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Frugivory and seed dispersal of *Carissa spinarum* (L.) in a tropical deciduous forest of central India

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Abstract: Four species of birds (*Carpodacus erythrinus, Passer domesticus, Pycnonotus cafer, Streptopelia decacto*) have been found to feed the ripen fruits of shrub *Carissa spinarum* (L.) in a tropical deciduous forest of Chhuhia, Rewa (M.P.). Birds usually swallowed whole fruit and voided seeds either by regurgitation (*P. domesticus*) or defecation (*C. erythrinus, P. cafer, S. decacto*) beneath the canopy of perching trees and shrubs of the forest. Each frugivore consumed an average of 4.42 fruits during any foraging bout. The frugivorous birds removed approximately 196 seeds per day per plant of the shrub within forest. Of the four birds, *Pycnonotus cafer, P. asser domesticus* and *S. decacto* performed much of potential seed dispersal events and proved themselves as principal dispersers of *Carissa spinarum* seeds in the Chhuhia forest.

Resumen: Cuatro especies de aves (*Carpodacus erythrinus*, *Passer domesticus*, *Pycnonotus cafer* y *Streptopelia decacto*) se alimentan de los frutos maduros del arbusto *Carissa spinarum* (L.) en un bosque tropical caducifolio de Chhuhia, Rewa (M.P.). Las aves por lo general tragan el fruto completo y evitaron las semillas ya sea por regurgitación (*P. domesticus*) o defecación *(C. erythrinus*, *P.cafer*, *S. decacto*) bajo el dosel de árboles y arbustos donde perchan en el bosque. Cada frugívoro consumió un promedio de 4.42 frutos durante cualquier turno de forrajeo. Las aves frugívoras retiraron aproximadamente 196 semillas por día por planta del arbusto en el interior del bosque. De las cuatro aves, *P. cafer*, *P. domesticus y S. decacto* llevaron a cabo gran parte de los eventos potenciales de dispersión de semillas y probaron ser los principales dispersores de semillas de *C. spinarum* en el bosque Chhuhia.

Resumo: Quatro espécies de aves (*Carpodacus erythrinus*, *Passer domesticus*, *Pycnonotus cafér*, *Streptopelia decato*) foram identificadas como alimentando–se de frutos maduros do arbusto *Carrisa spinarum* (L.) numa floresta decídua em Chhuhia, Rewa (M.P.). As aves usualmente engolem todo o fruto e evitam as sementes quer por regurgitação (*Passer domesticus*) ou por defecação (*Carpodacus erythrimus*, *Pycnonotus cafer*, *Streptopelia decacto*) sob a copado das árvores e arbustos da floresta. Cada pássaro frugívero consome uma média de 4,42 frutos durante cada surtida alimentar. As aves frugíveras removem cerca de 196 sementes por dia por arbusto na floresta. Das quatro aves, a *Pycnonotus cafer*, *Passer domesticus* e *Streptopelia dacacto* protoganizaram a maior parte do potencial de dispersão dos surtos seminais e provaram ser os principais agentes de dispersão das sementes da *Carissa spinarum* na floresta Chhuhia.

Key words: Frugivory, seed dispersal.

Introduction

Seed dispersal offers at least three ecological benefits to a plant. It provides an opportunity to seeds to escape themselves from the excessive crowding and mortality that invariably occurs under the crown of the parent tree on account of competition. Dispersal may also allow a seed to spread its species into new habitats. Finally, some types of dispersal may position a seed to spread its species into new habitats. Finally, some types of dispersal may position a seed in the precise site required for successful germination and seedling establishment. Vertebrate animals are important dispersal agents and among them birds are perhaps most commonly associated with

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seed dispersal (Van der Pijl 1972). Some tropical bird species have evolved obligate frugivory (Morton 1973). Avian frugivory and seed dispersal have been a subject of many recent studies (Cain *et al.* 2000; Hamann & Eberhard 1999; Holbrook & Smith 2000; Wenny 1999, 2000; Wenny & Levey 1998; Whitney et al. 1998). Except a few records (Ganesh & Davidar 2001; Hegde *et al.*) which dealt with community level, the role of frugivores in the seed dispersal of particular trees and shrubs of Indian forests have not been investigated properly

Carissa spinarum L. (Apocynaceae) is a small spinus evergreen shrub of tropical deciduous forest of Chhuhia, Rewa (M.P.) and other Indian forests of dry regions. Fruiting phenology reveals that majority of plant species of Chhuhia forest are producing fleshy fruits during the summer dry months. *C. spinarum* is one of the few species to produce fleshy fruits during the post monsoon months, a period of general fleshy fruit scarcity at this forest. The species is shown to maintain itself naturally in the forest through seed dispersal and natural regeneration. The objective of this study was to analyse the role of birds in frugivory and seed dispersal of *C. spinarum* in a dry tropical forest of central India.

Methods

This study was conducted during September 2001 in the Chhuhia forest (lat. 24°–20'N, long. 81^0–20'E, about 616 meter m.s.l.) which lies 25 km south–east of Rewa town. Annual rainfall of this region averages 1019 mm, with mean maximum and minimum temperature being 31.4°C and 19.2°C respectively. Twenty ripe fruits were collected from the shrub and measured for average length and diameter. The pulp and seeds of 50 ripe fruits were carefully separated and weighed for wet mass. These separated fruit fractions were subsequently dried at 40°C in an oven and re–weighed for dry mass. The pulp mass was then incinerated in a muffle furnace at 600°C for at least 8 hours and subsequently weighed for ash content. Total sugar content (as glucose) of fruit pulp was estimated by phenol reagent method (Dubois *et al.* 1956). Pulp (0.1g) was homogenised in 20 ml of 80% absolute alcohol and centrifuged for 15 minutes. To 1 ml extract, 1 ml 5% phenol and 5 ml conc. sulphuric acid were added and optical density of the mixture was measured by spectrophotometer at 480 nm. The concentrations were quantified based on a standard curve prepared using glucose solution. Total nitrogen of the pulp was estimated by micro–kjeldahl method. From nitrogen value, the protein value was calculated by multiplying by 4.4 (Milton & Dintzis 1981). The exchangeable cations (Na, K, Ca), extracted from the pulp, were determined by Mediflame 127 (Systronics) flame photometer (Jackson 1973).

Observations were made at a single shrub, with large fruit crop, for a period of one week, daily from 0500 to 1900 hours. Observations for 15 minutes each were made at hourly interval, which were confirmed in the subsequent weeks. At each observation, total number of bird species, their individual numbers, time of first appearance on plant, and their foraging behaviour were recorded. Information on foraging behaviour of birds included: their visit lengths (in seconds), time spent in searching, handling and feeding the fruits, total time spent on plant, and fruits consumed per foraging bout. A foraging bout is the time a bird actually spends in handling and ingesting fruit(s). Timing of the bout began when the frugivore reached to take the first fruit of a bout and ended when the frugivore had ingested the last fruit in the sequence (Hoppes 1987). Observations were recorded on how fruits were ingested and on methods of regurgitation and defecation of seeds.

Results and discussion

In *Carissa. spinarum* fruiting events take place during monsoon and post–monsoon months. The green fruits appeared during the last week of June and started ripening by middle of July. The shrub displayed ripened fruit crop upto middle of November. An average berry was 0.76 cm in diameter, 1.08 cm in length, 219.6 mg in fresh weight, 80.8 mg in dry weight, and single seeded (Table 1). Pulp accounted higher weight (49.2 mg)

Table 1. Fruit characteristics of *Carissa spinarum*.

Parameters	Values
Diameter (cm)*	0.76
Length of fruit (cm)*	1.08
Fresh weight (mg)*	219.6
Dry weight (mg)*	80.8
Pulp weight (mg)*	49.2
Seed weight (mg)*	31.6
Ash content (%)	2.53
Sugar (%)	1.45
Protein (%)	16.0
Ca (%)	2.51
K (%)	0.22
Na (%)	0.03

* Mean of 20 samples.

Table 2. Foraging behaviour of different bird species feeding fruits of *Carissa spinarum* (mean ± SE; n= 84).

Bird Species	*Carpodacus erythrinus*	*Passer domesticus*	*Pycnonotus cafer*	*Streptopelia decacto*	Average
Initiation of visit (h)	9.00	8.00	8.00	9.00	
No. of individuals per visit	2.0±0.02	2.6±0.2	1.6±0.1	1.6±0.1	
Searching time per visit(s)	17.7±1.5	16.7±4.7	16.9±1.5	13.2±1.1	16.0±2.2
Feeding time per visit (s)	32.8±1.3	27.2±3.3	27.4±2.8	33.9±3.2	30.3±2.6
Time spent on tree per foraging bout (sec.)	49.9±2.8	43.9±3.0	44.3±4.3	47.2±4.3	46.3±4.9
No. of fruits consumed per foraging bout	5.4±0.6	5.1±0.69	4.0±0.5	3.8±0.4	4.4±0.5

to the fruit than seed (31.6 mg). The unripe green fruits turn into dark purple red on ripening. Judging from the descriptions of dispersal syndromes (Van der Piji 1972), *C. spinarum* has a typical ornithochoric fruit. Fruits are smaller in size, bright coloured and set off against the contrasting green leaves, sessile and easier to swallow by birds.

Four species of birds *(Carpodacus erythrinus, Passer domesticus, Pycnonotus cafer, Streptopelia decacto)* were found to ingest the ripened fruits of this shrub in Chhuhia forest (Table 2). These frugivores initiated their visits to the shrub during morning hours (0800 to 0900 h). *P. domesticus* appeared to be more abundant (2.6 individuals) on the shrub compared to *C. erythrinus* (2.0 individuals), *P. cafer* (1.6 individuals) and *S. decacto* (1.6 individuals) at each observation.

Frugivores spent more time (average 30.3 s) in handling and feeding the fruits than searching them (average 16.0 s) at each foraging bout (Table 2). However, this difference in searching and feeding time was insignificant ($t=1.084$, d.f.=16, $p> 0.05$). Frugivores spent less than a minute (average 46.3 s) in the shrub during any single visit. Also, there was significant difference between the time spent by four frugivorous birds in the shrub ($F=4.051$, d.f. 14,3; $p <0.05$). The average time spent by these frugivores on fruiting shrub is similar to passerines, feeding the fruits of *Prunus mehalab* (Herrera & Jordano 1981). Murray (1987) suggested that fruit crop size influences the birds visit, their fruit consumption rate and stay period in the plant. He argued that because fruit crops produced by understory plants are small in relation to those produced by trees, frugivore foraging patterns are unlikely to be influenced by the same degree by shrubs as by trees. Longer visits may result in reduced long distance dispersal of seeds if more fruits are dropped beneath the parent plant canopy due to mishandling of fruits by frugivorous birds. It has been suggested that frugivores often become satiated and perch for long period in plants with superabundant fruits, dropping most seeds beneath the crown, where they may subject to high density dependent mortality (Howe 1981; Pratt & Stiles 1983).

Each frugivore consumed an average of 4.4 fruits during any foraging bout (Table 2). Among frugivores, *C. erythrinus* consumed maximum fruits (average 5.4 fruits) per visit to be followed by *P. domesticus* (5.1 fruits visit^{-1}), *P. cafer* (4.0 fruits visit^{-1}) and *S. decacto* (3.8 fruits visit^{-1}). This difference in fruit consumption rate among frugivorous birds was insignificant ($F=0.47$, d.f. 14.3, $p>0.05$). Fruit–eating vertebrates often differ in foraging behaviour (Moermond & Denslow 1985; Trainer & Will 1984) and fruit removal rates (Bronstein & Hoffman 1987; Englund 1993).

The most common feeding technique, adopted by the frugivores, was plucking fruits with the help of bill while perched on the branch supporting fruits or nearby branch close to a fruit. Birds usually swallowed whole fruit during feeding, including seed and pulp mass. Swallowing of fruits has been also observed as the common behaviour of frugivorous seed dispersers in other forests (Hegde *et al.* 1991; Herrera 1984; Rey *et al.* 1997). Herrera (1995) suggested that most of the fleshy–fruited plants rely on this bird feeding behaviour to disperse their seeds. Fruits are considered to be swallowable if their width is less than or equal to the birds gape width (Debussche & Isenmann 1989; Herrera 1984; Wheelwright 1985).

After completion of a foraging bout they flew to perching trees and shrubs of the area where they voided swallowed seeds intacted either by regurgitation *(P. domesticus)* or by defecation

Table 3. Consumption of fruits (per foraging bout) by frugivores and estimated rate of seed removal of *Carissa spinarum* shrub.

Bird species	*Carpodacus erythrinus*	*Passer domesticus*	*Pycnonotus cafer*	*Streptopelia decacto*	Total
No. of fruits consumed per foraging bout	5.4	5.1	4.0	3.0	
No. of visits per day	7.0	11.2	14.3	14.1	
No. of seeds removed per day	37.9	58.0	57.2	43.2	196
Seeds removed by birds (%)	19.3	29.5	29.1	22.0	

(C. erythrinus, P. cafer, S. decacto). Seed dispersal by birds to perches reported here is not unusual. Many recent studies have found that birds often disperse seeds to perching sites (Duncan & Chapman 1999; Guevara & Laborde 1993; McClanahan & Wolfe 1993; Nepstad *et al.* 1996; Robinson & Handel 1993; Wenny 2000).

The transport of seeds by these frugivores to perching trees and shrubs and already vegetated areas improves the chances of seedling establishment, as the seeds are deposited in those places where the presence of vegetation is earlier confirmed and also where there are fewer obstacles for walking (Chavez–Ramirez & Slack 1994; Schupp 1993,1995; Schupp & Fuentes 1995). The low shrub cover appears to increase the probability of saplings growth upto shrub height without herbivore damage (Herrera & Jordano 1981). Birds generally disperse seeds preferentially to structurally complex microhabitats where they perch while digesting fruits and voiding seeds (Chavez–Ramirez & Slack 1994; McClanahan & Wolfe 1993; Robinson & Handel 1993). Also, birds tend to regurgitate or defeacate relatively few seeds in a group which may be less likely to die from density dependent seed predation or competition. However, Chambers *et al.* (1999) have pointed out that this is not a universal expectation, since repeated use of a single perch by birds can lead to high densities of seeds. There is always a possibility that some seeds may land in light gaps within the forest where the probability of seedling establishment is higher (Augspurger 1984). Further studies are needed to assess the forest floor conditions at different perching sites, where the seeds are voided, for their role in seed germination and subsequently seedling establishment.

By combining information on visitation and ingestion rate, the number of seeds removed per day by each frugivore was determined (Table 3). Out of four birds, *P. domesticus* (58.0 seeds day $^{-1}$) and *P. cafer* (57.2 seeds day^{-1}) removed maximum number of seeds (collectively 59%) and appeared as principal dispersers of *C. spinarum* seeds in the forest. Remaining two birds *S. decacto* and *C. erythrinus* removed 43.2 and 37.9 seeds day^{-1}, respectively. Although individuals of *C. erythrinus* spent more time in the shrub (Table 2) and also ingested more fruits per foraging bout but were less frequent in visits (average 7.0 visits day^{-1}), and thus dispersed less seeds per day. In contrast, the remaining birds ingested comparatively low fruits per foraging bout but were more frequent in the visits, and thus dispersed more seeds per day. As number of visits made by a particular bird species to fruiting plants is often positively correlated with the number of seeds dispersed (Schupp 1993), we can thus assert that the above species performed much of potential seed dispersal events recorded during this study. Although *C. spinarum* attracted four bird species that carried away its seeds, the rate of seed dispersal from the shrub was low (16.3 seeds h^{-1}). Assuming a 12 h day, birds could disperse an average of 196 seeds per day. This result is in keeping with the reported percentage of fruits taken and seeds dispersed from some other plant species with larger crops of bird–dispersed seeds (e.g. Jordano 1995).

The species presents some features, which might have contributed to its attractiveness to birds. *C. spinarum* is one of the few species to bear fleshy fruits during the post monsoon months, a period of general fleshy fruit scarcity at Chhuhia forest. Another character that might have attracted frugivores is the dark purple red colour of ripen fruits of this shrub. Studies have shown that bird disseminated fruits frequently would be either black or red in colour (Corlett 1996; French 1991; Knight & Siegfried 1983; Lee *et al.* 1988; McDiarmid *et al.* 1977; Wheelwright *et al.* 1984; Willson 1986). This feature, together with other fruit characteristics observed (smaller in size, easier to swallow, sessile) suggest that fruits of C. *spinarum* are primarily adapted to birds. The lower contents (Table 1) of sodium and potassium in the fruit pulp mass suggest that fruits of this shrub could not be a good source of these minerals to birds.

On the other hand the fruit of *C. spinarum* seem to be a good source of calcium and protein to birds.

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