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Effect of Comparative Biochemicals and Nutritive Values on Asian Elephant *Elephas maximus* with Special Reference to Feeding Habits in the Nilgiris, Tamil Nadu, Southern India

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Abstract
This present study attempted to find out nutrient values of wild food plants influenced Asian Elephant *Elephas maximus* menace on the highway between Coonoor and Mettupalayam. The major objective was to find out comparative and biochemical nutritive values with special reference to elephants feeding habit in Coonoor-Mettupalayam highway. The settlements in the study area were surveyed through questionnaire method in order to find out elephants eaten plants along with field surveys. Altogether, plant parts of twelve different species eaten by elephants were identified from April 2015 to December 2015 and processed for biochemical nutrient value analysis through standard AOAC method. The major eaten plant species were *Artocarpus heterophyllus* (protein, carbohydrate, fibre, magnesium) *Bambusa aurundinacea* (minerals), *Albizia amara* (phosphrus), *Carica papaya* (fat) and *Caryota urens* (calcium). Overall, *Artocarpus heterophyllus* was found having all the critical nutrient values for elephants in the study area. The present study proved that the most preferred species, *Artocarpus heterophyllus*, in the diet of elephant may be due to odor, taste or nutritive values.

1. Introduction

A key element to understand interactions between elephants and their environment is study of their feeding ecology. Elephants are hindgut fermenters with rapid food passage through the gut and therefore, there is low digestibility and energy intake of food. Elephants are generalist feeders and consume a large number of plant species. They eat 10% of their body weight each day, *i.e.* between 170–200 kg of food per day and 80–200 liters of water a day for adults (Wikipedia 2017). Elephants feed on plants by plucking grasses, forbs and creepers, frequently uprooting them; by stripping leaves, fruits, twigs and bark from trees and shrubs; by breaking-off branches to facilitate consumption of edible parts; and by pushing over or uprooting trees and shrubs. Elephants do graze and browse on the tender and palatable portions of different plants and trees (Prajapati 2008).

Nutrients are chemical compounds used in an organism's metabolism or physiology. Organic nutrients include carbohydrates, fats, proteins, vitamins, *etc* (Holodo 2003; Mooney 2007). Inorganic nutrients are usually minerals (calcium, phosphorus, sodium, magnesium, *etc*

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(McCullagh 1969). Water, oxygen and carbon-dioxide may also be considered as nutrients. These nutrients are essential to the organisms. If it cannot be synthesized by own, it must be obtained from an external source.

Easa (1989) emphasized that proteins are essential nutrition components for elephants. Field (1971) reported that woody plants contain higher levels of crude protein in dry season. Owen-Smith (1988) & Sukumar (1989) have stated that bark feeding by elephants might be more because of the sap content in the cambium layer; particularly during the dry season. Owen-Smith (1998) also reported that mega-herbivores need more food and space than do smaller herbivores, and larger home range of the male elephants reported that the carbohydrates are essential nutrients for elephants. Asian elephants eat a wide variety of plants including grasses, shrubs, bamboo, *etc* while more than 100 different plant species may be eaten, only about 10 to 25 of them are likely to make up more than 8% of the diet. The percentage of grasses versus browsed eaten parts varies seasonally; the nutrient value of grass is the greatest early in the wet season while that of leafy browse is higher in the dry season. Elephants seem to show choice in feeding. For example, crops such as banana, sugarcane and rice are favoured.

Sukumar (1990) reported that the palatability and nutrient concentration of grasses are decreased from early rainy season to late rainy season and dry season. According to him, alteration between a predominantly browse diet during the dry season with a grass diet during the early wet season was related to the seasonally changing protein contents of grasses. He further reported that cultivated cereals and millet crops provided significantly more protein, calcium and sodium than the wild grasses, and ultimately, crop raiding can be thought of as an extension of elephants' optimal foraging strategy. He further added that the potential for deficiencies and the attraction of elephants to sources of specific nutrients lead to the question that whether nutrition could play a role in crop-raiding behaviour in the Eastern Ghats.

Although most of the earlier studies have attributed the crop raiding strategy to nutritional values, this short term study was carried out along the highway between Coonoor and Mettupalayam in order to find out whether the nutrient values of plants have any influence on elephants to climb on the slopes of the Jaccanare Reserved Forest of the Coimbatore and Nilgiri North Forest Divisions in Tamil Nadu. The main objectives of the present study were to find out preferable food plants to elephants and to estimate macro-and micro-nutritional values in eaten parts of plants by elephants along the highway between Coonoor and Mettupalayam in Tamil Nadu.

2. Materials and Methods

2.1. Study area

The Kallar-Jaccanari corridor lies between 76°52'5"–76°56'5" N and 11°21'23"–11°19'15"E and 410–830 meters elevation above sea level (asl) in the Coimbatore forest division and surrounded in the north by steep escarpment of the Jaccanari mountains and in the east by crop fields and development activities (Fig. 1). A long stripe of corridor beginning at Kotagiri road up to Kallar Reserve Forest along the foothills of Jaccanari Mountain bisects the Mettupalayam-Coonoor highway. The corridor between second hairpin bend of the Mettupalayam-Coonoor highway and Kallar is narrow with various development activities. The terrain is undulating. The length of the highway is 35 km while the length of the corridor is 7 km and width ranging from 0.2 to 1.5 km. The elephants show strong fidelity to the corridor during their annual seasonal migration, indicating its importance for their conservation. The newly established private Education Institute (Swami Sachidhanandha Jothi Niketan) on the periphery of this forest has considerably reduced the width of this corridor (Ramakrishnan *et al*. 1997). Currently, elephants are moving through this corridor by crossing Ooty main highway following undulating contours in the corridor of the Jaccanarai hills in the west. Occasionally, there are few evidences supporting the elephant herds crossed the highway just below the first hairpin bend (Davidar 1972; Ramakrishnan & Ramkumar 2007). Other threats to this corridor are collection of fuel wood and bamboo for commercial purposes. The recently developed Amusement Park (Water Theme Park; Black thunder) would cause disturbance to the movement of elephants due to noise. Mixed

deciduous forests in hill slopes and mixed secondary growth woody forest in lowland areas dominate this corridor. Bamboo and Jack fruits are attracting to elephants along the highway (Fig. 2). The moist deciduous forest is a major forest type found along the highway with dominant tree species such as *Limonia alata*, *Atlantia monophylla*, *Albizzia amara*, *Artocarpus heterophyllus* and *Tectona grandis.* Similarly *Cocus nucifera* and *Arecanut* are the dominant agriculture crops seen along the highway. This area gets an average rainfall about 900–1200 mm and the temperature ranging between 20°–27° C in a year.

2.2. Methods

Ocular observation of elephants was carried out in the study area. Foraged plants consumed by elephants were identified based on direct and indirect observations of elephants in the selected zones representing various habitat types. The preferred food plants of elephants were identified by two methods. Using focal animal sampling method described by Altmann (1974), plant species eaten by each visible member in a herd were recorded at 5-minute intervals. Figure 1 shows study area. Totally, 4 hours and 18 minutes direct field observation was made. In some places where sufficient direct observation was not possible, indirect observation was made by following elephant tracks as far as possible and the type of grass or plant consumed by elephants was identified. In total, 1.6 hectare of elephant feeding area was sampled by laying 50 x 20 meter quadrates to collect indirect observation (debarking, canopy feeding, uprooting, *etc.*) in order to identify preferred food plants to elephants in the study area. The grasses and plants were identified following The Flora of Nilgiri and Pulney Hill-tops (Fyson 1920) and The Flora of the Presidency of Madras (Gamble 1935). The collected plants were dried in the shade, powdered and stored in airtight containers until it could be used for further analysis. Protein was estimated by Lowry *et al.* (1951) method. Carbohydrate was estimated by anthrone reagent method. Lipid and fibre was estimated by Soxhlet method using petroleum ether, Ash was estimated by muffle furnace. The mineral profiles were analyzed in the standard laboratory by employing Atomic Absorption Spectrophotometer and the results were represented in tables.

2.3. Preparation of extracts

Briefly, 100g of each powdered sample was soaked separately in 500 ml of methanol (Petroleum ether, chloroform, ethyl acetate and acetone) for 24 hrs at 400°C on water bath. The obtained extract was filtered by using Whatman No. 1 filter paper. Each filtrate was concentrated under reduced pressure on a rotary evaporator until golden viscous mass was obtained. Finally the prepared extracts were stored at 40°C for further analysis.

3. Results

Among 21 plant species along the highway between Coonoor and Mettupalayam (Table 1), Jack fruit was the only eatable commercial plant by elephants in that area. Others were Glove, Curry leaf, Curry bark, Elachi, *etc.* which are not edible by elephants.

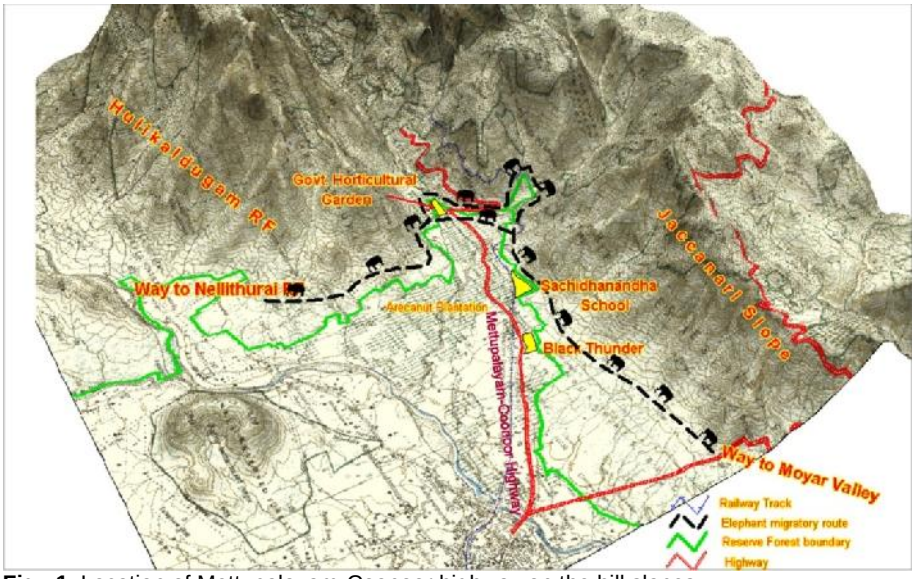

Fig. 1. Location of Mettupalayam-Coonoor highway on the hill slopes.

Table 1. Density and percentage of tree species recorded along the Mettupalayam-Coonoor highway (sampled area 1.6 ha).

No	Name of the tree species	No. of individuals	Density no./ha	Relative Density (%)	Elephant food species
1	*Anogeissus latifolia*	4	2.5	0.86	-
2	*Albizzia amara*	28	17.5	6.03	+
3	*Albizzia lebbeck*	4	2.5	0.86	+
4	*Atlantia monophylla*	52	32.5	11.21	-
5	*Azadirachta indica*	16	10	3.45	+
6	*Bauhinia racemosa*	16	10	3.45	+
7	*Tectona grandis*	40	25	8.62	+
8	*Artocarpus heterophyllus*	60	37.5	12.93	+
9	*Erthyroxylum monogynum*	16	10	3.45	-
10	*Euphorbia antiquorum*	32	20	6.90	-
11	*Fluggea leucopyrus*	8	5	1.72	-
12	*Grewia hirsute*	4	2.5	0.86	+
13	*Gyrocarpus* sp.	20	12.5	4.31	-
14	*Hardwickia binata*	4	2.5	0.86	+
15	*Limonia alata*	88	55	18.97	-
16	*Pteralobium hexapetalum*	24	15	5.17	+
17	*Randia dumetorum*	8	5	1.72	+
18	*Santalum album*	4	2.5	0.86	-
19	*Strychnos potatorum*	20	12.5	4.31	-
20	*Tamarindus indica*	8	5	1.72	+
21	*Ziziphus mauritiana*	8	5	1.72	+

+ Elephant's food species, – Non-Elephant's food species

Table 2. Macro-nutrient values estimated in the selected elephant food plants on the highway between Coonoor and Mettupalayam (dry weight) in 2015.

No	Plant species (eaten part)	English names	Protein g/kg	Carbohydrate g/kg	Fat g/kg	Fibre g/kg	Ash g/kg
1	*Carica papaya* (Fruit)	Papaya	70	20	18	22	22
2	*Mangifera indica* (Fruit)	Mango	30	165	4	19	19
3	*Psidium guajava* (Fruit)	Guava	60	102	10	12	15
4	*Citrus maxima* (Fruit)	Pomelo	1.7	25.6	-	10	10
5	*Citrus medica* (Fruit)	Citron	1.5	20	-	12	15
6	*Artocarpus heterophyllus* (Fruit)	Jack fruit	222	402	16	280	114
7	*Garcinia mangostana* (Fruit)	Mangostan	120	200	25	33	13
8	*Bambusa aurundinacea* (Stem)	Bamboo	190.2	300	13.8	270	125
9	*Albizia amara* (Stem)	Usil	0	280	82	100	32
10	*Albizia amara* (Leaf)	Usil	0	200	51	150	20
11	*Caryota urens* (Leaf)	Fish tail Palm	0	170	81	120	12
12	*Bambusa arundinnacea* (Leaf)	Bamboo	180	335	15.5	270	120

Table 3. Mineral values estimated in the selected elephant food plants on the highway between Coonoor and Mettupalayam (dry weight) in 2015.

No.	Plant species	Ca mg/kg	Mg mg/kg	P mg/kg
1	*Carica papaya*(Fruit)	2830	8	1420
2	*Mangefera indica* (Fruit)	2090	5	600
3	*Psidium guajava*(Fruit)	2450	6	1000
4	*Citrus maxima* (Fruit)	1000	500	1200
5	*Citrus medica* (Fruit)	900	450	1000
6	*Artocarpus heterophyllus*(Fruit)	3100	3000	1000
7	*Garcina mangostana* (Fruit)	1000	1200	1000
8	*Bambusa arundinaceae* (Stem)	2500	3000	1000
9	*Albizzia amara* (Stem)	2000	9.8	1380
10	*Albizzia amara* (Leaf)	3250	8.5	2000
11	*Caryota urens* (Leaf)	4050	8	1000
12	*Bambusa aurundinnacea* (Leaf)	2000	1500	1000

Among the macro-nutrients, protein was high in *Artocarpus heterophyllus* fruit (222 g/kg) followed by *Bambusa aurundinacea* stem (190.2 g/kg) but interestingly it was noted that protein value was nil in *Albizzia amara* leaf, stem, and *Caryota urens* leaf. Carbohydrate was high in *Artocarpus heterophyllus* fruit (402 g/kg), followed by *Bambusa aurundinacea* leaf (335 g/kg) but it was low in *Carica papaya* fruit and *Citrus medica* fruit (20g/kg). Fat contents were high in *Albizia amara* stem (82 g/kg), followed by *Caryota urens* leaf (81 g/kg) while were interestingly nil in *Citrus maxima* fruit and *Citrus medica* fruit. Fibre was high in *Artocarphus heterophyllus* fruit (280 g/kg) but very low in *Citrus maxima* (10 g/kg). The ash contents were high in *Bambusa aurundinacea* stem (125 g/kg) whereas were very low in *Citrus maxima* (10 g/kg). Overall, the macro-nutrient values were high in *Artocarphus heterophyllus* fruit and very low in *Citrus maxima* fruit and similar to *Citrus medica* fruit (Table 2).

Among the mineral contents, Calcium was high in *Caryota urens* leaf (4050 mg/kg) but very low in *Citrus medica* fruit (900 mg/kg). Magnesium was high in *Artocarpus heterophyllus* fruit and *Bambusa arundinacea* stem (3000 mg/kg) but low in *Mangifera indica* fruit (5 mg/kg). Phosphorus contents were high in *Albizzia amara* leaf (2000 mg/kg) but low in *Mangifera indica* fruit (60 mg/kg) (Table 3).

Fig. 2. Fruit of *Artocarpus heterophyllus* tree in the study area.

4. Discussion

Survival and reproduction of animals depend partly on the diet containing adequate and balanced essential nutrients. After all, an animal has to acquire enough protein, carbohydrate, fat, fibre, vitamins and trace elements to fulfill its biological processes (Dunbar 1988). Beside these, several other factors such as body size and weight and gut morphology (Rizvanovic *et al*. 2012) may also determine the food selection but can generally be regarded as evolutionary adaptation to other principal factors. Accordingly, larger species such as elephants tend to feed more because they need more energy.

Elephants digest crude fibre with the help of microbes present in the hind gut similar to other non-ruminant herbivores such as horses. Elephant's digestive system and teeth are adapted to a diet with high fibre contents. Being a continuous feeder with its large digestive tract, they take food low in energy but high in bulk (Asian Nature Conservation Foundation 2006).

The present study revealed that the Jack Fruit *Artocarpus heterophyllus* had higher nutrient values than other plants. Williams (2002) and Dhakal (1992) reported that *Mallotus phillippensis* was the most important woody plant for elephants during the dry season in northern India. Nitrogen, crude protein, organic matter and ether extract (fat) contents were higher in leaves than in bark of most of the elephant preferable food plants in Nepal (Prajajapati 2008). The natural diet of elephants is low in fat, found to be 1.2–1.8% of the dry matter intake (Asian Nature Conservation Foundation 2006). Among herbivores, only ruminants can synthesize several amino acids with the help of symbiotic microbes in the rumen. However, elephants being non-ruminant herbivores, both qualitative and quantitative presence of protein in the diet is important. Studies on Asian elephants in the wild in southern India showed that the browse intake during the wet season had higher contents of crude protein than in the dry season (Asian Nature Conservation Foundation 2006). Browse plants have higher levels of nitrogen than grasses, but the higher levels of nitrogen in browse were bound to the secondary compounds during chewing, making them less available for digestion by the micro-flora (Robbins *et al*. 1987). Not much is known about the requirements of various minerals and vitamins for elephants. The tendency of wild elephants to feed on the bark of certain trees suggests that this might be a source for some minerals (Sukumar 1989) and minerals contribute to a greater palatability (Field 1971). Estimation of Ca requirements for Asian elephant is believed to be 60 g per day (Sukumar 1989). While Ca concentration is generally high in legumes, but low in grasses, both P and Na are low in both legumes and grasses. At least 8–9 g of calcium is required for the proper growth of the tusks of elephants (McCullagh 1969; Laws *et al.* 1975). In addition to the requirements for body maintenance and growth, elephants and cows need extra calcium when they are in lactating (Sukumar 1989). The deficiency of certain minerals in elephants' body leads to productivity problems, poor growth, emaciation and listlessness; affecting the growth, reproduction and lactation. These all lead to abnormal growth, poor appetite, abnormality, anemia, pale mucus membrane and irregular pulse (Asian Nature Conservation Foundation 2006). Grass provides adequate nutrition and energy during wetter parts of the year, however during the dry season mineral contents in grass become too low for normal maintenance of the growth of adult elephants (Moe 1994). The majority of tropical grass species sprout, flower and set seed in the rainy season whilst during the dry season the above ground remnant of most grasses is lignified and indigestible (Sinclair 1975). Browse is an important food for elephants because it provides essential fatty acids and minerals (McCullagh 1969) while the

fibre contents in the bark probably contribute to ensure proper protein digestion (Laws *et al.* 1975).

There were five important plant parts that play vital role as nutrient values to elephants in the study area viz. *Artocarpus heterophyllus*, *Albizzia amara*, *Bambusa* a*rundinacea*, *Carica papaya* and *Caryota urens*. Among these five plants, fruit of *Artocarpus heterophyllus* scored the highest rank in critical macro-nutrients such as protein, carbohydrate, fibre, as well as minerals such as magnesium, calcium and phosphorus. With the above-mentioned findings, this study concludes that fruiting of *Artocarpus heterophyllus* was the main food source at the higher altitudes, especially along the highway between Coonoor and Mettupalayam during the dry season, *viz.* April, May and June.

Conclusion

The present study found that among 12 plant species, *Artocarpus heterophyllus* was the only plant species containing all the critical nutrient values of elephants along the highway between Coonoor and Mettupalayam. The fruiting of Jack Fruit *Artocarpus heterophyllus* attracted elephants to visit steep slope areas, creating menace traffic between Coonoor and Mettupalayam highway.

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