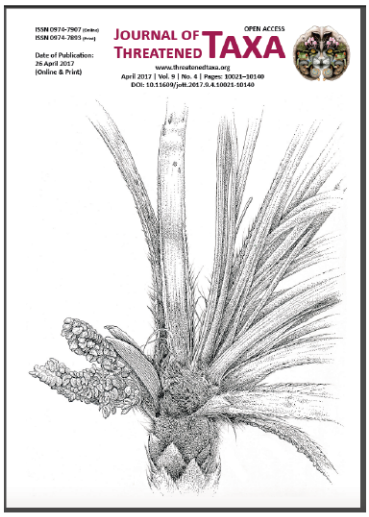

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TRADITIONAL HOME GARDEN AGROFORESTRY SYSTEMS: HABITAT FOR CONSERVATION OF BAYA WEAVER *PLOCEUS PHILIPPINUS* (PASSERIFORMES: PLOCEIDAE) IN ASSAM, INDIA

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Traditional home garden agroforestry systems: habitat for conservation of Baya Weaver *Ploceus philippinus* (Passeriformes: Ploceidae) in Assam, India

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Abstract: The present study was conducted in 18 homegarden agroforestry systems of Assam to assess the role in the conservation of Baya Weaver *Ploceus philippinus*. Observations were made on the type of host trees, location of host trees, their spatial arrangement pattern, height and diameter of host trees chosen for nesting and the number of complete and helmet stage nests. Trail walks were employed for assessing the encounter rates of predators. A total of 2357 individuals of potential host trees for nesting of *P. philippinus* were found belonging to *Areca catechu* (2272), *Cocos nucifera* (56), *Phoenix sylvasticus* (13) *and Borassus flabellifer* (16). According to the spatial arrangement pattern of host trees, among 2272 individuals of *A. catechu,* 96.5% (n=2192) and 3.5% (n=80) of individuals were arranged in block and row pattern respectively. The other three host trees were arranged in single pattern. Among these 80 individuals of *A. catechu* planted in row pattern, 47.5% (n=38) had nests (complete and helmet stage) on them. In total, 293 nests (both complete and helmet stage) were observed in *A. catechu*, out of which, 46.1% (n=135) were complete nests. The other three host trees had nests in various stages of development but none of them were completed by *P. philippinus*. The encounter rates of predators (arboreal mammals) was significantly higher in block patterns (2.56 ± 0.51) as compared to row patterns (0.53 ± 0.17) of host tree spatial arrangement whereas, the encounter rates of reptiles showed no statistical difference among the two patterns of host tree arrangement. Thus, *A. catechu* planted in row pattern was the most preferred host tree species for nesting by *P. philippinus* as compared to the other three host tree species. The height and DBH of *A. catechu* trees having nests varied from seven to 11 m (7.8 ± 1.11) and 10.5–16.5 cm (12.6 ± 1.4) respectively. The homegarden agroforestry systems provided suitable habitat for survival of *P. philippinus* as this system has ample water sources, feeding grounds, nesting material and host tree sources and conservation attitudes of the homegarden owners, thus, suggesting that homegarden agroforestry system can be a potential site for conservation of *P. philippinus* in human-modified land use.

Keywords: *Areca catechu,* Baya Weaver, conservation, homegarden agroforestry systems, nesting.

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Author Contribution: Y-U carried out the field work and drafted the manuscript. AK and MS had edited and finalized the manuscript.

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INTRODUCTION

Homegarden agroforestry systems (HAS) are complex combinations of multilayered and multispecies vegetation patterns (Kehlenbeck & Maass 2004) thereby, providing an ideal forest-like habitat to conserve wildlife species by providing sufficient nesting, breeding, food and temporary refuge opportunities all year round (Griffith 2000). HAS habitats are suitable for bird species, viz., Common Pigeon *Columba livia*, Spotted Dove *Spilopelia chinensis*, House Sparrow *Passer domesticus*, Scaly-breasted Munia *Lonchura punctulata*, Common Myna *Acridotheres tristis*, Baya Weaver *Ploceus philippinus*, among others, which are human-tolerant and adjusted to human habitats. These birds have been usually found to build nests and forage for food in and around human settlements (Soni et al. 2004). *P. philippinus* Linnaeus (Passeriformes: Ploceidae) is a common species found in agricultural and open savannah-like landscapes (Quader 2005). Their breeding season lasts from May to October (Ali & Ripley 1987). During breeding season, the males moult into a yellow and brown nuptial plumage, while females remain pale brown (Ali & Ripley 1987). They are granivorous (Avery 1979) birds forming enormous communal roosts (Gadgil & Ali 1974). Traditional HAS are one of the major land-use practices in Assam (Image 1a). Almost every household in rural areas of Assam has HAS in the available spaces of either backyard or front of house or both sides to fulfill daily basic needs for their family. The traditional cropping patterns like vegetables, fruits and supplementary food crops (Kumar & Nair 2004) are slowly being replaced and dominated with commercially important cash crops like Betelnut *Areca catechu*, Coconut *Cocos nucifera*, Rubber *Hevea brasiliensis*, etc., (Peyre et al. 2006). In Assam, *A. catechu* and *C. nucifera* trees form an inseparable part of HAS as well as the social and cultural life of the local people. Some studies have reported *A. catechu* as the most dominant component (52.7%) in HAS of Barak Valley of Assam (Das & Das 2005) and the second most frequent species (163 trees/ha) in HAS of Upper Assam (Saikia et al. 2012). The trees like *A. catechu, C. nucifera* (Borges et al. 2002), Date Palm *Phoenix sylvasticus*, Manila Tamarind *Pithecellobium dulce*, Indian Siris *Albizia lebbeck*, Toddy Palm *Borassus flabellifer* (Biswas et al. 2010), Bottlebrush *Callistemon* sp. (Kumar & Kumar 2015) are preferred by *P. philippinus* for nest building. In an exceptional case, nesting was also found on Royal Palm *Roystonea regia* (Image 1b). All of these above mentioned species are found in HAS of Assam with varied tree density. HAS are a source of water to the birds as it is composed of water reservoirs like small fish ponds, water tanks and wells. This system is also connected to paddy fields in the backyards of houses, thus, providing not only food for these granivorous bird species (*P. philippinus*) but also nest building materials for them. Thus, HAS and its surrounding environment provide welfare factors, which are preferred by *P. philippinus* for their refuge and nesting (Biswas et al. 2010). Thus, the present study is designed to highlight the importance of traditional HAS practiced by local people of Assam in the conservation of *P. philippinus*.

STUDY AREA

The study was carried out in 18 HAS in two villages namely Chengeli Mari Gaon (26^{0}52'57.1"N & 92^{0}47'8.4"E) and Tarajan (26^{0}55'36.9"N & 93^{0}49'10.2"E) (Fig. 1) in Sonitpur District of Assam, India from May 2014 to April 2015. HAS are composed of three to four sections namely ornamental trees groves (*Callistemon* sp., *Hibiscus rosa-sinensis, Jasminum grandiflorum, Duranta erecta*) in front of the house, multipurpose trees groves (*Borassus flabellifer, Eucalyptus* sp., *Bombax ceiba, Tetrameles nudiflora, Tamarindus indica*) in emergent layer, (*A. catechu, Albizia lebbeck, Acacia* sp., *Prosopis* sp., *Artocarpus heterophyllus, Cassia siamea, Mangifera indica, Phoenix* sp.) in the canopy layer, (*Musa* sp., *Citrus* sp., *C. nucifera, Litchi chinensis*) in understory layer, (flowering plants, *Agave* sp., etc.) in shrub layer and (medicinal plants and herbs) in herb layer and betel nut groves (*A. catechu* trees only) on either side of the house and bamboo groves (*Bambusa pallida, Bambusa tulda, Bambusa balcooa*, etc.,) in the backyard of the house which is connected to agricultural fields. Crops

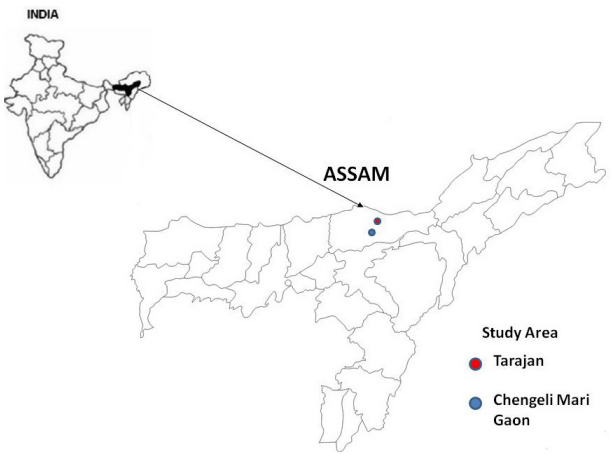

Figure 1. Study area

Image 1. a - Overview of homegarden agroforestry system; b - Nesting in *Roystonea regia*; c - *Areca catechu* plantation in row; d - Nesting in *Areca catechu* tree; e - *Ploceus philippinus* making helmet-stage nest using grasses; f - Complete nest of *Ploceus philippinus*.

like *Oryza sativa, Saccharum officinarum, Zea mays* are cultivated in the agricultural fields. This is similar to the pattern observed by (Das & Das 2005), in HAS of Barak Valley, Assam. Various water sources like ponds, tanks or wells are found in any one of these sections.

METHODS

Host/nesting trees assessment

To assess the contribution of HAS in providing nesting site for *P. philippinus*, a survey was made on the type of host trees, location of host trees and the height and diameter of host trees chosen for nesting (Quader 2005; Dutta & Raut 2015). The spatial arrangement

pattern of host trees were observed and categorized into three types as follows: (1) Block pattern: The trees were planted together in groups or in square pattern (distance between line to line and plant to plant is the same and plants are at the corner of each successive square (Kumar 2006) as seen in plantations; (2) Row pattern: The trees were planted in single rows or lines along the boundary of homes or HAS; (3) Single pattern: The trees were scattered or were singly placed in HAS. The number of helmet and complete nests in the colony were recorded. Here, helmet nests were those nests which were incomplete or were a partial nest structure at different developmental stages. Complete nests were those nests which were at final developmental stage and could be used for egg laying by the birds (Quader 2005).

Predator assessment

Two trails each were walked in the two villages covering all the three different host plants spatial arangement pattern (block, row and single pattern) with a total of 64 replicates. The total distance covered was 64km. The length of each trail was measured using a GPS. Each trail was walked twice in the morning for reptiles and arboreal mammals and twice at night for small carnivores in each of the four seasons (summer, monsoon, post-monsoon and winter). During night surveys a high beam LED torch was used. This survey was carried out from 21:00–23:00 hr. Once the eye-shine was detected, the animal was observed more closely using additional torches and the species was identified (Sreehari & Nameer 2016). Encounter rate was assessed by using the formula 'number detected per km.' (Datta & Goyal 2008). As there were no predators detected in the single host trees pattern, this category was removed from further calculations of predator's relative abundance. In addition, any information on the presence and absence of predators was gathered from the local inhabitants, indirect evidences like footprints, faecal deposits, calls, kills, foraging and roosting signs (Kumara & Singh 2004). Opportunistics sightings of predators were also noted.

Data analysis

The variables like number of reptile and mammal species individuals and their encounter rates were subjected to normailty tests. It was found that none among them were normally distributed and therefore, a non-parametric analysis was performed (Mann-Whitney U test). $p<0.05$ was considered statistically significant for all the above mentioned analyses. All analyses were run on SPSS (version 16.0 for Windows). Means and standard errors of mean (±SE) are given in text and tables.

RESULTS AND DISCUSSION

Potential host/nesting trees

In the present study, the potential host trees for nesting of *P. philippinus* were *A. catechu, P. sylvasticus, C. nucifera and B. flabellifer.* A total of 2357 individuals of host trees were found in the study area. Out of these 2,357 individuals, 2,272, 56, 13 and 16 individuals belonged to *A. catechu, P. sylvasticus, C. nucifera and B. flabellifer* respectively. According to the spatial arrangement pattern of host trees, among 2,272 individuals of *A. catechu,* 96.5% (n=2192) of individuals were arranged in block pattern and 3.5% (n=80) of individuals were arranged in row pattern along the boundary of HAS (Image 1c,d). All the individuals of the other three host trees were arranged in single pattern of spatial arrangement (Fig. 2). Out of 80 *A. catechu* trees planted in row pattern, 47.5% (n=38) had nests (complete and helmet stage) on them. Among 56 trees of *Cocos nucifera*, 13 trees of *Phoenix sylvasticus* and 16 trees of *Borassus flabellifer* planted in single pattern, 10.7% (n=6), 15.4% (n=2) and 6.3% (n=1) respectively, had nests (complete and helmet stage) on them (Fig. 3). This shows that *A. catechu* planted in row pattern was the most preferred host tree for nesting of *P. philippinus.* Similar plant species are also reported for nesting (Borges et al. 2002; Asokan et al. 2008, Biswas et al. 2010). These trees might have been chosen due to their unbranched pattern, smooth trunk and nature of leaves to sway in winds, which might provide protection from predators (Davis 1974). *A. catechu* has been observed as the most preferred host tree due to their abundance in homegarden as compared to other potential nesting trees. *A. catechu* are planted more in number by the homegarden owners as their fruits have economic and cultural importance in the life of local people of Assam.

Predator assessment

A total of three reptile species and two arboreal mammal species which could predate upon the eggs and chicks of *P. philippinus* were recorded in the block and row pattern spatial arrangement of host trees in HAS (Table 1). According to the IUCN Red List of Threatened Species status, two reptile species, viz., Painted Bronzeback *Dendrelaphis pictus* and Eastern Cat Snake *Boiga gokool* were not assessed and the rest were categorized as Least Concern. The overall number

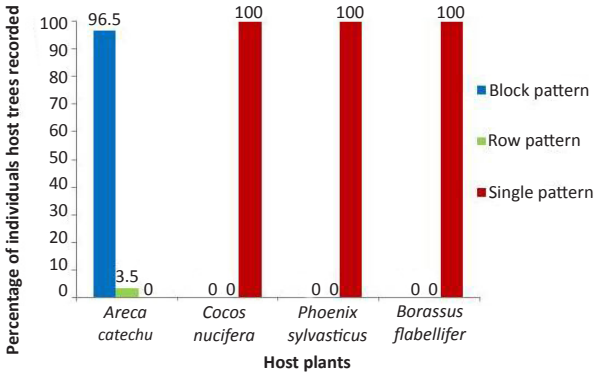

Figure 2. Host trees spatial arrangement pattern

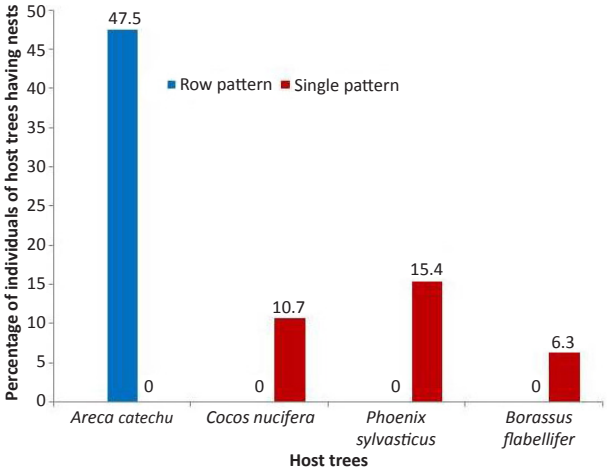

Figure 3. Host trees with nesting recorded

Table 1. Number and encounter rates of predators recorded in host tree spatial arrangement patterns.

Name of predator species	Block pattern		Row pattern	
	No. of Individual recorded	Encounter rate	No. of Individual recorded	Encounter rate
Reptiles				
Painted Bronzeback *Dendrelaphis pictus*	12	0.38 ± 0.11	2	0.06 ± 0.04
Eastern Cat Snake *Boiga gokool*	4	0.13 ± 0.06	0	0.00 ± 0.00
Copper-headed Trinket *Coelognathus radiatus*	3	0.09 ± 0.05	0	0.00 ± 0.00
Total	19	0.59 ± 0.14	2	0.06 ± 0.43
Arboreal mammals				
Common Palm Civet *Paradoxurus hermaphrodites*	1	0.03 ± 0.03	0	0.00 ± 0.00
Hoary-bellied squirrel *Callosciurus pygerythrus*	81	2.53 ± 0.51	17	0.53 ± 0.17
Total	82	2.56 ± 0.51	17	0.53 ± 0.17

of reptile species seen in block pattern and row pattern was 19 and two, respectively (Table 1) and significantly higher in block pattern (U = 1.000, p = 0.037). The overall encounter rates of the three reptile species in block pattern (0.59 ± 0.14 km^{-1}) however was not statistically different than the encounter rate of 0.06 ± 0.43 km^{-1} in row pattern (Table 1) of host plant arrangement (U = 4.000, p = 0.237). The overall number of arboreal mammal species recorded in block and row pattern was 82 and 17, respectively (Table 1) and significantly higher in block pattern (U = 0.000, p = 0.021). Similarly, the overall encounter rates of the four arboreal mammals in block pattern (2.56 ± 0.51 km^{-1}) was statistically higher than the encounter rate of 0.53 ± 0.17 km^{-1} in row pattern (Table 1) of host plant arrangement (U = 0.000, p = 0.021).

The higher occurrence of predators in block pattern than in row pattern of host trees spatial arrangment highlights the greater risk of evasion of *P. philippinus* nests in block pattern as compared to that of row pattern in HAS. This might be the reason for the interesting observation made in which the block pattern of *A. catechu* were devoid of any nests and only trees in row pattern were found bearing nests of *P. philippinus*. The tree-dwelling snakes viz. *D. pictus*, *B. gokool*, Copper-headed Trinket *Coelognathus radiatus* etc., and arboreal mammals, viz., Common Palm Civet *Paradoxurus hermaphroditus* and Hoary-bellied Squirrel *Callosciurus pygerythrus* which were recorded to a greater extent in block pattern as compared to row pattern are known to predate on bird chicks (Chuang & Lee 1997; Prater 2005; Ahmed et al. 2009) and eggs (Landry 1970). In the study site, the block pattern of trees consists mostly of monoculture plantations of *A. catechu* and sometimes mixed plantations of *A. catechu* with other multipurpose tree species, viz.: *Musa* sp., *Gmelina arborea*, *C. nucifera*, *Tectona grandis*, and *Carica papaya*. This vegetation composition might help in providing good canopy cover,

Table 2. Nesting material and host tree source and its occurrence in the study area.

Purpose	Plant species	Personal observation during present study	Source of nesting materials and nesting trees	Cited by
Nesting material	*Areca catechu*	√	Homegarden	Wood (1926); Davis (1974)
	Musa sp.	√	Homegarden	Wood (1926)
	Agave sp.	×	Homegarden	Wood (1926)
	Cocos nucifera	√	Homegarden	Borges et al. (2002)
	Saccharum officinarum	√	Homegarden & adjacent agricultural fields	Borges et al. (2002)
	Zea mays	√	adjacent agricultural fields	Davis (1974); Biswas et al. (2010)
Nesting trees	*Borassus flabellifer*	√	Homegarden	Ali (2009); Biswas et al. (2010)
	Phoenix sp.	√	Homegarden	Ali (2009); Biswas et al. (2010)
	Cocos nucifera	√	Homegarden	Quader (2003); Ali (2009)
	Eucalyptus sp.	×	Homegarden	Borges et al. (2002)
	Albizia lebbeck	×	Homegarden	Biswas et al. (2010)
	Acacia sp.	×	Homegarden	Quader (2003)
	Prosopis sp.	×	Homegarden	Quader (2003)
	Callistemon sp.	×	Homegarden	Kumar & Kumar (2015)

√ = observed during survey; × = not observed during survey

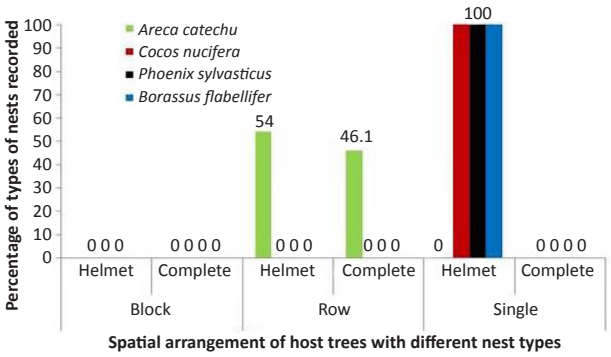

Figure 4. Parameters of nest types

leaf litter substratum, better microclimatic conditions as compared to that of row pattern. Therefore, block patterns provide a better shelter and place to hide and thus, less exposure to humans. This might be one of the reason for higher presence of predators in the block pattern of trees. Also, in block patterns as the canopy is well connected, it might provide easier routes for the arboreal predators to flee quickly when in danger. In the study site, the *A. catechu* trees alone or sometimes *A. catechu* intermixed with one or two trees of *Polyalthia* sp. or *C. nucifera* or *P. sylvasticus* were arranged in row patterns. All these row pattern of trees were found mostly along the boundary of homes, thus, increasing the chances of predators getting exposed to humans and ultimately increasing the chances of the predators being chased away or killed by the humans. Also, the canopy is not well connected and so the escape routes for the arboreal predators are meager. So, to ensure safety of nests from the predators, these birds might have preferred row pattern of *A. catechu* trees for building nests. Also, row pattern of trees might provide an unblocked view of the nests which might help the birds to keep an eye on them while flying (Soni et al. 2004) and foraging in the agricultural fields around. These fully visible nests might make it easier for the females to get attracted towards the nests and male displays and thus, initiate mating. The *P. philippinus* nesting sites had some specific characteristics. Majority of the nests (visual observation) were located on the outermost tip of the leaf. This is reported as a precautionary measure to avoid predators (Quader 2006). Most of the predators found in the study site as mentioned above are medium-sized animals and it would be very difficult for them to reach the tip of the leaf.

Nest attributes

In the current study, 293 nests (both complete and helmet stage) were observed on *A. catechu,* out of which, 46.1% (n=135) were complete nests and rest were helmet stage nests 54.0% (n=158). The other three host trees had only helmet-stage nests and neither of them were completed by *P. philippinus* (Fig. 4). In *P. philippinus*, the male completes the nest only

if the female selects a particular helmet-stage nest (Quader 2005) (Image 1e,f). So, the complete nests are the ones which are true nesting sites for *P. philippinus*. Therefore, it can be stated that in this particular study, *A. catechu* was the only potential host tree. The other potential host species like *C. nucifera, P. sylvasticus* and *B. flabellifer* were mostly found scattered within the block pattern of *A. catechu* and only a few trees were scantly found planted in single pattern in the study area.

Host tree atttributes

The height of the trees having nests varied from seven to 11m (mean: 7.8 ± 1.11) and seven to eight m (mean: 7.7 ± 0.47) for *A. catechu* and *C. nucifera* respectively. The mean DBH of trees on which nests recorded were 12.6 ± 1.4 cm with range of 10.5 to 16.5 cm in *A. catechu* and 36.1 ± 10.4 cm with range of 23.9 to 54.1 cm in *C. nucifera.* The mean height and girth of other potential host trees were not calculated due to low sample size. The results of the present study differs with the study done by Ali (2009) who reported the mean height and DBH (diameter at breast height) of nesting trees (*B. flabellifer*, *P. psuilla* and *C. nucifera*) to be 10m and 30.6cm respectively in Tamil Nadu. The affinity of the birds towards stout and tall trees might be because of the strength attained by trees due to DBH and safety of nestlings from predators due to height. Tall trees might be providing an ease in keeping an eye on the nest from a distance. It might also make the nests inaccessible to the predators (Borges et al. 2002; Ali 2009).

An interesting observation on the location of the host trees were made. The nesting trees were usually located around the water source and agricultural fields. Similar observations were also made by Wood (1926), Ali (2009) and Kumar & Kumar (2015). The birds might be selecting HAS for their breeding because of its proximity to welfare factors, such as foraging grounds, water source, nest building materials and nest safety. This might help them save time and energy during frequent travel to and fro at the time of food delivery to their nestlings. This close distance might also help them keep a watch on the nests even when they are away from nest for foraging in nearby fields. The *P. philippinus* are mainly granivorous (Avery 1979) but also feed on insects like caterpillars, grasshoppers, and leafhoppers during their developing stage (Ali 2009). Thus, they are predators of agricultural pests (biological controller) as well as pests of agricultural crops (Bhatt & Kumar 2001) and this fact is acknowledged by the residents of the study sites. According to some earlier observations made by other authors, the plant fibres and host trees preferred by *P. philippinus* for nesting are abundantly available in HAS and the adjacent agricultural fields in the study site (Table 2). During the surveys, a few individuals of *P. philippinus* were observed carrying leaf fibres from *S. officinarum*, *Z. mays* and *A. catechu* to build their nests (Table 2). The same observations were also made by the local inhabitants. Similar observations were made by Davis (1974) and Biswas et al. (2010) in West Bengal. HAS owners also mentioned the prolonged use of *A. catechu* trees by *P. philippinus* as host trees for nesting purpose. Thus, the present study suggests that HAS and the adjacent agricultural fields are a good source of nesting materials and host plants for nesting of *P. philippinus.* After the breeding season, when the nests are abandoned by these birds, the residents usually remove the hanging intact nests from the trees and keep them at homes for decoration purposes. The residents in the study area appreciate the weaver's ecological role as a biological controller of agricultural and horticultural pests and therefore, do not resist the birds while they are feeding on mature grains in paddy fields. Some of the residents were observed keeping water in a vessel and some grains scattered on the floor for the birds to feed upon to maintain their continued presence in the area. Keeping all these factors in mind, HAS plays an important role in the conservation of *P. philippinus*.

CONCLUSION

The three factors—(i) *A. catechu* being the most dominant crop in HAS, (ii) *A. catechu* planted in rows being the most preferred host plant for the nesting by *P. philippinus* and (iii) recognizing *P. philippinus* as natural biological control agent by local people—are the main drivers for future conservation of *P. philippinus* in HAS. It is quite evident that the *A. catechu* trees planted in single pattern of spatial arrangement are the most preferred nesting trees of these birds. The possible reasons for this preference might be reduction of risk from predators in row pattern of trees, more visibility of nests which help them keep a watch on their nests from far off and increase in the chance of females getting attracted towards the nests. Therefore, row pattern of *A. catechu* along the boundary of houses must be promoted in HAS. Thus, traditional homegarden agroforestry systems might have a huge habitat potential for conservation of *P. philippinus* in human-modified land use.

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