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Journal of Threatened Taxa

10.11609/jott.2023.15.8.23631-23826
www.threatenedtaxa.org

26 August 2023 (Online & Print)
15(8): 23631-23826
ISSN 0974-7907 (Online)
ISSN 0974-7893 (Print)

Open Access

ISSN 0974-7907 (Online); ISSN 0974-7893 (Print)

Publisher
Wildlife Information Liaison Development Society
www.wild.zooreach.org

Host
Zoo Outreach Organization
www.zooreach.org

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Cover: Coromandal Sacred Langur *Semnopithecus priam* - made with acrylic paint. © P. Kritika.

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 August 2023 | 15(8): 23742–23749
ISSN 0974-7907 (Online) | ISSN 0974-7893 (Print)
https://doi.org/10.11609/jott.8390.15.8.23742-23749
#8390 | Received 03 February 2023 | Final received 18 July 2023 | Finally accepted 08 August 2023
COMMUNICATION
OPEN ACCESS

Notes on nesting behavior of Yellow-footed Green Pigeon *Treron phoenicopterus* (Latham, 1790) in Aligarh Muslim University campus and its surroundings, Uttar Pradesh, India

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Abstract: The nesting behavior of the Yellow-footed Green Pigeon *Treron phoenicopterus* was observed during its breeding season in 2021 in an urban region encompassing the Aligarh Muslim University Campus and the surrounding areas. Data were collected by searching nests in the study area. The breeding season for the species in the study sites begins in March and re-nesting is attempted even in July. A total of 31 nests were found on 24 trees belonging to eight species. The analysis of nest site characteristics revealed that *Millingtonia hortensis*, *Azadirachta indica*, and *Dalbergia sissoo* were the most important nest tree species, accounting for 69% of the identified nests during the study period. These findings contribute to our understanding of the nesting behavior of the Yellow-footed Green Pigeon in an urban environment and have implications for its conservation and management.

Keywords: Aligarh Fort, canopy, columbidae, incubation, mating season, nest site characteristics, squabs, urban region.

Hindi: हरियल (ट्रेरॉन फोनीकोप्टेरस) का घोंसला बनाने का व्यवहार 2021 में इसके प्रजनन के मौसम के दौरान देखा गया था। एक शहरी क्षेत्र में जिसमें अलीगढ़ मुस्लिम विश्वविद्यालय परिसर और आसपास के क्षेत्र शामिल हैं। घोंसले खोजकर डेटा एकत्र किया गया। अध्ययन क्षेत्र में. अध्ययन स्थलों में प्रजातियों के लिए प्रजनन का मौसम मार्च में शुरू होता है और जुलाई में भी पुन: घोंसले बनाने का प्रयास किया जाता है। कुल आठ प्रजातियों के 24 पेड़ों पर 31 घोंसले पाए गए। घोंसला स्थल की विशेषताओं के विश्लेषण से पता चला कि नीम चमेली, नीम, और शीशम सबसे महत्वपूर्ण घोंसला वृक्ष प्रजातियाँ थीं, जो इस दौरान पहचाने गए घोंसलों में से 69% के लिए जिम्मेदार थीं। ये अनुसंधान के परिणाम हमें शहरी पर्यावरण में हरियल के घोंसला बनाने का व्यवहार की समझ में योगदान करते हैं और इसके संरक्षण और प्रबंधन के लिए प्रासंगिकताएँ रखते हैं।

Editor: Anonymity requested.

Date of publication: 26 August 2023 (online & print)

Citation: Maslehuddin, A.M. & S. Kumar (2023). Notes on nesting behavior of Yellow-footed Green Pigeon *Treron phoenicopterus* (Latham, 1790) in Aligarh Muslim University campus and its surroundings, Uttar Pradesh, India. *Journal of Threatened Taxa* 15(8): 23742–23749. https://doi.org/10.11609/jott.8390.15.8.23742-23749

Funding: The first author was awarded Junior Research Fellowship and subsequently Senior Research Fellowship by the University Grants Commission to conduct research.

Competing interests: The authors declare no competing interests.

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Author contributions: AMM undertook field surveys, noted behavioral data, took images in the field, collected the literature for manuscript preparation and wrote the manuscript. SK designed and planned the study including interpretation of the data. SK checked the manuscript and provided inputs for improvements.

Acknowledgements: First author acknowledge Uttam, Amber, and Arif for their constant support and encouragement. Also, all help extended by Uttam during fieldwork is highly recognized and appreciated.

INTRODUCTION

The Columbidae family is one of the world's most threatened families. Despite its widespread distribution, the family, which contains pigeons and doves worldwide has received little conservation attention; is considered to have 369 species, 16 of whom are extinct, and one is extinct in the wild (the Socorro Dove *Zenaida graysoni*) (Birdlife International 2020). Thirty-three species of Columbidae have a distribution in India. It is most likely because it is one of a group of birds threatened by human persecution, habitat degradation, and introduced predators (Owens & Bennett 2000).

India has an incredible diversity of Columbiformes, inhabiting 33 species, including fruit pigeons (Ali & Ripley 1987; Grimmett et al. 2016). Frugivorous birds are the key functional species, performing valuable seed dispersal services and regeneration and their decline or local extinction may have severe consequences for the functioning of an ecosystem (McConkey & Drake 2002). Yellow-footed Green Pigeon is frugivorous species and is a common resident species in Aligarh district in Uttar Pradesh, where no studies have been carried out on its status, distribution, or ecology. As a result, we planned to investigate the Yellow-footed Green Pigeon nesting ecology in this area. It breeds in the Aligarh Muslim University campus and adjoining areas regularly, and the Indian Jungle Crow *Corvus macrorhynchos* and House Crow *Corvus splendens* prey on their clutches and nestlings. A few studies on Columbidae are by Bhattacharya (1994) on morphological adaptations, Somasundaram (2006) and Devi (2012) on the ecology of Nilgiri Wood Pigeon and Yellow-footed Green Pigeon, respectively, and Kour (2016) on eco-biology of some species from Jammu. Therefore, the present study was conducted to present preliminary data on the nesting behavior of Yellow-footed Green Pigeons in an urban region.

Study Area

Aligarh Muslim University is in Aligarh district in Uttar Pradesh, India, in the Ganga-Yamuna doab region. It is located at the northernmost part of the Agra division, stretching from 27.4833^{0}N to 28.0166^{0}N latitude and 77.4833^{0}E to 78.6666^{0}E longitude (Image 1). The district covers an area of 3,650 km^2 and is 130 km from Delhi. The flora in the area is dry deciduous with mostly deciduous trees in most areas. The locations of the nest and random plots at both the study sites, i.e., AMU campus (NC_i & RC_i) and Aligarh Fort (NQ_i & RQ_i) are shown in Image 2.

The study area has arid open scrub called 'Rakhs' (Champion & Seth 1968). The study region has soil known as 'usar', mesquite plantation, and agricultural terrain. *Prosopis juliflora* (a weed species from central America) dominates most forest patches, followed by *Acacia catechu, P. cineraria, P. specigera, Melia azadirach, Azadirachta indica, Cordia dichotoma, Pongamia pinnata, Syzygium cumini, Dalbergia sissoo, Butea monosperma, Acacia nilotica, Acacia leucophloea*, and *Phoenix sylvestris* (Yasmin 1995).

In central Ganga Plain, the interfluvial stretch of the Ganga and Yamuna passes through Aligarh district. Most of the principal physiographic are made out of alluvial infill. The deposition of the Ganga and Yamuna rivers significantly influences the main soil types in the district. The Aligarh Fort and AMU Campus in Aligarh city (27.9135^{0}N, 78.0782^{0}E) harbor a diverse range of flora, including exotic species that have been intentionally planted. The Aligarh Fort, now managed by the Aligarh Muslim University, serves as a botanical garden and spans over an area of 47.87 ha with an average elevation of around 200 m. The vegetation within the Fort can be classified into different types. The central plain area, covering 10.31 ha, predominantly consists of ornamental and fruit trees such as *Terminalia arjuna*, *Mangifera indica*, *Psidium guajava*, *Emblica officinalis*, *Syzigium cuminii*, *Morus alba*, *Tectona grandis*, *Bombax ceiba*, and others. Surrounding this central plantation is an elevated ridge of scrubland with eight bastions, covering 6.85 ha, featuring natural vegetation including *Azadirachra indica*, *Dalbergia sissoo*, and a dominant shrub cover of *Capparis sepiaria*. *Prosopis juliflora* is notably prominent in the ridge area of the Fort. Encircling the ridge is a 50-m-wide depression that consists of barren land, covering an area of 12.1 ha. During the monsoon season, this area is adorned with herbaceous plants, while dry seeds of these monsoon herbs are available for the rest of the year. The flora of the Fort includes various plants including shrubs, climbers, and trees. Additionally, the area is inhabited by several mammalian species, including the Indian Grey Mongoose *Herpestes edwardsii*, Jungle Cat *Felis chaus*, Indian Hare *Lepus nigricollis*, Indian Gerbil *Tatera indica*, Five-striped Palm Squirrel *Funambulus pennantii*, India Bush Rat *Golunda ellioti*, and Rhesus Monkey *Macaca mulatta*, as documented in previous studies (Qureshi 1991; Khan 1992; Khan 2014).

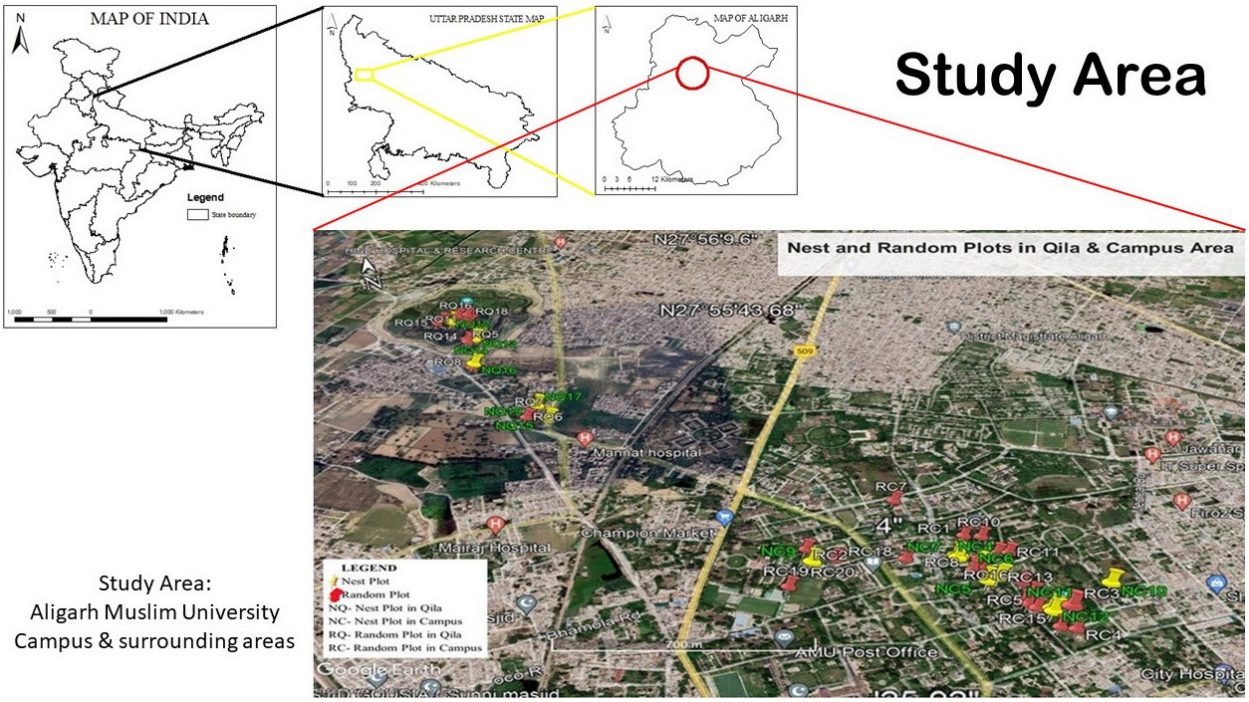

Image 1. Study area – Aligarh Muslim University Campus and Aligarh Fort.

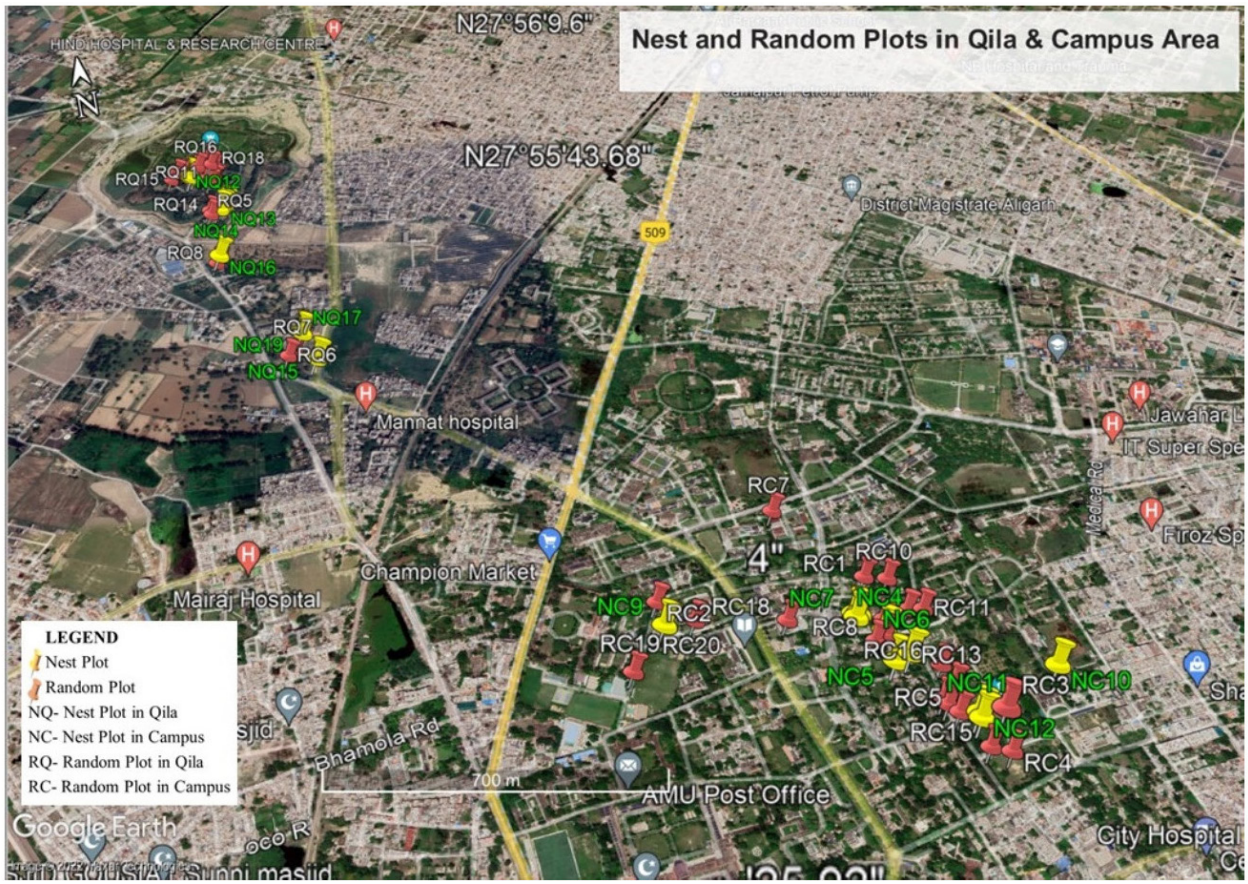

Image 2. Map depicting Nest plots (NCi and NQi) and Random Plots (RCi and RQi) located in AMU Campus and Aligarh Fort.

METHODS

Based on Devi (2012), the study focused on observing the nesting behavior of the Yellow-footed Green Pigeon during its 2021 breeding season in an urban region. The study sites included the Aligarh Muslim University (AMU) campus, Naqvi Park (27.9022° N, 78.0733° E), and the Aligarh Fort (27.9135° N, 78.0707° E). The methodology adopted by Devi (2012) aimed to understand the characteristics of the nesting sites and the factors influencing nesting site selection. To quantify the nesting environment, the methods outlined by James & Shugart (1970), subsequently refined by Mudappa & Kannan (1997), were employed. Data on nesting trees and nesting environment factors were collected and quantified. In order to detect nests of Yellow-footed Green Pigeons in the beginning of their nesting season, we largely depended on their behavioral cues such as collecting nesting material. During the mating season of Yellow-footed Green Pigeons, nest searches were conducted in the study region, and observations on nest trees and nest-site characteristics were made, following the methods used in previous studies (Gokula 2001; Devi & Saikia 2012). To ensure minimal disturbance to the nesting birds, all observations of their nesting activities were conducted from a safe distance, thus preserving the natural nesting behavior of the Yellow-footed Green Pigeon.

Observations of its nesting sites and nest site characteristics were undertaken from 10 March to 13 July 2021, when the final fledglings of active nests fledged. Once an individual or pair was sighted gathering twigs from the trees or constructing a nest, they were followed using binoculars or a camera and their nesting activities were recorded daily from 0630 h to 1130 h. A comprehensive dataset was obtained by closely observing selected nests, while additional nests were also monitored to determine the overall nesting success and gather supplementary data.

Adult birds undertaking breeding activities such as nest construction, incubation, and feeding the young in or near the nest indicated the presence of an active nest. A circular plot with a radius of 10 m was set up around each nesting tree to measure nest-site selection along with random plots which were also placed at a distance of 30–50 m from the nest plot. All characteristics were recorded in these plots as exercised in some earlier investigations (James & Shugart 1970; MacKenzie & Saely 1981; Clark et al. 1983; Sieg & Becker 1990; Liebezeit & George 2002).

Nest site and random site characteristics recorded during the study were tree number to be used subsequently for density calculations (trees/hectare), tree height (m), tree GBH (cm), basal area (m^2), the height of the first branch (m), distance from the nearest road (m), distance from nearest habitation (m), ground cover (%), shrub cover (%), canopy cover (%), canopy spread (m^3) and nest height (m). In addition, the species of nesting trees were identified and recorded. To ensure comparability and permit statistical analysis, the collected data were normalized beforehand. In the Qila (Aligarh Fort) area, the listed nest plots were labeled as NQi, while the random plots were labeled as RQi. On the other hand, in the University Campus area, the nest plots were labeled as NCi, and the random plots as RCi.

RESULTS

The Yellow-footed Green Pigeon's mating season begins in March and continues until July having re-nesting attempts towards the end of June and July. During this period, birds whose nests have been destroyed by predators seek to re-nest (Ayesha Mohammad Maslehuddin pers. obs. 31 May 2021). A total of thirty-one nests of Yellow-footed Green Pigeons

Table 1. Characteristics of nest tree species of Yellow-footed Green Pigeon in the study area.

	Tree species	Tree height (m)	Tree GBH (m)	Wood type	Foliage type	No. of nests
1	*Millingtonia hortensis*	15–25	0.20–0.55	Softwood	Deciduous	9
2	*Azadirachta indica*	10–21	0.19–1.09	Softwood	Deciduous	5
3	*Dalbergia sisso*	10–15	1.20–1.40	Hardwood	Deciduous	4
4	*Prosopis juliflora*	10–17	0.20–0.65	Softwood	Deciduous	6
5	*Holoptelea integrifolia*	17–27	0.22–1.11	Softwood	Deciduous	3
6	*Mangifera indica*	15–21	0.36–0.85	Softwood	Deciduous	2
7	*Syzygium cumini*	17–21	0.57–0.67	Softwood	Deciduous	1
8	*Bombax ceiba*	18–20	0.25–0.71	Softwood	Deciduous	1

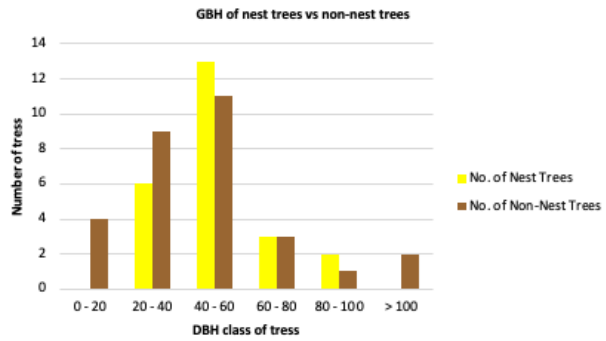

Figure 1. Girth at breast height (GBH) of nest trees and non-nest trees.

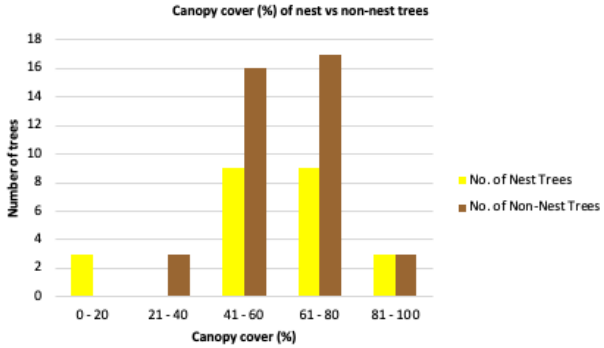

Figure 2. Canopy cover of nest trees and non-nest trees.

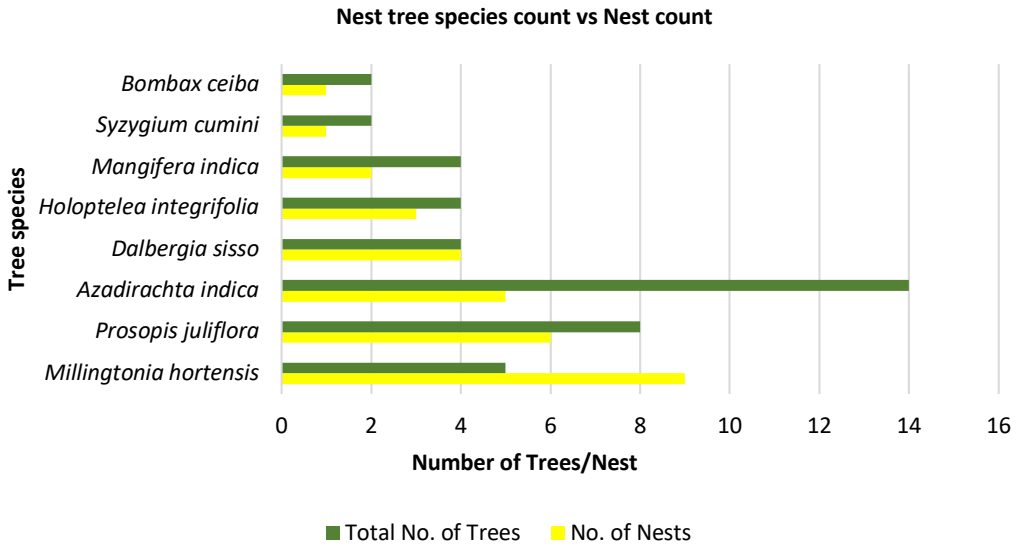

Figure 3. Total counts of nest tree species in nesting and random plots and number of nests.

were found, with 14 nests located at Aligarh Fort and 12 nests situated on the AMU campus. These nests were distributed among 26 trees in the study area. Out of the 26 nest trees, six were *Prosopis juliflora* (25%), five *Azadirachta indica* (Neem) (21%), four *Millingtonia hortensis* (Indian Cork Tree), and *Dalbergia sissoo* (Sheesham) (17%), two were *Mangifera indica* (Mango) and one each of *Holoptelea integrifolia* (Jungle Cork Tree), *Syzygium cumini* (Black Plum), and *Bombax ceiba* (Silk Cotton Tree) (Table 1).

The GBH of non-nest trees (0.46 ± 0.03) was slightly higher than that of the nest trees (0.42 ± 0.05) (Figure 1), but there was no significant difference ($t = -0.754$, $p > 0.05$) among them.

The canopy cover of non-nest trees (63.35 ± 2.26) was greater than the canopy cover of nest trees (58.37 ± 4.36) (Figure 2), and the difference was significant ($t = 17.958$, $p < 0.05$).

Tree species used for nesting by Yellow-footed Green Pigeons were *Millingtonia hortensis, Prosopis juliflora, Azadirachta indica, Dalbergia sisso, Holoptelea integrifolia, Mangifera indica, Syzygium cumini,* and *Bombax ceiba*. The number of nests on different tree species and the total number of individuals of each species, including those in the centre of random plots, are shown in Figure 3. The maximum number of nests were found on *Millingtonia hortensis.*

DISCUSSION AND CONCLUSION

The semi-natural plantations on the AMU Campus provide habitat to a wide variety of avifaunal species. The current study was one of the few attempts to acquire useful data regarding the ecology of species nesting.

Nest site characteristics show that *Millingtonia*

hortensis, *Azadirachta indica,* and *Dalbergia sissoo* are essential nest tree species accounting for 69% of the total nest trees identified during the study period. These tree species ranged 11–25 m in height and were branched and bifurcated to provide a better place to hold the nest and a safe base for the pigeons to make their nests. Another reason was the abundance of these tree species at the study site.

The study revealed that the breeding season of Yellow-footed Green Pigeon is from late March to July in the study area. Nest building begins in early April, and they make open nests of mostly twigs (Image 3). Nests of Yellow-footed Green Pigeons are very simple in structure and made up of small twigs placed crisscrossed over one another. Both sexes were seen sharing nest building and duty of incubation, i.e., one of the breeding males or females continued to sit on the eggs while the other pair went foraging. As per observation, only one squab is hatched per nest. The duration from nest building until the fledgling left the nest was 39–44 days.

Nest building by Yellow-footed Green Pigeons was observed during the study period. Most of the nest-building activity occurred 0630–1000 h. Nest materials such as twigs were collected from dried branches of *Holoptelea integrifolia*, *Azadirachta indica*, *Tectona grandis*, *Eucalyptus citriodora*, *Syzygium cumini*, and *Casuarina equisetifolia* trees 15–30 m away from nest site by one of the mates. One of the breeding pair individuals broke suitable twigs from the branches and carried them toward the nest. The waiting individual on the tree gently arranged it into the nest securely. Also, it was observed that the individual carrying the twig never landed directly at the location where another mate was building the nest; instead, it would land on branches higher in the canopy and then move down towards the nest location cautiously. Apart from these, the frequency of nest-building trips was maximum during the 2nd and 3rd days of nesting, which gradually declined in the following days.

During the study, birds of prey such as Pariah Kites *Milvus migrans* and occasionally crows (*Corvus splendens* or *C. macrorhynchos*) were commonly seen preying on nests of Yellow-footed Green Pigeon. Some competitors like Common Mynas *Acridotheres tristis*, Eurasian Collared Dove *Streptopelia decaocto*, and Indian Palm Squirrel *Funambulus palmarum* mostly destroyed the nests; they forcefully entered the nest area of the pigeon, destroyed it and occupied the territory. Natural calamities like heavy rain and the storm destroyed most nests during the pre-hatching stage. Generally, the Yellow-footed Green Pigeons construct their nests on softwood trees, which are easily broken due to heavy rain and storm.

Association of yellow-footed Green Pigeons with the Black Drongo *Dicrurus macrocercus* during nesting season (Image 3) may be a great driver in predicting nests' success and subsequently emerging chicks. Around 40% of nests were successfully raised due to a Black Drongo nest in the vicinity of nests of Yellow-footed Green Pigeons. It has also been observed by Ali & Ripley (1987).

The success of nesting attempts by Yellow-footed Green Pigeons was determined based on the presence of hatched squabs in each nest. Of all the nests encountered, it was determined that only 35% achieved successful nesting, indicating the successful hatching of squabs. In contrast, the remaining 65% of nests were deemed unsuccessful due to their destruction by storms or abandonment caused by excessive disturbance, resulting in the absence of hatched squabs.

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Image 3. Nesting behavior of *Treron phoenicopterus* in the study area: a—Breeding pair | b—Nest building activity | c—Incubation activity | d—Nest exchange behavior of breeding pair | e—One of the parents with nestling | f—Feeding the nestling | g—One of the parents with the fledgling | h—built their nest nearby the nest of *Dicrurus macrocercus*. © Ayesha Mohammad Maslehuddin.

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Journal of Threatened Taxa is indexed/abstracted in Bibliography of Systematic Mycology, Biological Abstracts, BIOSIS Previews, CAB Abstracts, EBSCO, Google Scholar, Index Copernicus, Index Fungorum, JournalSeek, National Academy of Agricultural Sciences, NewJour, OCLC WorldCat, SCOPUS, Stanford University Libraries, Virtual Library of Biology, Zoological Records.

NAAS rating (India) 5.64

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Journal of Threatened Taxa

www.threatenedtaxa.org

ISSN 0974-7907 (Online) | ISSN 0974-7893 (Print)

August 2023 | Vol. 15 | No. 8 | Pages: 23631–23826
Date of Publication: 26 August 2023 (Online & Print)
DOI: 10.11609/jott.2023.15.8.23631-23836

Publisher & Host

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Threatened Taxa