Apidologie 33 (2002) 539–543

DOI: 10.1051/apido:2002034

Original article

Spatial distribution of the dwarf honey bees in an agroecosystem in southeastern Thailand

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(Received 17 January 2002; revised 5 March 2002; accepted 19 March 2002)

Abstract – Colonies of *Apis andreniformis* and *A. florea*, had highly significant tendencies to be located near nests of their own species in a southeastern Thailand agro-ecosystem. *A. andreniformis* and *A. florea* chose similar nest sites, but the spatial correlations of their nesting sites were significantly negative, indicating that colonies may avoid areas containing nests of the other species. *A. andreniformis* nested at heights averaging about 6 m while *A. florea* nested at heights averaging about 4 m. The tendency of colonies of these species to establish their nest sites near existing nest sites of colonies of the same species may increase the probability that the newly selected nest sites are near suitable floral resources capable of supporting the survival and reproduction of the newer arrivals to the area. More importantly, spatial clumping probably helps assure that a colony's future reproductives will have potential mates within their mating range. Avoiding close association with colonies of conspecifics may help diminish interspecific interference with mating that may arise from the species having similar sex pheromones.

Asian honeybees / *Apis andreniformis* / *Apis florea* / spatial distribution / Thailand

1. INTRODUCTION

Colony aggregations are common in at least three members of the genus *Apis* L. The Asian *Apis dorsata* Fabr. forms aggregations of an extreme type, sometimes having more than 100 nests attached to the branches of a single large tree (Ruttner, 1988; Oldroyd et al., 2000; Seeley et al., 1982). *A. dorsata* colonies return to the same trees year after year following their annual migrations (Oldroyd et al., 2000) with the same colonies returning to the same exact sites (Paar et al., 2000; Neumann et al., 2000). *A. laboriosa*, F. Smith another giant Asian honey bee common in Nepal, forms nest aggregations on cliffs (Roubik et al., 1985). Wild *A. mellifera* L. can also form nest aggregations (McNally and Schneider, 1996; Oldroyd et al., 1995).

The genus *Apis* contains several other species that may also aggregate. Three of these species are sympatric with *A. dorsata* in southeastern Thailand. The dwarf honey bees, *A. andreniformis* F. Smith and *A. florea* Fabr., build single comb nests that are almost always

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attached to tree branches (Wongsiri et al., 1997; Rinderer et al., 1996). This study was undertaken to determine if these species also aggregate.

2. MATERIALS AND METHODS

The Chanthaburi Tropical Fruit Research Centre (CTFRC) of the Thai Department of Agriculture near Chanthaburi, Thailand was chosen as the study site. The CTFRC is within the natural range of *A. andreniformis, A. florea, A. dorsata*, and *A. cerana* Fabr. The Centre is comprised of horticultural plantings of a large variety of tropical fruit crops, and numerous buildings. Some, but not all, of the plantings receive agricultural sprays. Sprayed areas are unsuitable for the survival of the nests of *A. andreniformis* and *A. florea.* However, a large tract of unsprayed land provides potential habitat for all four native *Apis* species (Fig. 1).

We intensively and systematically searched the CTFRC for colonies of all honey bee species for a period of three weeks in March 2000. Each tree within the research station was observed, usually from within the canopy, and on more than one occasion by more than one observer. Our own efforts were assisted by information regarding bee nest locations supplied to us by numerous employees of the CTFRC who maintain the orchards and adjacent grounds. Since very few new nests were discovered in the last week of our study period, most, if not all nests in the study area were found. Few trees at the site exceed 10 m, and they are planted in orderly rows and roadways which were easy to search systematically.

Using a Global Positioning System receiver, the precise location of each nest was mapped (Fig. 1). Bee species identifications were made in the field using nesting habits as the primary characteristic. Only the nests of *A. andreniformis* and *A. florea* can be confused. Nests of these two species were distinguished by their species-specific nest structures (Rinderer et al., 1996; Wongsiri et al., 1997) and worker morphology (Wongsiri et al., 1997; Rinderer

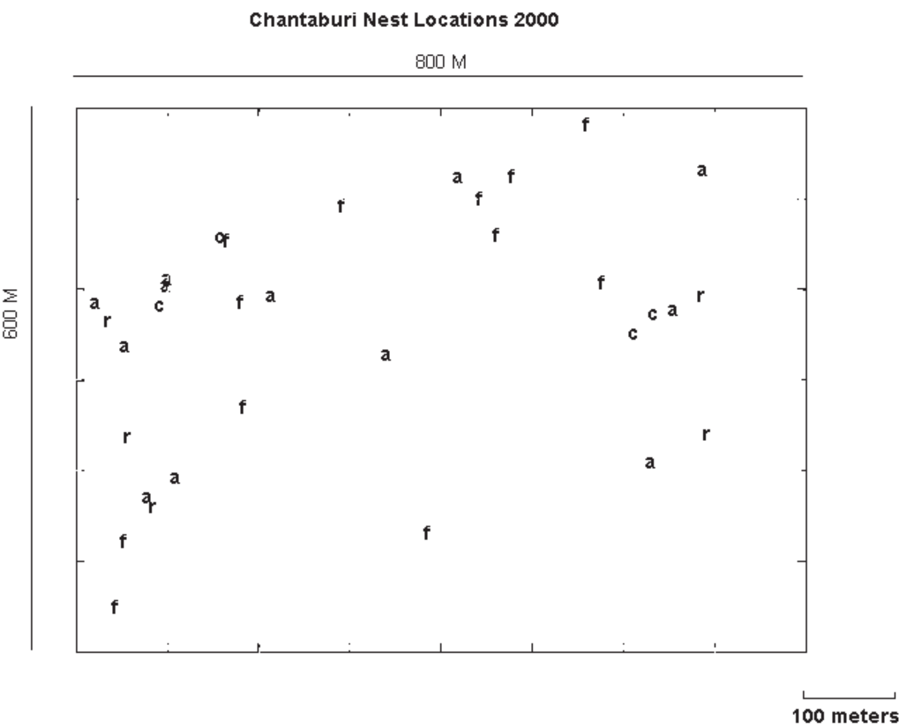

Figure 1. Graphic of the locations of honey bee nests at the Chanthaburi Tropical Fruit Research Centre. a = *A. andreniformis*, c = *A. cerana,* f = *A. florea*, d = *A. dorsata.*

et al., 1995). The height of each nest was estimated to the nearest meter and the species of the tree utilized for nesting was recorded.

We used the T-square sampling procedure (TSSP) (Ludwig and Reynolds, 1988) to determine whether or not the distribution of bee colonies was randomly distributed or aggregated. A 100 m^2 grid was superimposed on the map of colony locations (Fig. 1). Then distances from each grid point to the nearest nest and from that nest to the next nearest nest on the upper side of the grid were determined (Ludwig and Reynolds, 1988). From these distances, an index of spatial pattern (*C*) was calculated as the ratio of squared point-to-individual distances, x_i and squared individual-to-next nearest individual distances, y_i as:

$$C = \frac{\sum_{i=1}^{N}\left[x_i^2/(x_i^2+1/2y_i^2)\right]}{\mathrm{N}}.$$

The significance of *C* is determined from the *z* distribution with *z* calculated as

$$z = \frac{C-0.5}{1/(12\mathrm{N})}$$

C is approximately normally distributed with a variance estimated by 1/(12N). Statistical significance is obtained from a probability table for the standard normal distribution.

Spearman's rank correlation was calculated to test for associations of nest abundance for *A. andreniformis* and *A. florea* within the study area.

3. RESULTS

We found 31 honey bee colonies: 2 *A. dorsata*, 5 *A. cerana*, 12 *A. andreniformis*, and 12 *A. florea*. Thus, the overall density of nests was about 95 colonies/km^2, with the dwarf honey bees being by far the most common.

The dwarf honey bees

The distribution of *A. andreniformis* and *A. florea* nests was strongly aggregated within the area studied (Fig. 1). For *A. andreniformis,* the mean distance from the superimposed grid points to the nearest colony was 164 m and the mean distance from the nearest colony to the next nearest colony was 113 m. The index of clumping (*C*) was 0.76 and the *z*-statistic was 3.65 ($P < 0.005$). For *A. florea,* the mean distance from grid points to the nearest colony was 187 m and the mean distance from the nearest colony to the next nearest colony was 105 m. The index of clumping (*C*) was 0.73 and the *z*-statistic was 3.21 ($P < 0.005$).

The number of colonies of *A. florea* and *A. andreniformis* per 100 m^2 quadrat were negatively correlated (Spearman's correlation = –0.55, $P < 0.05$). This correlation suggests that the two species tend to aggregate in different areas even though *A. florea* and *A. andreniformis* chose similar plant species for nesting sites (Tab. I). A Chi-square analysis of the association of tree type and bee species was not significant ($\chi^2 = 2.5$, $df = 4$, $P = 0.476$).

A. florea and *A. andreniformis* established nests at different average heights. *A. florea*: = 4.0 m, $SEM = 0.75$, $n = 12$; *A. andreniformis*: = 6.2 m, $SEM = 0.58$, $n = 12$. Two-tailed *t*-test = – 2.53, $df = 10$, $P = 0.03$.

Apis cerana and *A. dorsata*

Visually, the 5 *A. cerana* colonies seemed to be aggregated into two groups. However, there were too few colonies to have confidence that this apparent aggregation is biologically important. Only two nests of *A. dorsata* were found on the station. One was on a water tower at a height of about 25 m. The other was 500 M distant, about 5 m high in a mango tree. Hence,

Table I. The number of colonies of dwarf honey bee nests located in various plant species.

Plant	*A. andreniformis*	*A. florea*
Phyllostachys sp. (Bamboo)	3	1
Mangifera indica L. (Mango)	3	1
Garcinia mangostana L. (Mangosteen)	5	7
other	2	3

the study area did not contain a sufficient number of *A. dorsata* colonies to include in the evaluations of aggregation although this species is often highly aggregated at other sites.

4. DISCUSSION

The study area contained clear aggregations of *A. andreniformis* and *A. florea*, and a suggestion of aggregation of *A. cerana*. Although it did not contain an aggregation of *A. dorsata*, there is indisputable evidence from other studies that *A. dorsata* aggregates to an extreme degree (Ruttner, 1988; Oldroyd et al., 2000; Seeley et al., 1982) as does *A. laboriosa* (Underwood, 1990; Roubik et al., 1985; Batra, 1996). The watertower of this study (Fig. 1) has hosted multi-colony *A. dorsata* aggregations in the past (Rinderer et al., 1993). Separate reports (Oldroyd et al., 1995; McNally and Schneider, 1996; Oldroyd et al., 1997) confirm the occurrence of nest aggregations of *A. mellifera,* though these are not always apparent (Taber, 1979). Hence, four members of the genus are now known to form colony aggregations. The four species that have not yet been evaluated for forming colony aggregations (*A. cerana, A. koschevnikovi, A. nuluensis* and *A. nigrocincta*) are all cavity nesting species. If they form aggregations, the aggregations will probably be loose ones like those of *A. mellifera*, and their occurrence will depend on nest density and the availability of suitable cavities.

The value for honey bees to nest in aggregations must be reasonably high, since doing so clearly has risks. Individual colonies increase the risk of acquiring pests and diseases from other colonies since overlapping foraging ranges and the tendency for bees to drift between nests must be increased by aggregation. Also, the propensity of "robbing" weaker colonies is well-known in *A. mellifera* and probably occurs to some degree in the other species. Since weaker colonies are often weaker because they are diseased, "robbing" will both spread disease and further debilitate if not destroy the weaker colonies. Finally, nest aggregations may enhance the nest finding abilities of predators which may learn to return to aggregations to prey on many of the nests (Seeley et al., 1982).

The tendency of *Apis* to form nest aggregations recommends future studies that follow aggregations of several species through several years and include inter- and intra-aggregation evaluations of colony relatedness. This would be very useful in understanding the origins and implications of nest aggregation both in *Apis* and perhaps more generally (Gueron, 1996; Parrish, 1999). Finally, enhanced understanding of why natural aggregations of Apis form may suggest management criteria for commercial apiaries that will enhance the benefits and reduce the costs of these man-made aggregations of honey bee nests.

Résumé – Répartition spatiale des abeilles naines dans un agroécosystème dans le sud-est de la Thaïlande. Les agrégations de colonies sont communes chez au moins trois membres du genre *Apis, A. dorsata, A. laboriosa* et *A. mellifera*. Le but de l'étude était de déterminer si les abeilles naines, *A. florea* et *A. andreniformis*, formaient aussi des agrégations. La répartition spatiale des colonies d'*Apis* a été notée dans une région du sud-est de la Thaïlande près de Chanthaburi. Le site d'étude, d'une surface de trois ha, était constitué des terrains d'une station de recherche horticole contigus à une forêt naturelle. Il comprenait des vergers, des plantations ornementales, des bâtiments et le long des cours d'eau des bandes étroites de forêts ayant repoussé. La disposition régulière des plantations a facilité la recherche systématique. Les colonies ont été localisées par une équipe de six chercheurs examinant intensément chaque arbre durant trois semaines au cours du mois de mars 2000. Chaque arbre et chaque bâtiment ont été inspectés plusieurs fois par différents chercheurs sous différents angles. Ces recherches formelles ont été complétées par les rapports faits par les nombreux ouvriers agricoles qui travaillaient sur le site. Lorsque des colonies étaient repérées, leur localisation précise était reportée sur une carte de la station à l'aide d'un appareil GPS (global positioning system) (Fig. 1). Nous avons trouvé 31 colonies d'abeilles : 2 d'*A. dorsata*, 5 d'*A. andreniformis* et 12 d'*A. florea*. La densité globale des nids était d'environ 95 colonies/km^2, les colonies d'abeilles naines étant les plus communes. Nous avons utilisé le procédé d'échantillonnage T^2 (Ludwig, 1988) pour déterminer si la répartition des colonies était ou non distribuée au hasard ou agrégée. Cette analyse a montré que la répartition des nids d'*A. andreniformis* et d'*A. florea* était fortement agrégée dans l'aire étudiée. Le nombre de colonies d'*A. dorsata* et d' *A. cerana* était insuffisant pour évaluer

statistiquement le niveau d'agrégation. D'autres études ont pourtant noté la forte tendance d'*A. dorsata* à se regrouper et l'inspection visuelle de la figure 1 suggère une tendance d'*A. cerana* à se regrouper. Il est connu également que *A. mellifera* peut former des agrégations lâches (Oldroyd et al., 1995 ; McNally et Schneider, 1996). *A. florea* et *A. andreniformis* ont établi des nids à différentes hauteurs. *A. florea* : 4,0 m, SEM = 0,75, $n = 12$; *A. andreniformis* : 6,2 m, SEM = 0,58, $n = 12$. Test-*t* bilatéral = –2,53, df = 10, $P = 0{,}03$. Mais les deux espèces semblent utiliser les mêmes plantes comme sites de nidification (Tab. I). Nous faisons remarquer que la formation d'agrégations peut être coûteuse pour les colonies et ceci peut suggérer qu'il existe des bénéfices significatifs qui sont encore indéterminés.

***Apis andreniformis / Apis florea* / répartition spatiale / abeille asiatique / Thaïlande**

Zusammenfassung – Räumliche Verteilung von Zwerghonigbienen in einem Agro-Ökosystem in Südost thailand. Die räumliche Verteilung von *Apis* Völkern wurde in einem Gebiet in Südost-Thailand in der Nähe von Chanthaburi erfasst. Das 3 ha große Untersuchungsgebiet befand sich auf dem Gelände einer an einen natürlichen Wald grenzenden Gartenbau-Forschungsanstalt. Es setzte sich aus Obstplantagen, Ziergehölzpflanzungen, Gebäuden und schmalen Streifen nachwachsenden Waldes entlang von Wasserläufen zusammen. Die regelmäßige Anordnung der Pflanzen erleichterte die systematische Suche. Mit Hilfe von sechs Mitarbeitern wurden die Völker während einer dreiwöchigen Periode im März 2000 durch intensives Absuchen von Baum zu Baum lokalisiert. Jeder Baum und jedes Gebäude wurden mehrfach von verschiedenen Mitarbeitern aus unterschiedlichen Blickwinkeln inspiziert. Diese formelle Suche wurde durch Berichte der zahlreichen auf dem Gelände tätigen Farmarbeitern ergänzt. Wurden Völker entdeckt, so wurde ihre genaue Lokalisation mit Hilfe eines Global Positioning System – Gerätes auf einer Karte festgehalten (Abb. 1). Wir fanden 31 Honigbienenvölker: 2 *A. dorsata*, 5 *A. cerana*, 12 *A. andreniformis* und 12 *A. florea*. Somit betrug die Gesamtdichte an Nestern 95 Völker/km^2, wobei die Zwerghonigbienen die bei weitem häufigsten waren. Um zu bestimmen, ob die Verteilung der Bienenvölker zufällig oder gehäuft war, benutzten wir die T^2 Sammelmethode (TSSP, Ludwig, 1988). Diese Analyse zeigte, dass in dem untersuchten Gebiet die Verteilung der Nester von *A. andreniformis* und *A. florea* stark gehäuft war (Abb. 1). Die Anzahl der Völker von *A. dorsata* und *A. cerana* war für eine statistische Auswertung des Häufungsgrades zu gering. Andere Untersuchungen erwähnen allerdings die starke Tendenz von *A. dorsata* zur Aggregation, und die Betrachtung von Abbildung 1 lässt eine Tendenz von *A. cerana* zur Aggregation vermuten. Es ist auch bekannt, dass *A. mellifera* lockere Aggregationen bilden kann(Oldroyd et al., 1995; McNally und Schneider, 1996). *A. florea* und *A. andreniformis* gründeten ihre Nester auf unterschiedlichen Durchschnittshöhen. *A. florea*: 4,0 m, s = 0,75, $n = 12$; *A. andreniformis*: 6,2 m, s = 0,58, $n = 12$. Zweiseitiger T-Test = – 2,53, FG = 10, $P = 0{,}03$. Sie scheinen aber gleiche Pflanzenarten als Nistplätze zu nutzen (Tab. I). Wir merken an, daß Aggregationbildung für Völker kostspielig sein könnte, was wiederum auf einen deutlichen bisher allerdings noch unbestimmten Nutzen von Aggregationen schließen lassen könnte.

Asiatische Honigbienen / *Apis andreniformis* / *Apis florea* / Räumliche Verteilung / Thailand

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