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A Study on the Seed Dispersal Capability of Asian Elephants in the Northwestern Region of Sri Lanka

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Introduction

Herbivores are shown to be involved in seed dispersal of many plant species. Thus they will have an impact on habitat quality and maintenance. Elephants are megaherbivores that consume a large amount of plant matter including fruiting bodies. Further, they have large home ranges and therefore can disperse seeds over long distances. Many studies have demonstrated that African elephants play a major role in dispersal of seeds of a number of plant species (Short 1981; Keon 1983; Lieberman *et al*. 1987; Dudley 1999; Cochrane 2003). Further, Cochrane (2003) has demonstrated that seed dispersal of *Balanites wilsoniana* is dependent on African elephants. In contrast to African elephants very few studies have been done on the seed dispersal capability of Asian elephants (Vinod & Cheeran 2000; Kitamura *et al.* 2007).

In Sri Lanka, even though there are several studies on the feeding behavior of Asian elephants (Mueller-Dombois 1972; McKay 1973; Vancuylenberg 1977; Ishwaran 1983), studies on seed dispersal by elephants are lacking, except for one study on the effect of changes in gut passage time due to seasonal differences in diet and its impact on seed dispersal distance (Campos-Arceiz *et al.* 2007). The aim of this investigation was to identify the seeds that are dispersed by Asian elephants and to determine the germination potential of these seeds under different conditions to determine the role of Asian elephants on dispersal of seeds of the dominant plant species identified in the area.

Materials and methods

Study area

The study area is located in the northwestern region of Sri Lanka encompassing the Mahaweli system H and adjoining areas. The study area is demarcated by the towns of Puttalam in the East, Mahawa in the South, Habarana in the West, and Anuradhapura in the North. The extent of the study area is approximately 3000 km^2 and includes 15 administrative divisions.

Identification of plant seeds in elephant dung

A total of 145 dung piles from different parts of the study area were examined. From each dung pile examined, two boli were placed in a tray and separated by hand. All the intact seeds or seed fragments present were removed and placed in a sample vial. These seeds were identified subsequently by comparing it with the reference collection of plant seeds constructed from both cultivated and non-cultivated plant species found in the area.

Determination of germination potential in situ

If seeds were found during macroscopic analysis of two boli from a dung pile, some of the remaining dung boli were left in the same location, marked and observed until the boli decayed completely. In order to determine the effect of shade, dung piles were selected from shaded habitats as well as open habitats and the experiment was carried out both during the dry season and wet season. Therefore, in situ germination potential was investigated under four conditions, namely wet open (n=50), wet shade (n=80), dry open (n=52) and dry shade (n=75).

Determination of germination potential ex situ

If seeds were found during macroscopic analysis of the two boli from a dung pile, a dung bolus was removed and placed in a green house. First, the affect of disintegration on germination of

seeds was tested with 10 replicates for each treatment. Second, all six conditions were tested under green house conditions, namely shade vs. open, broken vs. intact boli, with watering vs. without watering, resulting in eight experimental combinations. Five replicates were assigned to each combination. In both the experiments dung boli were assigned randomly to each experimental condition.

Determination of germination potential of seeds removed from dung

Elephant dung contains large amounts of undigested material, which may interfere with the germination of the seeds. Therefore to determine the germination potential of seeds in the absence of dung, seeds removed from elephant dung were placed in plastic cups containing soil that had been exposed to steam for 30 min. Then the plastic cup was placed in a green house and watered daily for 14 days. Seeds of 10 plant species (*Tamarindus indica, Drypetes gardneri, Bauhinia racemosa, Panicum maximum, Clitoria ternatea, Elusine coracana, Cucurbita maxima, Oryza sativa, Cucumis melo* and *Capsicum annum*) were selected for this study based on the density of seeds present in elephant dung, habit of the plant and occurrence (cultivated vs. natural). A total of 10 seeds were tested from each plant species selected.

Relative abundance of indigenous plants

In order to determine whether elephants play a major role in dispersal of dominant plant species found in the natural habitats of the study area, the relative abundance of plant species present in the area was determined. A total of 111 transects, each 1 km x 5 m, were carried out in different regions of the study area. The relative abundance of a given plant species was determined based on the number of transects in which the plant was recorded relative to the total number of transects carried out.

Results

Out of the 145 dung piles examined 107 (74%) contained seeds of one or more plant species. A total of 188 seed groups were recovered from these 107 dung piles. Majority of the seeds

Table 1. List of non-cultivated plant species whose seeds were observed in elephant dung (n=145).

Family	Scientific name	Vernacular name	Habit*	RA**	# dung piles
Euphorbiaceae	*Drypetes gardneri*	Eta wira	T	0	6
Fabaceae	*Aeschynomene indica*	Diya siyambala	H	17	1
	Alysicarpus vaginalis	Aswenna	H	0	1
	Atylosia scarabaeoides	Wal kollu	C	0	3
	Bauhinia racemosa	Maila	T	81	3
	Cassia tora	Peti tora	S	66	6
	Clitoria ternatea	Katarodu	C	23	1
	Indigofera tinctoria	Nil awari	H	0	5
	Mimosa pudica	Nidikumba	H	78	6
	Tamarindus indica	Siyambala	T	41	22
Hernandiaceae	*Hernandia nymphaeifolia*	Palatu	T	0	1
Myrtaceae	*Syzygium gardneri*	Damba	T	0	1
Nymphaeaceae	*Nymphaea nouchali*	Manel	H	3	1
	Nymphaea pubescens	Olu	H	35	9
Passifloraceae	*Passiflora fitida*	Dal batu	C	49	2
Poaceae	*Cymbopogon nardus*	Heen pengiri	H	13	1
	Eleusine indica	Bela-tana	H	0	5
	Panicum curviflorum	Meneri-thana	H	0	1
	Panicum maximum	Guinea tana	H	51	12
	Pennisetum spicatum	Bajiri	H	0	8

* T = tree, H = herb, C = climber, S = shrub

** RA = relative abundance of each species calculated based on % occurrence in 111 transects

Table 2. List of cultivated plant species whose seeds were observed in elephant dung (n=145).

Family	Scientific name	Vernacular name	Habit*	# dung piles
Anacardiaceae	*Mangifera indica*	Amba	T	2
Cucurbitaceae	*Benincasa hispida*	Alu puhul	C	2
	Cucumis melo	Kekiri	C	11
	Cucurbita maxima	Wattaka	C	3
	Lagenaria siceraria	Diya labu	C	1
Fabaceae	*Arachis hypogaea*	Rata kadju	H	1
	Vigna unguiculata	Cowpea	C	2
	Vigna marina	Me karal	C	1
Poaceae	*Eleusine coracana*	Kurahan	H	16
	Oryza sativa	Wee	H	16
	Panicum miliaceum	Meneri	H	1
	Zea mays	Bada iringu	H	4
Solanaceae	*Capsicum annum*	Miris	H	10
	Solanum melongena	Ela batu	H	1

* T = tree, C = climber, H = herb

tend to pass through the gut undamaged except for large seeds which showed signs of damage. Out of these, 22 seed groups (12%) could not be identified. Of the remaining 166 seed groups 95 (50%) belonged to non cultivated plant species (Table 1) while the remaining 71 (38%) belonged to cultivated varieties (Table 2). The 22 unidentified seed groups were represented by 10 species of plants. The 95 seed groups of non cultivated plants were represented by 20 species of plants while the 71 seed groups from cultivated plants were represented by 14 species.

Majority of the seeds (55%) of non cultivated plants were from herbaceous plant species followed by trees (25%), climbers (15%), and shrubs (5%). In the case of cultivated plant species once again the majority of the seeds belonged to herbaceous plants (50%) followed by climbers (42%) and trees (8%). Seeds belonging to only three dominant plant species (*Bauhinia racemosa*, *Cassia tora* and *Panicum maximum*) of the open scrub/ grass mosaic occupied by these elephants were found in their dung.

In situ germination trial no seed germination was observed in the 127 dung boli tested during the dry season. However, during the wet season seed germination was observed in 23% of the dung boli tested (Table 3). Further, germination was found to be higher (40%) in dung boli left in the open area (Fig. 1) compared to the dung boli left in the shade (13%).

The impact of disintegration of the dung bolus on seed germination potential was tested under green house conditions which indicated that germination potential increases (Table 4) when the dung bolus is broken (70%) compared to intact dung boli (20%).

When all three conditions were tested under green house conditions seed germination was observed in watered dung piles irrespective of whether the dung was kept in shade or open areas. No major difference was observed between broken and intact boli when water is present. However, in the trials without water overall germination rate was only 5% compared to 35% overall germination rate observed in the with water trials.

Out of the 10 plant species tested for the germination potential of seeds removed from the elephant dung, seeds belonging to seven plant species showed germination. Highest germination ability was shown by *Cucurbita maxima* (70%) followed by *Oryza sativa* (60%),

Table 3. Comparison of the in situ germination potential of seeds in intact dung boli kept in open and shaded areas during wet and dry season.

Treatment		n	# dung boli
dry season	shade	75	no germination
	open	52	no germination
wet season	shade	80	10
	open	50	20

Clitoria ternatea (30%) and *Eleusine coracana* (30%), *Cucumis melo* (20%), *Capsicum annum* (20%), *Panicum maximum* (10%), *Bauhinia racemosa* (10%). Seeds of *Drypetes gardneri* and *Tamarindus indica* did not germinate at all.

The major habitat type seen in the study area can be defined as open scrub which is evident in the composition of the dominant plant species observed in the area (Table 5). The plant assemblage was dominated by shrub species (44%) followed by trees (28%) which forms an open canopy and herbaceous plants (20%) makes up the lower layer. Few species of climbers (10%) were observed associated with the tall trees.

Table 4. A comparison of the germination potential of seeds in dung boli tested under various conditions in a green house.

Treatment			n	# boli	# plants
Broken			10	7	10
Intact			10	2	4
Shade	water	broken	5	2	4
		intact	5	2	3
	no water	broken	5	1	1
		intact	5		
Sun	water	broken	5	1	1
		intact	5	2	5
	no water	broken	5		
		intact	5		

Discussion

Approximately 75% of the dung piles examined in this study contained seeds belonging to one or more plant species. Altogether seeds belonging to 44 species of plants were discovered in elephant dung. Out of these, 14 species can be classified as cultivated plants. This may have resulted due to raiding of crops or stored grain. However, our observations indicate that elephants do graze in fallow chenas (slash-and-burn agriculture fields) where a substantial number of plants with fruiting bodies remain even after the farmer has abandoned the chena. Therefore, presence of seeds of cultivated plant varieties cannot be ascribed to crop raiding alone.

Majority, of the seeds that belonged to non-cultivated plant species were of herbaceous plants. Seeds belonging to only four tree species were found in elephant dung during this study. Of these four species, seeds of *Tamarindus indica* made up nearly 25% of all the identifiable seeds of non-cultivated species. However, subsequent germination studies indicate that these seeds do not germinate readily even after removal from the dung. Perhaps, the period of observation (14 days) may have not been long enough for germination to take place as some plant seeds take a longer period for germination.

Figure 1. Germination of *Cucurbita maxima* seed in a disintegrated elephant dung pile deposited in an open area during the rainy season.

Seeds belonging to only three dominant plant species (*Bauhinia racemosa*, *Cassia tora* and *Panicum maximum*) of the open scrub/ grass mosaic occupied by these elephants were found in their dung. The other plant species whose seeds were present in elephant dung were relatively rare. Therefore, it can be concluded that elephants do not play a major role in seed dispersal of the dominant plant species in the scrub/grass mosaic habitat occupied by them. Further, germination study also supports this hypothesis as the seeds that readily germinate in elephant dung were non-recalcitrant seeds that belonged mostly to herbaceous species. However, the habitat occupied by the elephants in this study is a scrub/grass mosaic, which can be defined as an early seral stage resulting due to high human activity. Therefore, care should be taken when extrapolating these results to elephants inhabiting climax vegetation. A similar study focusing on elephants inhabiting natural

Table 5. Dominant plant species (recorded in 50% or more of the 111 transects) in the study area.

Classification	Scientific name	Common name	Habit*	Total	%
Fabaceae	*Cassia fistula*	Ehela	T	55	50
Poaceae	*Panicum maximum*	Rata tana	S	57	51
Asteraceae	*Vernonia zeylanica*		H	58	52
Asteraceae	*Xanthium indicum*	Urukossa	S	58	52
Typhaceae	*Typha angustifolia*	Hambupan	S	59	53
Sapindaceae	*Lepisanthes tetraphylla*	Dambu	T	60	54
Amaranthaceae	*Achyranthes aspera*	Gas karal heba	H	61	55
Amaranthaceae	*Aerva lanata*	Polpala	H	61	55
Ulmaceae	*Holoptelea intergrifolia*	Godakirilla	T	64	58
Asteraceae	*Vernonia cinerea*		H	65	59
Fabaceae	*Pongamia pinnata*	Karanda	T	65	59
Sapindaceae	*Schleichera oleosa*	Koon	T	65	59
Convolvulaceae	*Ipomoea obscura*	Tel kola	C	67	60
Fabaceae	*Derris scandens*	Kala wel	C	69	62
Malvaceae	*Hibiscus vitifolius*	Maha epala	S	70	63
Malvaceae	*Sida acuta*	Gas bavila	S	71	64
Rubiaceae	*Mitragyna tubulosa*	Helamba	T	71	64
Fabaceae	*Cassia occidentalis*	Peni thora	S	72	65
Fabaceae	*Cassia tora*	Pethi thora	S	73	66
Fabaceae	*Dichrostachys cinerea*	Andara	S	74	67
Verbenaceae	*Lantana camara*	Gandapana	S	74	67
Asclepiadaceae	*Calotropis gigantea*	Wara	S	75	68
Moraceae	*Streblus asper*		T	75	68
Combretaceae	*Terminalia arjuna*	Kumbuk	T	76	68
Myrtaceae	*Syzygium cumini*	Madan	T	76	68
Fabaceae	*Tephrosia purpurea*	Pila	H	78	70
Malvaceae	*Abutilon indicum*		S	81	73
Asteraceae	*Mikania cordata*	Wathu palu	C	86	77
Euphorbiaceae	*Croton laccifer*	Keppetiya	S	86	77
Euphorbiaceae	*Phyllanthus reticulatus*	Kaila	S	86	77
Fabaceae	*Mimosa pudica*	Nidi kumba	H	87	78
Rhamnaceae	*Ziziphus oenoplia*	Heen-eraminiya	S	87	78
Tiliaceae	*Grewia orientalis*	Keliya	S	87	78
Cyperaceae	*Cyperus spp.*	Pan	H	88	79
Cyperaceae	*Fimbristylis spp.*	Pan	H	90	81
Fabaceae	*Bauhinia racemosa*	Maila	T	90	81
Meliaceae	*Azadirachta indica*	Kohomba	T	98	88
Asteraceae	*Eupatorium odoratum*	Podi-singho maran	S	100	90
Euphorbiaceae	*Flueggea leucopyrus*	Katupila	S	101	91

* T = tree, H = herb, C = climber, S = shrub

vegetation is needed before a final conclusion can be arrived at, regarding the role of Asian elephants as a seed dispersal agent.

Most of the seeds present in the dung are capable of germination. Yet only few seeds germinated under natural conditions. Presence of water is the main factor that determines the seed germination in elephant dung. Seeds present in the dung deposited during the rainy season germinated readily while no seed germination was observed in the dung piles deposited during the dry season. However, seeds present in the dung deposited in the dry season may remain dormant till the next rainy season before they begin to germinate. This hypothesis could not be tested during this study as all the dung piles deposited during the dry season decayed completely before the onset of the rainy season. Further, dung piles left in open areas showed a high germination rate compared to dung piles left in the shade. A similar situation is reported by Cochrane (2003) for *Balanites wilsoniana*.

Disintegration of dung piles also resulted in a higher rate of germination compared to intact dung boli. Disintegration of dung piles in nature is determined by number of factors such as rain and animal assemblage in the area as some animals such as jungle fowl, and mongooses tend to break up the dung piles in search of food. Some of these animals in turn may feed on the seeds present in elephant dung and act as secondary dispersal agents. During the rainy season dung piles tend to disintegrate rapidly which could have also contributed to the increased rate of germination observed during the rainy season.

Conclusion

Fruiting bodies appear to be a major component of elephants diet as approximately 75% of the dung piles observed during this study contained seeds belonging to one or more species. Most of the seeds present in the dung are capable of germination. Yet only few seeds germinated under natural conditions. Germination of seeds in the elephant dung is governed by a number of factors such as availability of water, amount of shade and presence or absence of agents that can disintegrate elephant dung. Based on the composition of plant species whose seeds were found in elephant dung and germination rate of these seeds it can be concluded that elephants do not play a major role in dispersal of seeds of the dominant plant species of the scrub/ grass mosaic occupied by them.

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