.4	<i>Kedrostis leloja</i>	0.1
<i>Cissus</i> spp.	1.0	<i>Drypetes reticulata</i>	0.1
<i>Tamarindus indica</i>	0.8	Unidentified (7 species)	
<i>Acacia brevispica</i>	0.8		

* cultivated crop. Unidentified species were distinguished as different species based on characteristics like morphology, colour and texture.

Table 2. Seedlings that germinated naturally from elephant dung in Arabuko-Sokoke Forest ($n = 176$ dung piles)

Plant	Seeds (no.)	Piles with seeds (%)
<i>Acacia brevispica</i>	1	0.6
<i>Anacardium occidentale</i> *	1	0.6
<i>Balanites wilsoniana</i>	4	0.6
<i>Boerhaavia</i> spp.	2	0.6
<i>Cajanus cajan</i> *	1	0.6
<i>Carica papaya</i> *	38	10.8
<i>Cissus</i> spp.	7	2.3
<i>Citrullus lanatus</i> *	7	2.3
<i>Commelina</i> spp.	55	9.1
<i>Croton pseudopulchellus</i>	41	1.1
<i>Flueggea virrosa</i>	7	4.0
<i>Grewia holstii</i>	115	19.9
<i>Grewia sulcata</i>	18	3.4
<i>Indigofera trita</i>	3	1.1
<i>Kedrostis leloja</i>	147	22.2
<i>Manilkara sulcata</i>	1	0.6
<i>Phyllanthus reticulata</i>	1	0.6
<i>Rytigynia</i> spp.	552	18.8
<i>Solanum incanum</i>	19	5.7
<i>Strychnos spinosa</i>	6	3.4
<i>Tephrosia pumila</i>	11	4.5
<i>Tremnus labialis</i>	6	2.8
Unidentified (30 species)	87	

* cultivated crop. Unidentified species were distinguished as different species based on characteristics like morphology, colour and texture.

species. Merz (1981) found that elephants at Tai National Park, Ivory Coast, fed on fruits of 44 plant species. Short (1983) documented large-scale migration of elephants in response to seasonal fruiting patterns. At Santchou Reserve, Western Cameroon, 65% of all dung piles examined ($n = 250$) had some trace of fruits with 22 plant species being recorded (Tchamba and Seme 1993).

The large number of plant species whose seeds were found in elephant dung and that germinated implies that elephants contribute to seed dispersal in Arabuko-Sokoke Forest. However, germination success for *Balanites wilsoniana* was low. Its seeds were encountered in 20% ($n = 736$) of all dung piles examined but germinated naturally in only one ($n = 176$ dung piles); even under improved conditions, its seeds germinated in only five ($n = 366$). Chapman et al. (1992) demonstrated that passage of these large seeds through elephants greatly improved their germination success. Further research on the dispersal and germi-

nation of this seed in the forest is needed.

Other studies have shown that mammals are important seed-dispersal agents in tropical forests (Estrada and Coates-Estrada 1984; Chapman et al. 1992; White 1994; Feer 1995). Seed-dispersing mammals concentrate seeds of diverse plant species in their dung (Tchamba and Seme 1993; White et al. 1993; Wrangham et al. 1994; Remis 1997). Passage of seeds in animal gut increases their speed and probability of germination. This has been demonstrated in many animals including howler monkeys (Estrada and Coates-Estrada 1984), birds (Barnea et al. 1990), elephants (Chapman et al. 1992), pygmy chimpanzee (Idani 1986), baboons (Lieberman et al. 1979), chimpanzees (Wrangham et al. 1994) and gorillas (Voysey et al. 1999 a,b). Some plant species rely almost exclusively on one animal disperser (Chapman et al. 1992; White 1994). It is important to find out whether there are plant species in the forest that are exclusively

dispersed by elephants. This would help in designing conservation policies for the forest.

Seeds from maize, cowpea, cashewnut and mango were recovered from elephant dung, and seedlings of guava, papaya, mango, cashewnut, maize, watermelon, and cowpea were germinated. This substantiates community claims that elephants do invade their cultivated crops. Examination of elephant dung and germination of seedlings from it can provide useful information about the role of cultivated crops in elephant diet.

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Table 3. Plants that germinated from irrigated elephant dung in Arabuko-Sokoke Forest from November 1996 to October 1997 ($n = 366$)

Plant species	T	Pw (%)	Plant species	T	Pw (%)
<i>Landolphia kirkii</i>	463	15.0	<i>Hibiscus</i> sp.	7	0.8
<i>Psidium guajava</i> *	103	6.3	<i>Indigofera hirsuta</i>	7	1.4
<i>Tremnus labialis</i>	97	1.9	<i>Polysphaeria parviflora</i> .	6	1.1
<i>Flueggea virosa</i>	73	8.2	<i>Garcinia livingstonei</i>	5	1.4
<i>Hoslundia opposita</i>	59	1.9	<i>Ximenia americana</i>	5	0.3
<i>Ficus sycomorus</i>	57	12.6	<i>Cajanus cajan</i> *	5	0.3
<i>Solanum incanum</i>	57	6.6	<i>Anacardium occidentale</i> *	4	0.8
<i>Strychnos spinosa</i>	56	4.6	<i>Haplocelum inopleum</i>	4	0.8
<i>Trema orientalis</i>	49	9.0	<i>Chamaecrista</i> sp.	4	0.8
<i>Rhynchosia</i> spp.	44	4.9	<i>Indigofera vohemarensis</i>	3	0.6
<i>Kedrostis leloja</i>	42	4.6	<i>Ipomoea</i> spp.	3	0.6
<i>Salacia</i> spp.	42	0.8	<i>Manilkara sulcata</i>	3	0.6
<i>Commelina</i> spp.	40	6.6	<i>Asystasia gengetica</i>	3	0.8
<i>Drypetes reticulata</i>	40	3.4	<i>Mundulea sericea</i>	2	0.6
<i>Grewia holstii</i>	33	5.7	<i>Hibiscus micranthus</i>	2	0.6
<i>Cissus</i> spp.	24	6.0	<i>Acacia adenocalyx</i>	2	0.3
<i>Agathisanthemum bojeri</i>	22	3.3	<i>Maerrua tryphylla</i>	2	0.3
<i>Carica papaya</i> *	22	1.9	<i>Zea mays</i> *	2	0.6
<i>Indigofera trita</i>	21	3.3	<i>Vigna unguiculata</i> *	2	0.6
<i>Bourreria petiolaris</i>	20	4.1	<i>Manilkara zansibarensis</i>	2	0.6
<i>Citrullus lanatus</i> *	20	2.5	<i>Teclea trichocarpa</i>	2	0.6
<i>Metaporana densiflora</i>	19	1.6	<i>Nesogordonia africana</i>	1	0.3
<i>Phyllanthus reticulatus</i>	15	2.5	<i>Ficus tremula</i>	1	0.3
<i>Celosia hirsuta</i>	15	1.9	<i>Dichrostachys cinerea</i>	1	0.3
<i>Acacia brevispica</i>	13	1.1	<i>Abutilon mauritianum</i>	1	0.3
<i>Tephrosia pumila</i>	13	2.7	<i>Psychotria amboniana</i>	1	0.3
<i>Balanites wilsoniana</i>	13	1.4	<i>Kitia</i> spp.	1	0.3
<i>Monanthes taxifolia</i>	12	2.2	<i>Crotalaria laburnifolia</i>	1	0.3
<i>Allophyllus alnifolius</i>	8	0.8	<i>Ruellia prostrata</i>	1	0.3
<i>Mangifera indica</i> *	8	1.4	<i>Rytigynia</i> sp.	1	0.3
<i>Guatenbergia pembensis</i>	7	1.6	Unidentified species (23 species)	104	

T – number of seedlings that germinated; Pw – percentage of dung piles in which seedlings germinated; * cultivated crop. Unidentified species were distinguished as different species based on characteristics like morphology, colour and texture.

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Erratum: In issue no. 29, p. 50, table 1 of the field note 'Population estimate of elephants in Arabuko-Sokoke Forest': the range for elephants in the first row of the last column should read 111–144 (not 111–114).