THE DRONE MATING FLIGHT OF THE EASTERN HONEYBEE (*APIS CERANA* F.): DURATION, TEMPORAL PERIOD, AND INTER-FLIGHT PERIOD

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ABSTRACT

Drone flight from a queen-right *Apis cerana* F. colony was investigated in northern Thailand. The majority of drone flights took place between 1445 h and 1645 h, with two-thirds of all flights occurring between 1500 to 1600 h. The flight period encompasses 2 h and 40 min. The average drone flight lasted 16 min. Drones averaged 3.4 flights per day, with individual drones taking as many as 7 flights per afternoon. The time drones spent in the colony between consecutive flights averaged 8.5 min. Considerable overlap was seen in the drone flight periods of *A. cerana vs. A. florea* F. as recorded from the same geographical location.

Key words: Drone flight, *Apis cerana*, northern Thailand

INTRODUCTION

Sympatric *Apis* species occur throughout East and Southeast Asia (RUTTNER, 1988). The mechanisms for reproductive isolation between *Apis* species are several and have been reviewed by KOENIGER & KOENIGER (2000a, 2000b). As inter-specific similarities exist in the sex attractant pheromones, the question arises as to how these species prevent mis-mating? To minimize this, one hypothesis has been that drones from each species utilize different temporal periods for their circadian flight activity. The parameter of drone flight circadian phenology has been examined for at least five Asian honeybee species (OTIS *ET AL.*, 2000). Several investigations have shown that there does appear to be sufficient temporal separation of drone flights of different *Apis* species to reproductively isolate them (KOENIGER & WIJAYAGUNASEKERA, 1976, OTIS *ET AL.*, 2000, RINDERER *ET AL.*, 1993, WONGSIRI *ET AL.*, 1996). Aside from the circadian drone flight period, other areas of Asian *Apis* drone flight behavior have been much less studied.

Drone mating flight behavior is relatively well known for only two honeybee species in the genus *Apis* (*A. mellifera* L. and *A. florea* F.). Over many years numerous researchers have reported on various aspects of *A. mellifera* drone flight (*e.g.*, HOWELL & USINGER, 1933, OERTEL, 1940, 1956, KURENNOI, 1954, MINDT, 1962, TABER, 1964, WITHERELL, 1971,

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1972, BURGETT, 1973, 1974), to the point where our knowledge of *A. mellifera* drone flight behavior is relatively well understood, most especially when compared to other members of the genus. A recent paper (BURGETT & TITAYAVAN, 2005) revealed the general characteristics of *A. florea* drone flight as observed in northern Thailand, *e.g.*, average length of flight, time interval between flights, temporal period. Many aspects of reproductive biology in the other *Apis* species are still poorly understood or as yet, unknown.

A. cerana is a cavity nesting species that constructs multiple parallel combs (PUNCHIHEWA, 1994). The natural nest architecture is similar to that reported for *A. mellifera* (SEELEY & MORSE, 1976). *A. cerana* has a large range, occurring throughout East and Southeast Asia, and is found as far north as 46°N and as far south as 8°S. Four subspecies have been described (RUTTNER, 1988).

Apart from studies that focused on the circadian flight period, little else is known regarding *A. cerana* drone mating flight behavior. We report here on a more in-depth study of drone flights of *A. cerana* as observed in northern Thailand.

MATERIALS AND METHODS

Observations on *A. cerana* drone flight were conducted on the Chiang Mai University campus, Chiang Mai, Thailand. Flight records for individual drones were collected in February 2005; the dry "winter" period. A traditional style colony (fixed comb, plank hive) was located in the village of San Sai north of Chiang Mai and relocated to the CMU campus in mid-January. The first drone flights from the colony were seen in early February.

In order to identify individual drones, a cadre of 24 males of unknown age was marked with numbered color tags (Opalithplättchen, Chr. Graze KG, Stuttgart Germany). All recordings of individual drone flights involved at least two observers, often three. Individual drone departures and returns were entered as to the h-m-s according to Thai standard time (GMT + 7:00). Flight times reported here have been corrected to solar azimuth time according to the methodology described by OTIS *ET AL.*, (2000). This required subtracting 24 m from the local time at Chiang Mai (99°E).

Data gathered allowed us to determine the following: the circadian drone flight period; the average time of an individual drone flight; the average amount of time a drone spends in the colony between consecutive flights, and the average number of drone flights per day.

RESULTS

During the February observation period, a total of 165 complete drone flights were recorded (a complete flight is defined as a recorded 'exit and return' for an individual drone). Observations were conducted on 7 days during the period February 11–21, 2005. The weather during the observation period was considered ideal for drone flight; the 7 observation days experienced sunny and warm afternoons (≥25°C) with little to no cloud cover.

Drone flights began at 1412 h, and the latest time a drone was observed returning to the colony was 1652 h, an inclusive flight period of 2 h and 40 min. Flight activity per 10-minute interval is displayed in Figure 1. The average time spent for a mating flight was 16 min. 5 s (N = 115 complete flights). Fifty flights of less than 4 min. duration were classified

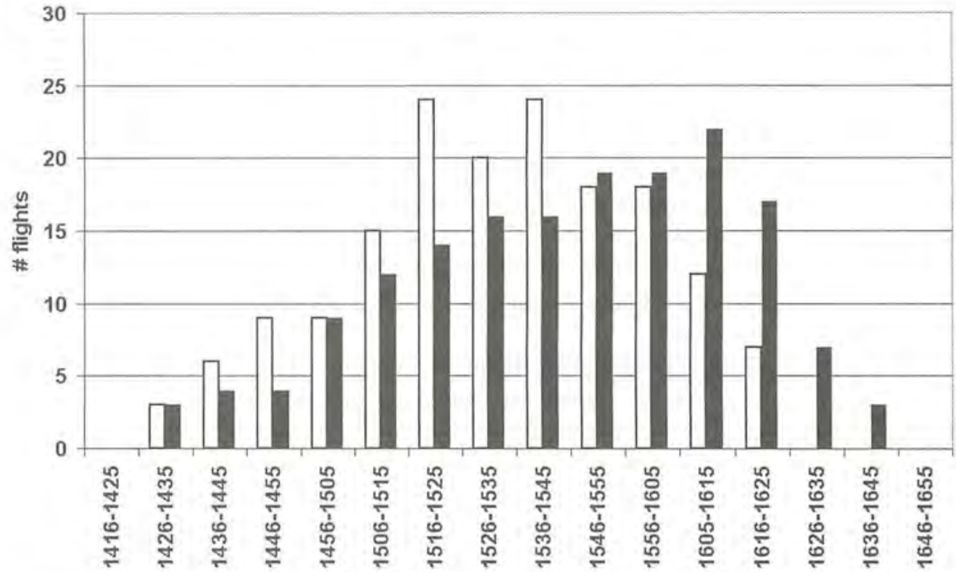

Figure 1. *Apis cerana*: drone flight period – Chiang Mai, Thailand. Open bars = drone egress; black bars = drone return. Time = solar azimuth (99°E)

Table 1. *Apis cerana*: Drone mating flight - statistical summary

	Length of flight	**Inter-flight time**	**No. flights/day**
Mean	16 m 5 s	8 m 37 s	3.4
SD	7 m 2 s	8 m 20 s	1.5
n	115	87	57

as orientation flights and averaged 1 min. 32 s in duration. For an individual drone, the mean time spent in the colony between consecutive flights was 8 min. 37 s based on a sample size of 87 observations. The average number of flights per day by individual drones was 3.4 with a range of 1–7 flights (Table 1).

DISCUSSION

The circadian drone flight period is confined to a 2 h and 40 min. flight window commencing in the mid-afternoon (*ca.* 1410 h). The period of major flight activity was between 1505 and 1605 h, which included 65% of all recorded flights. KOENIGER & KOENIGER (2000a) point out that the daily *A. cerana* drone flight period displays more variability than the other *Apis* species studied. In Sri Lanka Koeniger and WIJAYAGUNASEKERA (1976) reported a period of 1615–1715 h. RINDERER *ET AL.* (1993) working in central Thailand, observed a flight period of 1515–1730. And from Sabah in Borneo KOENIGER *ET AL.* (1996) reported a flight period of 1400–1615 h. Our observations in northern Thailand are in close agreement with KOENIGER's (1996) finding in Borneo.

The average individual *A. cerana* male mating flight time (*ca.* 16 min.) is the first known observation for this aspect of *A. cerana* drone flight. This flight time is significantly shorter than that reported for *A. mellifera* drones, 27.3 min. (HOWELL & USINGER, 1933), and *A. florea* males, 27.5 min. (BURGETT & TITAYAVAN, 2005). Influencing this shorter drone flight time would be the observation that *A. cerana* drone congregation areas are reported to be less than 2 km from the parent colonies of the drones (Tingek as cited in KOENIGER & KOENIGER, 2000a) and thus drones would hypothetically require less time in transit to and from the congregation area(s).

We recorded 50 shorter orientation flights of less than 4 min. in length. Short orientation flights by young drones are known also from *A. mellifera* (HOWELL & USINGER, 1933), and *A. florea* (BURGETT & TITAYAVAN, 2005). Short drone orientation flights relative to the longer mating flights, exhibit a well defined dichotomy in *A. mellifera* and *A. florea.* Such is not the case for *A. cerana.* The observed 165 mating flights display a relatively smooth curve from the shortest to longest flight and the cut-off time that separates orientation flights from mating flights is not readily apparent. We have chosen 4 min. to separate the two flight types. Considering the observation that *A. cerana* drones normally fly less than 2 km to mating congregation areas, it is reasonable to believe short flights lasting 4–10 min. can be classified as mating flights.

The observed number of flights per day per drone averaged 3.4 with a range of 1–7 flights. The number of flights per day by an individual *A. cerana* drone is similar to that of *A. mellifera* males. Observing *A. mellifera* in central California (U.S.A.), HOWELL & USINGER (1933) reported an average of 3.1 flights on sunny days and 1 flight under cloudy conditions. OERTEL (1956) reported some *A. mellifera* drones making as many as 4 flights per day, and we recorded a few instances of individual *A. cerana* drones undertaking 7 flights in an afternoon.

A. cerana drones spent an average of 8 min. 37 s in the colony between consecutive flights, which is similar to *A. florea* but considerable shorter than the inter-flight time reported for *A. mellifera* drones, 17.1 min. (WITHERELL, 1971).

Comparing the drone flight periods of *A. cerana* and *A. florea* from the same geographical locale, we see an overlap of 1 h 10 min., which is nearly half of the total flight period for either species (Fig. 2). For *A. cerana*, 45% of the drone flights were within the flight period of *A. florea* drones.

SUMMARY

While somewhat different in the period of afternoon flight, both *A. cerana* and *A. florea* drones exhibit a flight window of *ca.* 2.7 h. The length of the average *A. cerana* drone flight (ca. 16 min.) is considerably shorter than that of either *A. florea* (27.5 min.) or *A. mellifera* (27.3 min.). The average number of flights per day (3.4) is very similar to that reported for *A. mellifera* drones, 3.1 (HOWELL & USINGER, 1933). The time interval between consecutive mating flights for *A. cerana* drones (ca. 8.5 m) is close to that reported for *A. florea*; 8 min. (BURGETT & TITAYAVAN, 2005) and considerably shorter than that of *A. mellifera*; *ca.* 17 min. (WITHERELL, 1971).

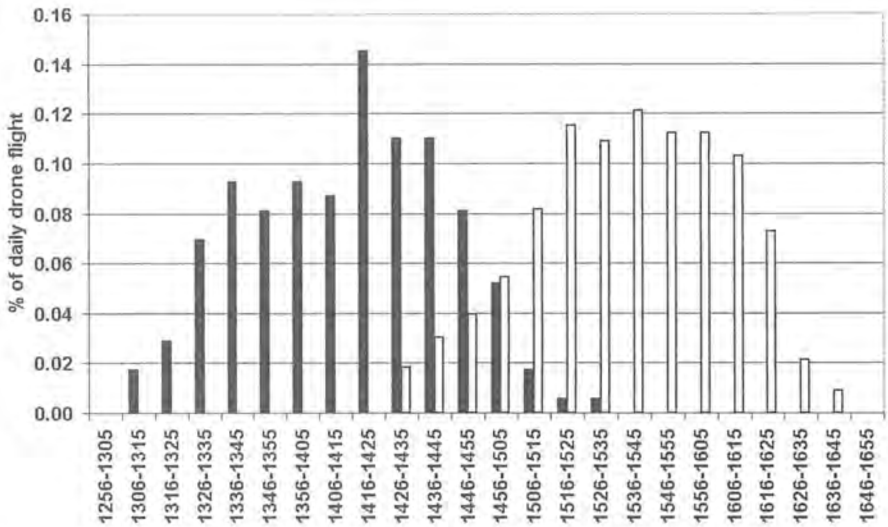

Figure 2. Drone circadian flight period: *A. florea* vs. *A. cerana* in northern Thailand. Black bars = *A. florea*; open bars = *A. cerana*. *A. florea* ♂ flight data recorded February 2004; *A. cerana* ♂ flight data recorded February 2005. Time = solar azimuth (99°E).

The time afternoon flight commences for *A. cerana* males in northern Thailand was shown to differ from several published reports for this species in other areas of Southeast Asia, but this is not surprising considering both the latitudinal and longitudinal range of *A. cerana* which would produce significant differences in day length, period of the day when drone flight temperature minimums are met, et alia. This is further verification of the variability for males of this species to adapt their flight period to local environmental conditions (KOENIGER & KOENIGER, 2000b).

Considerable overlap does appear for the mating flight periods of *A. cerana* and *A. florea* drones in the same geographical area of northern Thailand. This puts into question the validity of temporal flight period separation serving as a major mating barrier between sympatric species of Asian *Apis* (KOENIGER & KOENIGER, 2000b). OTIS *ET AL.* (2000) comment that there is almost no overlap in the flight distributions of sympatric species within a locality. Such is not the case for our findings in northern Thailand with drones of *A. cerana* and *A. florea*. However, as discussed by KOENIGER & KOENIGER (2000b) temporal separation of drone flight times, or lack of a complete separation, is but one of several mechanisms that would prevent mismatings by sympatric species, such as pronounced morphological differences of the endophallus between species. Another potential barrier for mis-mating could be seasonal differences in the peak of drone production and hence drone flight for the various sympatric *Apis* species. This area of Asian *Apis* drone biology is completely unknown at the present time and is deserving of study. Additionally, *Apis* drones and queens are known to use species-specific drone congregation areas, which could putatively preclude usage by sympatric drone species. However, the parameters for *A. florea* drone congregation areas are yet to be described (KOENIGER & KOENIGER, 2000b).

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REFERENCES

BURGETT, D. M. 1973. Drone engorgement in honey bee swarms. *Ann. Entomol. Soc. Amer.* 66: 1005–1006.

BURGETT, D. M. 1974. Drone honey bee flight from clustered swarms. *Ann. Entomol. Soc. Amer.* 67: 683–684.

BURGETT, D. M., AND M. TITAYAVAN. 2005. *Apis florea* drone flights: duration, temporal period and inter-flight period. *J. Apic. Res.* 44(1): 36–37.

HOWELL, D. C., AND R. L. USINGER. 1933. Observations of the flight and length of life of drone bees. *Ann. Entomol. Soc. Amer.* 26: 239–346.

KOENIGER, N., AND H. N. P. WIJAYAGUNASEKERA. 1976. Time of drone flight in three Asiatic honeybee species (*Apis cerana, Apis florea, Apis dorsata*). *J. Apic. Res.* 15: 67–71.

KOENIGER, N., AND G. KOENIGER. 2000a. Reproductive isolation among species of the genus *Apis*. *Apidologie* 31: 313–339.

KOENIGER, N., AND G. KOENIGER. 2000b. Behavioral mating barriers among sympatric species of the genus *Apis*. Proceedings of the 7th International Conference on Tropical Bees: Management and Diversity, and the 5th Asian Apicultural Association Conference, 19–25 March 2000, Chiang Mai, Thailand. IBRA, Cardiff, U.K. pp. 79–85.

KOENIGER, N., G. KOENIGER, M. GRIES, S. TINGEK, AND A. KELITU. 1996. Reproductive isolation of *Apis nuluensis* Tingek, Koeniger and Koeniger, by species-specific mating time. *Apidologie* 27: 353–359.

KURENNOI, M. N. 1954. On the flight activity and sexual performance of drones. *Pchelovodstvo* 31: 24–28 (in Russian).

MIKHAILOV, A. B. 1928. On drone flight activity. *Opytnaia Paseka* 3: 209–214 (in Russian).

MINDT, D. 1962. Untersuchungen über das Leben der Drohnen, insbesondere Ernährung und Geschlechtsreife. *Z. Bienenforsch.* 6: 9–33.

OERTEL, E. 1940. Mating flights of queen bees. Glean. Bee Cult. 68: 292–293, 333.

OERTEL, E. 1956. Observations on the flight of drone honey bees. *Ann. Entomol. Soc. Amer.* 49: 497–500.

OTIS, G. W., N. KOENIGER, T. E. RINDERER, S. HADISOESILO, T. YOSHIDA, S. TINGEK, S. WONGSIRI, AND M. MARDAN. 2000. Comparative mating flight times of Asian honey bees. Proceedings of the 7th International Conference on Tropical Bees: Management and Diversity, and the 5th Asian Apicultural Association Conference, 19–25 March 2000, Chiang Mai, Thailand. IBRA, Cardiff, U.K. pp. 137–141.

PUNCHIHEWA, R. W. K. 1994. *Beekeeping for Honey Production in Sri Lanka.* Canadian International Development Agency, Hull, Quebec.

RINDERER, T. E., B. P. OLDROYD, S. WONGSIRI, H. A. SYLVESTER, L. I. GUZMAN, S. POTICHOT, W. S. SHEPPARD, AND S. L. BUCHMANN. 1993. Time of drone flight in four honey bee species in south-eastern Thailand. *J. Apic. Res.* 32: 27–33.

RUTTNER, F. 1988. *Biogeography and Taxonomy of Honeybees.* Springer-Verlang, Berlin.

SEELEY, T. D., AND R. A. MORSE. 1976. The nest of the honey bee (*Apis mellifera* L.). *Insectes Sociaux* 23(4): 495–512.

TABER, S. 1964. Factors influencing the circadian flight rhythm of drone honey bees. *Ann. Entomol. Soc. Amer.* 57: 769–775.

WITHERELL, P. C. 1971. Duration of flight and of inter-flight time of drone honey bees, *Apis mellifera*. *Ann. Entomol. Soc. Amer.* 64: 609–612.

WITHERELL, P. C. 1972. Flight activity and natural mortality of normal and mutant drone honeybees. *J. Apic. Res.* 11: 65–75.

WONGSIRI, S., C. LEKPRAYOON, R. THAPA, K. THIRAKUPT, T. E. RINDERER, H. A. SYLVESTER, B. P. OLDROYD, AND U. BOONCHAM, 1996. Comparative biology of *Apis andreniformis* and *Apis florea* in Thailand. *Bee World* 77(4) 23–35.