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RESEARCH ARTICLE
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Nutritional evaluation of fodder, its preference and crop raiding by wild Asian elephant (*Elephas maximus)* in Sonitpur District of Assam, India

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Abstract

Aim: The present investigation was carried out to evaluate the nutritive value of fodder in natural habitat, cultivated crops and their preference by wild Asian elephant (*Elephas maximus*) in forest and non-forest areas in four seasons using field observation in Sonitpur District of Assam; since, there were frequent incidences of crop raiding by wild elephant leading to loss of property and human-elephant conflict.

Materials and Methods: The study was conducted in four seasons. The study included forest areas of Sonai-Rupai Wildlife Sanctuary, part of Nameri National Park and high human-elephant conflicted areas of non-forest near to the sanctuary and parks. The consumed fodders were identified, collected and evaluated. The proximate composition was determined using AOAC (1990).

Results: Total 39 different fodder species of 18 families including herbs, climber, grasses, paddy seeds, paddy saplings, plants and its leaves, bark, fruits, and roots were recorded to be utilized by elephants. The first three family of fodder that elephant relished more were *Poaceae* (46.15%), *Musaceae* (7.69%) and *Zingiberaceae* (5.13%) respectively. The crude protein content of fodder in all seasons, total ash content only in winter and post monsoon seasons and neutral detergent fiber content of fodder between forest and non-forest were significant ($p<0.05$). Elephants preferred to forage more on nutritionally rich fodder than poor natural fodder. Incidence of crop raiding was more in post monsoon season could be due to availability of nutritionally rich fodder than the poor natural fodder and generally happened in the night.

Conclusions: The study revealed that during post monsoon season, there were abundant nutritionally rich sources of cultivated crops than the fodder of natural habitat that might provoke the wild elephants to raid crops. *Poaceae* shared a major portion of their diet. The findings will definitely help nutritionist, ecologist and policy makers to understand wild elephant's needs and also to take appropriate measures for conservation of endangered wild Asian elephant as well as mitigation of human-elephant conflict.

Keywords: crop, fodder, raiding, wild Asian elephant.

Introduction

Wild Asian elephants (*Elephas maximus*) are the Asia's largest terrestrial herbivores. The population of wild elephant in Assam is about 5000 with a captive population of about 1250 [1]. They have become endangered [2] after disappearing from most of their historical ranges. The requirements of large home ranges with plenty of forage, the elephants are compelled to come in greater contact with human settlements. With the increase in human population and encroachment of forest areas, the elephant habitats have been rapidly degraded and fragmented leading to human-elephant conflicts such as loss of property, human life and crop damage. Elephants consume natural vegetation as well as cultivated crops. The factors that influence the decision to consume or reject a plant are palatability of the item and presence of toxic substances [3]. Elephants are generally coarse feeders, and they feed on a wide variety of plants.

Wild elephants in the study area selectively consumed wild plants. Although a large population of elephants is found in the North-Eastern region of India, particularly in Assam, hitherto very few efforts have been made to study about their preference of fodder in natural habitat as well as crops.

Therefore, the present study was considered essential to provide insight into the nutritional composition of preferred fodder as a part of their feeding strategy for long-term survival of the species with reduced human-elephant conflicts.

Materials and Methods

The study was conducted in Sonitpur district of Assam covering the high human-elephant conflicted areas located in 26°37′E to 27°E latitude and 92°42′N to 92°50′N longitude. The study areas in the forest were Sonai-Rupai Wildlife Sanctuary, part of Nameri

National Park and non-forest areas with frequent crops and household damage by the elephants. The forest type is deciduous and evergreen. The study was conducted in four seasons *viz.* Winter (December, January and February), summer (March and May), monsoon (June, July, August and September) and post monsoon (October and November). The temperature in winter ranges from 10°C to 22°C and 26.20-34.23°C in summer with an average rainfall of 1600 mm and 40% relative humidity. The observations on feeding evidences were made from a flight distance during foraging. In most cases, elephants were observed while feeding on a fodder, after they had moved away, representative part of the consumed plants samples by then collected for analysis. In few cases, samples were collected by observing indirect evidences like uprooting of small plants, breaking of tree branches, debarking and even presence of undigested part of consumed fodder in feces. A minimum quantity of 300 g sample was collected as per standard method along the trail of elephants into a numbered polythene packet from the study areas. The weighed samples were placed in a hot air oven at 100±1°C for 8 h for dry matter (DM) estimation. The dried samples were grounded and stored in labeled glass jars for further chemical analysis. The analysis of samples was carried out at Department of Animal Nutrition, College of Veterinary Science, Assam Agricultural University, Khanapara, Guwahati, Assam.The DM, crude protein (CP), crude fiber (CF), ether extract (EE), total ash (TA), and nitrogen free extract (NFE) were determined as per method of AOAC [4]; and neutral detergent fiber (NDF), acid detergent fiber (ADF) and lignin were determined as per Goering and Van Soest [5]. Data were analyzed using SAS [6] system.

Results

A total 39 fodder species belonging to 18 families with varying nutrient values was found to be consumed by elephants (Tables 1-4). Availability of fodder in winter, summer, monsoon and post monsoon seasons was 11, 11, 16 and 21 within the recorded species, respectively.The elephants consumed whole plant or its parts *viz.* leaf, stalk, bark, fruit and root. Overall utilization of fodder (Table-5) by elephants revealed maximum 46.15% of *Poaceae*, followed by 7.69, 5.13 and 5.13% of *Musaceae*, *Zingiberaceae* and *Euphorbiaceae* respectively. About 2.56% utilization was observed each of *Anonaceae*, *Bigoniaceae*, *Bombaceanaceae*, *Caesalpiniaceae*, *Canabiaceae*, *Cucurbitaceae*, *Dilenaceae*, *Dipterocarpaceae*, *Marantaceae*, *Minoceae*, *Maraceae*, *Sterculiaceae*, *Urticcariaceae* and *Verbenaceae*. The proximate values (%) of fodder plants particularly CP, EE, TA, and NFE contents were recorded in a higher range in non-forest areas than the forest areas (Table-6). The total availability of fodder in post monsoon season was higher in non-forest areas than the forest areas and it has also been observed that the crops basically

Table-1: Percent chemical composition of fodder (mean±SE) in forest and non forest areas (DM basis) during winter season.

Season	Botanical name	Local name	DM	CP	CF	EE	TA	NFE	NDF	ADF	Lignin
Winter	Forest										
	A. officinarum	Tara	24.35±2.55	13.75±0.25	29.00±1.0	1.76±0	7.75±1.75	47.74±1.0	80.0±0	36.00±0	10.00±0
	C. nardus	Chitronella	32.60±0.60	8.55±0.05	24.88±0.12	1.32±0.25	8.08±0.17	57.18±0.25	68.00±0	33.00±0	10.00±0
	I. cylindrica	Ulu	28.38±1.62	7.05±0.05	34.50±0	0.76±0.46	5.42±0.41	52.28±0.93	86.00±0	54.00±0	9.00±0
	N. porphyrocoma	Narenga	35.83±2.17	3.12±0.50	44.00±5.0	0.79±0.49	8.00±3.00	44.095±1.00	88.00±0	60.00±0	8.00±0
	S. spontaneum	Kohua	37.52±0.30	2.87±0.12	34.33±1.33	0.71±0.23	6.97±0.32	55.1±0.86	58.33±12.83	44.33±2.33	8.00±1.0
	T. elephantina[a]	Maduri	31.62±0	17.00±0	38.50±0	1.17±0	6.66±0	36.67±0	96.00±0	57.00±0	6.70±0
	Non-forest										
	B. tulda[a]	Jati bah	38.00±0	9.00±0	28.75±0	1.77±0	10.25±0	50.23±0	67.00±0	55.00±0	10.00±0
	D. indica[a]	Ou tenga	15.46±0	6.50±0	26.75±0	0.59±0	6.00±0	60.16±0	48.00±0	42.00±0	12.00±0
	M. denticulata[a]	Jarath	29.82±0	17.00±0	21.00±0	0.88±0	7.30±0	53.82±0	55.00±0	43.00±0	7.50±0
	M. champa[a]	Cheni kol	28.57±0	22.75±0	20.50±0	1.47±0	9.00±0	46.28±0	68.00±0	29.00±0	9.00±0
	M. chinensis[a]	Jahaji kol	25.00±0	21.87±0	21.50±0	1.76±0	11.00±0	43.87±0	78.00±0	46.00±0	8.00±0

[a]Single observation. DM=Dry matter, CP=Crude protein, CF=Crude fiber, EE=Ether extract, TA=Total ash, NFE=Nitrogen free extract, NDF=Neutral detergent fiber, ADF=Acid detergent fiber, *A. officinarum=Alpinia officinarum*, *C. nardus=Cymbopogon nardus*, *I. cylindrica=Imperata cylindrica*, *N. porphyrocoma=Narenga porphyrocoma*, *S. spontaneum=Saccharum spontaneum*, *T. elephantina=Typha elephantina*, *B. tulda=Bambosa tulda*, *M. denticulata=Macaranga denticulata*, *M. champa=Musa champa*, *M. chinensis=Musa chinensis*

Table-2: Percent chemical composition of fodder (mean±SE) in forest and non-forest areas (DM basis) during summer season.

Season	Botanical name	Local name	DM	CP	CF	EE	TA	NFE	NDF	ADF	Lignin
Summer	Forest										
	A. officinarum	Tara	22.25±0.65	13.00±0	32.50±0	1.025±0.73	7.33±1.33	46.14±0.59	79.00±1.0	43.00±7.0	11.00±1.0
	C. nardus	Chitronella	33.00±1.0	8.70±0.05	24.12±0.37	1.16±0.01	8.13±0.13	57.89±0.28	56.50±11.50	33.50±3.50	10.00±0
	D. indica[a]	Ou tenga	15.40±0	5.25±0	26.00±0	0.59±0	6.00±0	62.16±0	48.00±0	42.00±0	12.00±0
	I. cylindrica	Ulu	28.10±2.90	7.75±0.25	35.00±0	0.72±0.44	9.34±2.34	47.18±2.15	53.00±3.0	49.50±2.50	9.00±0
	P. pubinerve[a]	Koupat	19.50±0	26.25±0	32.00±0	1.17±0	11.00±0	29.58±0	70.00±0	43.00±0	6.00±0
	Polyalthia spp.[a]	Janghali badam	40.00±0	8.00±0	17.00±0	2.00±0	8.00±0	65.00±0	80.00±0	46.00±0	5.00±0
	S. spontaneum	Kohua	36.55±1.45	2.93±0.17	36.00±2.0	0.57±0.28	4.66±1.33	55.84±0.21	81.50±6.50	56.50±7.50	7.40±0.10
	Non-forest										
	B. tulda[a]	Jati bah	37.00±0	11.75±0	34.25±0	1.17±0	17.66±0	35.17±0	40.00±0	22.00±0	10.00±0
	C. sativa[a]	Bhang	17.00±0	14.00±0	16.00±0	2.50±0	6.00±0	61.5±0	55.00±0	46.00±0	6.00±0
	C. maxima	Ranga lau	12.75±0.25	16.75±0.25	11.25±0.25	1.42±0	2.66±0	67.92±0	44.00±0	31.00±0	2.00±0
	M.chinensis[a]	Jahaji kol	25.00±0	15.57±0	21.50±0	1.78±0	11.00±0	50.15±0	78.00±0	46.00±0	8.00±0

[a]Single observation. DM=Dry matter, CP=Crude protein, CF=Crude fiber, EE=Ether extract, TA=Total ash, NFE=Nitrogen free extract, NDF=Neutral detergent fiber, ADF=Acid detergent fiber, SE=Standard error, *A. officinarum=Alpinia officinarum, C. nardus=Cymbopogon nardus, D. indica=Dillenia indica, I. cylindrica=Imperata cylindrica, P. pubinerve=Phrynium pubinerve, S. spontaneum=Saccharum spontaneum, B. tulda=Bambosa tulda, C. sativa=Cannabis sativa, C. maxima=Cucurbita maxima, M. chinensis=Musa chinensis*

Table-3: Percent chemical composition of fodder (mean±SE) in forest and non-forest areas (DM basis) during monsoon season.

Season	Botanical name	Local name	DM	CP	CF	EE	T. ASH	NFE	NDF	ADF	Lignin
Monsoon	Forest										
	A. officinarum	Tara	26.00±0.50	11.25±0.25	27.33±1.36	1.45±0.01	6.10±0.44	53.85±2.03	69.66±2.33	29.66±1.66	9.33±0.66
	A. donax	Nol	29.40±0	8.79±1.21	18.50±0	0.85±0	9.04±0.71	62.82±0.50	78.00±0	35.00±0	7.50±0.50
	B. variegata	Kanchan	25.15±0.60	16.80±0.70	2050±1.0	1.05±0.20	9.73±0.40	51.91±0.09	82.00±0	36.00±0	6.25±1.25
	B. ceiba[a]	Simolu	26.57±0	17.50±0	37.00±0	3.50±0	9.14±0	32.86±0	72.00±0	37.00±0	9.00±0
	C. aromatica	Keturi	10.86±0.38	17.50±0	19.50±0	0.28±0	18.33±0	44.39±0	76.00±0	45.00±0	7.00±1.0
	C. nardus	Chitronella	29.36±2.19	8.61±0.20	27.25±1.03	1.28±0.24	7.88±0.11	54.96±0.94	69.75±8.25	42.00±4.0	8.75±0.62
	D.bipinnata[a]	Kuch	24.77±0	17.50±0	22.50±0	0.57±0	11.00±0	48.43±0	88.00±0	41.00±0	5.00±0
	F.glomerata[a]	Jyaga dimoru	30.00±0	14.50±0	42.50±0	2.28±0	10.00±0	30.72±0	63.00±0	40.00±0	12.00±0
	I. cylindrica	Ulu	25.66±0.44	8.10±0.05	26.08±0.71	1.31±0.04	15.13±1.31	49.37±0.67	56.00±0	52.00±0	10.06±0.06
	O. indicuma	Bhatghilla	14.53±0	26.26±0	16.00±0	0.57±0	10.33±0	46.84±0	38.00±0	32.00±0	6.00±0
	Panicum spp.[a]	Thupa ghah	25.47±0	11.00±0	21.50±0	3.82±0	11.66±0	52.02±0	80.00±0	29.00±0	5.00±0
	S. spontaneum	Kohua	34.31±0.81	3.63±0.12	36.00±0	1.67±0.17	8.00±0	50.7±0.05	88.00±0	64.00±0	8.50±0.50
	S. robusta[a]	Sal	28.50±0	17.50±0	34.00±0	1.42±0	4.00±0	43.08±0	68.00±0	53.00±0	13.00±0
	Non-forest										
	B. tuldaa	Jati bah	30.00±0	9.5±00	28.40±0	1.80±0	9.00±0	51.3±0	67.00±0	55.00±0	10.00±0
	M. chinensis	Jahaji kol	18.75±5.25	17.37±4.62	37.77±0.22	0.74±0.46	7.67±1.17	36.43±5.65	66.50±8.50	57.00±8.0	7.00±1.0
	O. sativa var Ranjit[a]	Kothia	31.45±0	13.12±0	15.00±0	0.85±0	12.85±0	58.18±0	74.00±0	34.00±0	6.00±0

[a]Single observation. DM=Dry matter, CP=Crude protein, CF=Crude fiber, EE=Ether extract, TA=Total ash, NFE=Nitrogen free extract, NDF=Neutral detergent fiber, ADF=Acid detergent fiber, SE=Standard error, *A. officinarum=Alpinia officinarum, A. donax=Arundo donax, B. variegata=Bauhinia variegata, B. ceiba=Bombax ceiba, C. aromatica=Curcuma aromatica, C. nardus=Cymbopogon nardus, D. bipinnata=Desmostachya bipinnata, F. glomerata=Ficus glomerata, , I. cylindrica=Imperata cylindrica, O. indicum=Oroxylum indicum, S. spontaneum=Saccharum spontaneum, S. robusta=Shorea robusta, B. tulda=Bambosa tulda, M. chinensis=Musa chinensis, O. sativa=Oryza sativa*

Table-4: Percent chemical composition of fodder (mean±SE) in forest and non-forest areas (DM basis) during post monsoon seasnon.

Season	Botanical name	Local name	DM	CP	CF	EE	T.ASH	NFE	NDF	ADF	Lignin
Post monsoon	Forest										
	C. nardus	Chitronella	34.00±0	8.27±0.02	24.50±0	1.12±0.02	8.00±0	58.11±0	45.00±0	30.00±0	9.50±0.50
	A. officinarum[a]	Tara	26.75±0	8.75±0	32.00±0	1.42±0	7.50±0	50.33±0	75.00±0	37.00±0	10.00±0
	B. ceiba	Simolu	18.80±0.20	8.51±0.25	45.00±0	3.50±0	10.25±0.25	32.50±0	80.00±0	62.00±0	9.00±0
	Bridellia spp.[a]	Kuhir	33.00±0	8.80±0	17.00±0	2.60±0	13.66±0	57.94±0	60.00±0	43.00±0	8.50±0
	C. serratum[a]	Nangal bhanga	35.06±0	17.50±0	12.50±0	2.00±0	7.30±0	60.7±0	63.00±0	37.00±0	8.50±0
	H. amplexicaulis[a]	Dol	33.00±0	6.00±0	17.00±0	2.10±0	13.66±0	61.24±0	60.00±0	43.00±0	7.00±0
	T. elephantina	Maduri	30.69±0	17.50±0	38.50±0	1.17±0	6.66±0	36.17±0	96.00±0	55.00±0	6.70±0
	Non-forest										
	O. sativa var Aizong[a]	Aizong	34.70±0	12.00±0	23.50±0	0.58±0	12.00±0	51.92±0	64.00±0	50.00±0	5.00±0
	O. sativa var Boradhan[a]	Boradhan	40.62±0	13.50±0	30.50±0	0.88±0	9.00±0	46.12±0	64.00±0	50.00±0	9.00±0
	O. sativa var Gudumonia[a]	Gudumoni	34.60±0	13.51±0	22.50±0	0.59±0	17.15±0	46.25±0	60.00±0	44.00±0	6.00±0
	O. sativa var Jahenga[a]	Jahenga	39.50±0	14.75±0	30.00±0	1.01±0	10.00±0	44.24±0	56.00±0	29.00±0	4.00±0
	O. sativa var Kachari sali[a]	Kachari Sali	27.26±0	8.75±0	31.00±0	0.29±0	11.33±0	48.63±0	82.00±0	54.00±0	7.00±0
	O. sativa var Kunkuni joha[a]	Kunkuni joha	27.85±0	15.84±0	33.00±0	0.62±0	13.66±0	36.88±0	80.00±0	41.00±0	10.70±0
	O. sativa var Ranjit[a]	Ranjit	25.71±0	14.10±0	21.50±0	1.98±0	14.13±0	48.29±0	58.00±0	51.00±0	6.00±0
	A. lebbeck[a]	Siris	28.00±0	15.00±0	21.50±0	3.42±0	5.66±0	54.42±0	72.00±0	23.00±0	4.00±0
	B. balcooa[a]	Bholuka bah	33.50±0	13.75±0	30.00±0	1.14±0	12.00±0	43.11±0	40.00±0	22.00±0	9.00±0
	L. crenulata[a]	Surat	19.50±0	17.00±0	24.00±0	4.50±0	20.00±0	34.50±0	66.00±0	65.00±0	6.50±0
	M. denticulata[a]	Jarath	29.80±0	24.00±0	15.50±0	0.88±0	7.30±0	52.32±0	36.00±0	36.00±0	5.50±0
	M. balbisiana[a]	Bhimkol	10.50±0	12.50±0	31.72±0	2.12±0	3.66±0	50.00±0	78.00±0	23.00±0	7.80±0
	M.chinensis[a]	Jahaji kol	25.00±0	14.75±0	40.00±0	1.73±0	11.00±0	32.52±0	65.00±0	46.00±0	7.00±0
	S. villosa[a]	Uddal	31.20±0	10.00±0	46.00±0	0.88±0	7.00±0	36.12±0	74.00±0	49.00±0	10.00±0

[a]Single observation. DM=Dry matter, CP=Crude protein, CF=Crude fiber, EE=Ether extract, TA=Total ash, NFE=Nitrogen free extract, NDF=Neutral detergent fiber, ADF=Acid detergent fiber, SE=Standard error, *C. nardus=Cymbopogon nardus, A. officinarum=Alpinia officinarum, B. ceiba=Bombax ceiba, C. serratum=Clerodendrum serratum, H. amplexicaulis=Hymenachne amplexicaulis, T. elephantina=Typha elephantina, O. sativa=Oryza sativa, A. lebbeck=Albizia lebbeck, B. balcooa=Bambosa balcooa, L. crenulata=Laportea crenulata, M. denticulata=Macaranga denticulata, M.balbisiana=Musa balbisiana, M. chinensis=Musa chinensis, S. villosa=Sterculia villosa*

Table-5: Available fodder in forest and non-forest area and their utilization by wild Asian elephants.

Family	Botanical name	Percent contribution	Local name	Available fodder		
				Occurrence of utilization	Percent in forest	Percent in non-forest
Anonaecae	*Polyalthia* spp.	2.56	Jangholi badam	1	8.3	-
Bigoniaceae	*O. indicum*	2.56	Bhat ghila	1	8.3	-
Bombacaceae	*B. ceiba*	2.56	Simolu	3	25	-
Caesalpiniaceae	*B. variegata*	2.56	Kanchan	1	8.3	-
Cannabaceae	*C. sativa*	2.56	Bhang	1	-	8.3
Cucurbitaceae	*C. maxima*	2.56	Rangalou	2	-	16.66
Dilleniaceae	*D. indica*	2.56	Ou tenga	1	-	8.3
Dipterocarpaceae	*S. robusta*	2.56	Sal	1		
Euphorbiaceae	*M. denticulata*	5.13	Jarath	1	-	8.3
	Bridelia spp.		Kuhir	1	8.3	-
Poaceae	*A. donax*	46.15	Nol	2	16.66	-
	B.balcooa		Bholuka bah	1	-	8.3
	B. tulda		Jati bah	3	-	25
	C. nardus		Chitronella	10	83.33	-
	D. bipinnata		Kuch ghah	1	8.3	-
	H. amplexicaulis		Dol	1	8.3	-
	I. cylindrica		Ulu	7	58.33	-
	N. porphyrocoma		Narenga	2	16.66	-
	O. sativa var Aizong		Aizong dhan	1	-	8.3
	O. sativa var Boradhan		Bora dhan	1	-	8.3
	O. sativa var Gudumoni		Gudumoni dhan	1	-	8.3
	O. sativa var Jahenga		Jahenga dhan	2	-	16.66
	O. sativa var Kachari sali		Kachari sali	1	-	8.3
	O. sativa var Kunkuni joha		Kunkuni joha	1	-	8.3
	O. sativa var Ranjit		Ranjit	1	-	8.3
	Panicum spp.		Thupa ghah	1	8.3	-
	S. spontaneum		Kohua	6	50	-
	T. elephentina		Maduri	2	16.66	-
Marantaceae	*P. pubinerve*	2.56	Koupat	1	8.3	-
Mimosaceae	*A. lebbeck*	2.56	Siris	1	-	8.3
Moraceae	*F. glomerata*	2.56	Jyaga dimoru	1		
Musaceae	*M. champa*	7.69	Cheni champa kol	1	-	8.3
	M. chinensis		Jahaji kol	4	-	33.33
	M. balbisiana		Bhim kol	1	-	8.3
Sterculiaceae	*S. villosa*	2.56	Uddal	1	-	8.3
Urticaceae	*L. crenulata*	2.56	Surat	1	-	8.3
Verbenaceae	*C. serratum*	2.56	Nangal bhanga	1	8.3	-
Zingiberaceae	*C. aromatica*	5.13	Keturi	2	16.66	-
	A. officinarum		Tora	7	58.33	-

-=Not recorded in respective area, *O. indicum=Oroxylum indicum, B. ceiba=Bombax ceiba, B. variegata=Bauhinia variegata, C. sativa=Cannabis sativa, C. maxima=Cucurbita maxima, D. indica=Dillenia indica, S. robusta=Shorea robusta, M. denticulata=Macaranga denticulata, A. donax=Arundo donax, B. balcooa=Bambosa balcooa, B. tulda=Bambosa tulda, C. nardus=Cymbopogon nardus, D. bipinnata=Desmostachya bipinnata, H. amplexicaulis=Hymenachne amplexicaulis, I. cylindrica=Imperata cylindrica, N. porphyrocoma=Narenga porphyrocoma, O. sativa=Oryza sativa, S. spontaneum=Saccharum spontaneum, T. elephentina=Typha elephentina, P. pubinerve=Phrynium pubinerve, A. lebbeck=Albizia lebbeck, F. glomerata=Ficus glomerata, M. champa=Musa champa, M. chinensis=Musa chinensis, M. balbisiana=Musa balbisiana, S. villosa=Sterculia villosa, L. crenulata=Laportea crenulata, C. serratum=Clerodendrum serratum, C. aromatica=Curcuma aromatica, A. officinarum=Alpinia officinarum*

paddy is the main cultivated item in this region with a good source of nutrients. Due to the abundance, the elephant preferred this richer source of crop. The crop raiding activity of elephants becomes more marked along with increased availability and nutritional quality of fodder and proximity to the forest areas in post monsoon season.

Discussion

The elephants consume a wide variety of forages to maintain their body demand and productive life. The study at Sonitpur District revealed that 39 different fodder species consumed by wild Asian elephants containing varying nutrient contents throughout the year. Earlier workers [7] reported that a total 50 plants species was observed to be favorite fodder species for elephants. This number was more than that our findings and might be due to larger study area. A previous study [8] reported that out of 52 recorded species, only 22 plants species were found to be utilized either fully or partially as evidenced by branch breaking, uprooting etc with values of forages *viz*. CP 3.18-21.25%, CF 20.00-54.00%, NDF 57-74%, ADF 24.8-40% and lignin 4-9.1 %. Earlier researcher [9] recorded 20 species of plants, grass and trees with an average value of CP 11.8%, EE 2.85%, CF 23.95%,

Table-6: Lower and higher proximate value (%) of consumed fodder in study area by wild Asian elephants.

Proximate value (%)	Foraging area	Utilized fodder	Season			
			Winter	Summer	Monsoon	Post monsoon
CP	Forest	*S.spontaneum*	2.87	-	-	-
		O.indicum	-	-	26.26	-
	Non forest	*D.indica*	6.50	-	-	-
		M.denticulata	-	-	-	24.00
CF	Forest	*C.serratum*	-		-	12.50
		N.porphyrocoma	44.00		-	-
	Non-forest	*C.maxima*	-	11.25	-	-
		S. villosa	-	-	-	46.00
EE	Forest	*C.aromatica*	-	-	-	0.28
		Bridelia spp.	-	-	-	2.60
	Non-forest	*O.sativa var Kachari sali*	-	-	-	0.29
		L.crenulata	-	-	-	4.50
TA	Forest	*S.robusta*	-	-	4.00	-
		C.aromatica	-	-	18.33	-
	Non-forest	*C.maxima*	-	2.66	-	
		L.crenulata	-	-	-	20.00
NFE	Forest	*I. cylindrica*	-	29.58	-	-
		D.indica	62.16	-	-	-
	Non-forest	*M.chinensis*	-	-	-	32.52
		C.maxima	-	67.92	-	-
NDF	Forest	*O.indicum*	-	-	38.00	-
		T.elephantina	-	-	-	96.00
	Non-forest	*M. denticulata*	-	-	-	36.00
		O. sativa var Kachari sali	-	-	-	82.00
ADF	Forest	*Panicum* spp.	-	-	29.00	-
		S.spontaneum	-	-	64.00	-
	Non-forest	*B.tulda and B.balcooa*	-	22.00	-	22.00
		L.crenulata	-	-	-	66.00
Lignin	Forest	*Polyalthia* spp.*D. bipinata*	-	5.00	-	-
		S. robusta	-	-	13.00	-
	Non-forest	*C. maxima*	-	2.00	-	-
		D. indica	12.00	-	-	-

-=No lower and higher value observed. CP=Crude protein, CF=Crude fiber, EE=Ether extract, TA=Total ash, NFE=Nitrogen free extract, NDF=Neutral detergent fiber, ADF=Acid detergent fiber, *S. spontaneum=Saccharum spontaneum, O. indicum=Oroxylum indicum, D. indica=Dillenia indica, M. denticulata=Macaranga denticulata, C. serretum=Clerodendrum serratum, N. porphyrocoma=Narenga porphyrocoma, C. maxima=Cucurbita maxima, S. villosa=Sterculia villosa, C. aromatic=Curcuma aromatic, O. sativa=Oryza sativa, L. crenulata=Laportea crenulata, S. robusta=Shorea robusta, I. cylindrica=Imperata cylindrica, D. indica=Dillenia indica, M. chinensis=Musa chinensis, O. indicum=Oroxylum indicum, T. elephantina=Typha elephantina, M. denticulata=Macaranga denticulata, B. tulda=Bambusa tulda , B. balcooa=Bambusa balcooa, L. crenulata=Laportea crenulata, D. bipinata=Desmostycha bipinata*

NFE 48.25%, TA 11.55% in forages. Similarly an earlier study [10]also reported in their study that 20 plants species were found to be utilized either fully or partially as evident by branch breaking, debarking and uprooting with value ranges of CP 2.97-12.76%, ADF 32.26-56.27% and lignin 9.92-33.31%. In the present study, the percent CP content in forest and non-forest areas in all seasons was more and varied from 2.87 to 26.66 and 6.50 to 24.00, respectively. The protein level in all fodder and crops was significant ($p<0.05$) with an increased level in non-forest areas than forest areas in all season. The ungulates show a positive selection on plant species and plant parts with the highest protein value [11]. The nitrogen or protein content of the plant is only one of the many plant characteristics that are vitally important to herbivores [12]. The views of previous works supported the findings of the present study. The grass formed the major portion of elephant diet in Mudumalai Wildlife Sanctuary [3]. In our study area, about 46.15% of their consumed fodder belonged to grasses. This result agreed with the findings of earlier workers [13-15]. Plant family Areeacea (*Calamus* sp.) was selected more, followed by Moracea (*Artocarpus, Ficus* species) [16] this finding contradict out finding as we recorded the highest share of fodder was from *Poaceae*. The percent TA content in forest and non-forest areas varied within the range of 2.66-20.00%. The increased level of ash in post monsoon season in non-forest areas may be attributed in inviting elephants to raid crops as the availability of crops were increased with palatability.

The elephants consumed barks of *Bombax ceiba* and *Sterculia villosa* containing CP 8.5% and 10.00%, respectively; in post monsoon season. The debarking of many food plants by elephants has been observed in various parts of the tropics [17]. The present finding also agrees with the findings of the previous worker [17]. The percent NDF content of fodder in forest and non-forest areas was varied from 38 to 96, and 36 to 82, respectively. No significant

changes were observed among seasons, but significant difference was observed ($p<0.05$) between forest and non-forest areas, as NDF content was higher in forest irrespective of the season. The level of cellulose, hemicelluloses and lignin increased considerably during post monsoon season in forested areas, which signify the decreased palatability and intake of natural vegetation. Thus, the elephant moves away from their natural habitat to find out alternative source of fodder with high nutritive value such as cash crops and other agricultural crops. Similar observation was also made by earlier worker [8]. It has also been reported that the raiding of agricultural fields by elephants sometimes occurs due to proximity with cultivation [18-20]. Crop raiding in the study area was a herd activity, but sometimes a lone dominated male (makhna) or mother along with a calf was involved and mostly occurred in the night. The elephants raid crops when the quality of the preferred food item, grass began to decline in their natural habitat [21]. In the present study, the increased incidence of crop raiding was observed particularly in post monsoon season when increased number of fodder along with higher content of CP, TA and lower content of NDF were present than the forest areas. Other studies also reported on the crop raiding in increased intensity during certain months when the grain matures and continue till harvesting [22].The availability of fodder and its preference found to have a significant relation when the nutrient content of fodder decreases along with reduced number of fodder in forest areas, at the same time the availability of nutritionally rich source of crops become abundant in non-forest areas. Again, due to maturation of fodder in forest areas, the lignifications reduce the palatability of fodders and elephants are bound to forage more time in search of required quantity of fodder to maintain their biological needs. On the other hand, in non-forest areas, particularly in post monsoon season, palatable crop along with an abundant quantity also reduces the foraging time. Therefore, these findings establish a correlation between the availability of fodder and its preference by crop raiding elephants in the study areas.

Conclusions

The present investigation revealed that the fodder with high nutritive value and availability in proximity to the forest areas provoked the elephants to consume agricultural crops in some parts of the year. As a consequence, the findings would contribute into a useful insight into the management of habitat for conservation of large herbivores like elephant in the long run and in mitigation of human-elephant conflicts.

Authors' Contributions

The present study is a part of M.V.Sc. program of BJD and the manuscript was prepared by BJD. BNS major guide during M.V.Sc. research contributed in the designing the research work and manuscript preparation. KKB and AB member of research advisory committee contributed valuable suggestions during the preparation of the manuscript. MB guided and contributed in statistical analysis part. All authors read and approved the final manuscript.

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Competing Interests

The authors declare that they have no competing interests.

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