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Authors: Sung, I-Hsin, Lu, Sheng-Shan, Chao, Jung-Tai, Yeh, Wen-Chi, and Lee, Wei-Jie

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RESEARCH

Establishment of *Vespa bicolor* in Taiwan (Hymenoptera: Vespidae)I-Hsin Sung,¹ Sheng-Shan Lu,^{2,3} Jung-Tai Chao,² Wen-Chi Yeh,² and Wei-Jie Lee⁴¹Miaoli District Agricultural Research and Extension Station, Council of Agriculture, Executive Yuan, Miaoli 363, Taiwan²Taiwan Forestry Research Institute, Council of Agriculture, Executive Yuan, Taipei 100, Taiwan³Corresponding author, e-mail: sslu@tfri.gov.tw⁴Raptor Research Group of Taiwan, Taipei 104, Taiwan

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ABSTRACT. The establishment of a hornet, *Vespa bicolor* F., in Taiwan was confirmed based on successful field collection of adults of both sexes and two subterranean colonies. Information on nesting habitat, nest measurement, and colony composition of this species are provided in this article. *V. bicolor* is the ninth hornet species ever recorded from Taiwan. Possible pathway for the introduction of this alien species is also discussed.

Key Words: honey bee predator, hornet, new record, social wasp, Taiwan

The hornets (genus *Vespa*) are predacious social wasps that often attack honey bees or paper wasps (Matsuura 1995). The following eight *Vespa* species have so far been recorded in Taiwan: *Vespa affinis* (L.), *Vespa analis* F., *Vespa basalis* Smith, *Vespa ducalis* Smith, *Vespa mandarinia* Smith, *Vespa velutina* Lepeletier, *Vespa vivax* Smith, and *Vespa simillima* Smith (Kojima et al. 2011). Although the first seven species might be native to Taiwan and are widely distributed in continental Asia (Carpenter and Kojima 1997), *V. simillima* may have recently been accidentally introduced into Taiwan, and it is not certain if this species is established there (Sung et al. 2006). In addition to these eight *Vespa* species, *Vespa bicolor* F., was collected in 2003 at an apiary in Shengang of Taichung City by one of us (J.T.C.). However, J.T.C. was unable to collect males or colonies or both to confirm the establishment of *V. bicolor* in Taiwan. *V. bicolor* is known to occur widely in continental Asia from India, Nepal, western China (Fujian, Guangxi, Jiangxi, Sichuan, Yunnan, and Hong Kong), and eastern Vietnam (Carpenter and Kojima 1997). However, the species has never been recorded on any islands (including Taiwan) off the shore of the Asian continent. In 2011, *V. bicolor* was found again in Miaoli County, a county north of Taichung in central Taiwan. This article presents the results of our research made from 2011 to 2013 on the distribution and biology of *V. bicolor* in Taiwan.

Materials and Methods

In August 2011, numerous hornets and paper wasps were found gathering on an old mango tree at Yue-Ying Elementary School in Sanyi Township of Miaoli County, central Taiwan. Among these social wasps, several individuals of *V. bicolor* were observed. During the period from August 2011 to January 2013, field research including collection of adult wasps and nests as well as feeding habits of *V. bicolor* was conducted in Gongguan, Sanyi, and Tongluo Townships of Miaoli County (Fig. 1B). All voucher specimens were deposited at the Forest Arthropod Collection of Taiwan in the Taiwan Forestry Research Institute (TFRI). Two nests collected in Tongluo area on 12 September 2012 and 31 January 2013 (Fig. 1B; nest 1, locality D; nest 2, locality C) were dissected, and for each comb, the numbers of cells and brood of each stage—eggs, larvae, or pupae—were determined. Foraging behavior of *V. bicolor* on the western honey bee, *Apis mellifera* L., was observed at four apiaries in the aforementioned three townships (Fig. 1B, locality B and C, each of 45 beehives; E, 120

beehives) for a total of 150 min on 28 and 31 August, 3 and 5 September, and 19 October 2012.

Results

Occurrence of *V. bicolor* in Taiwan. As the result of the field research in Miaoli County and examination of the specimens deposited in TFRI, we obtained the following specimens of *V. bicolor*.

Taichung City: 6 ♀, Shengang, vii.2003, J.T.C.; Miaoli County: 6 ♀, Yue-Ying Elementary School, Sanyi Township, 24°23'N, 120°45'E, 390 m, 25.viii.2011, IH Sung, 2.ix.2011, SS Lu; 1 ♂, 3 ♀, Guaninshan, Gongguan Township, 24°26'N, 120°50'E, 550 m, 15.xi.2011, IH Sung, 10.i.2012, SS Lu; 1 ♀, Hsinchilong, Tongluo Township, 24°25'N, 120°48'E, 180 m, 20.vi.2012, IH Sung; 1 ♀, Bagui, Sanyi, 24°22'N, 120°45'E, 330 m, 5.ix.2012, IH Sung; 1 ♀, Shengsing, Sanyi, 24°23'N, 120°46'E, 350 m, 26.vi.2012, IH Sung; 1 ♂, 11 ♀ (include 1 ♂, 6 ♀ collected from nest), Jiuhu, Tongluo, 24°28'N, 120°46'E, 230 m, 19.x.2012, 31.i.2013 IH Sung; 1 ♂, 2 ♀, Tongluo Industrial Park, Tongluo, 24°28'N, 120°46'E, 170 m, 19.x.2012, 15.xi.2012, IH Sung; 40 ♀ (Nest), Wenfeng, Tongluo, 24°27'N, 120°46'E, 160 m, 12.ix.2012, IH Sung.

The localities of *V. bicolor* collected in Taiwan are shown in Fig. 1. Although the first collection of *V. bicolor* took place in Taichung City, all the other collections came only from Miaoli County. The straight-line distance between the earliest collected locality in Shengang in 2003 in Taichung City, where *V. bicolor* was first collected in Taiwan and Yue-Ying Elementary School in Miaoli County was ~16 km (Fig. 1A).

Nests. Two subterranean nests of *V. bicolor* were found near the apiaries in Tongluo area, i.e., Nest 1, ~450 m from apiary B, and Nest 2, ~100 m from apiary C (Fig. 1B). Nest 1 was located in a burrow on a hillside next to an old field. The opening of the burrow was partly covered with grasses and vines. The whole colony was collected on 12 September 2012. In addition to a queen and 83 workers, the colony contained 711 immatures (Table 1). Nest 2 was built at the end of a 70-cm burrow (7–8 cm in diameter; Fig. 2A) excavated from a hillside adjacent to a paddy field, was collected on 31 January 2013. Mold was found spreading over part of the combs. Only one male, six workers, and nine immatures remained in the colony. Nest measurement and composition of the two colonies are shown in Table 1.

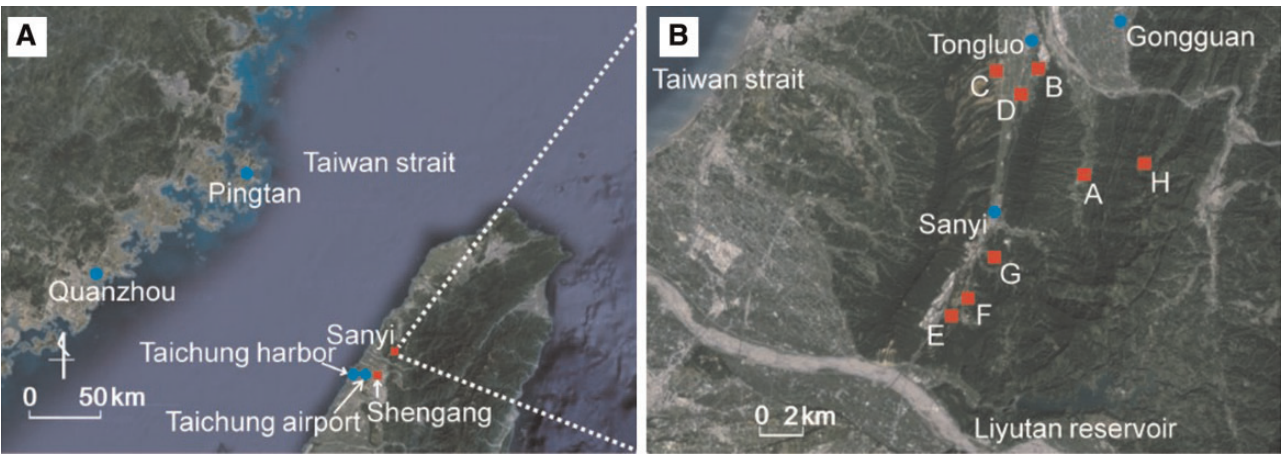


Fig. 1. (A) Map showing the localities of *V. bicolor* collected in Shengang in Taichung City and Sanyi in Miaoli County, marked with red points. (B) An enlargement of Miaoli area, Tongluo Township: A, Hsinchilong; B, Tongluo Industrial Park; C, Jiuahu; D, Wenfeng; Sanyi Township: E, Bagui; F, Yue-Ying Elementary School; G, Shengsing; Gongguan Township: H, Guaninshan; marked with red points.

Table 1. Measurement and colony composition of two *V. bicolor* nests collected from Taiwan in September 2012 and January 2013, respectively

Combs	Dimension (cm by cm)	No. of eggs	No. of larvae	No. of pupae	No. of empty cells	No. of total cells
Nest1						
comb1 (top)	13.5 by 13	51	125	120	45	341
comb2	13.5 by 11.5	21	174	122	41	358
comb3 (bottom)	8.5 by 5	21	71	6	35	133
Total	—	93	370	248	121	832
Nest2						
comb1 (top)	12.5 by 11.5	0	0	0	—	325
comb2	18.5 by 13	0	0	1	—	403
comb3	17.5 by 12.8	0	8	0	—	354
comb4	9.5 by 4.8	0	0	0	—	110
comb5 (bottom)	Damaged	0	0	0	—	92
Total	—	0	8	1	—	1,284

Diets and Foraging Behavior. Large numbers of wasps, including *V. bicolor*, were attracted to and fed on honeydew secreted by gregarious leafhoppers on mango tree leaves at Yue-Yin Elementary School in July and August of 2011 and 2012. *V. bicolor* was also found feeding on nectar of *Musa* spp. (Musaceae) in June and *Gordonia* sp. (Theaceae) in November. Males were seen visiting *Gordonia* sp. flowers for nectar on several occasions from late 2011 until early January 2012.

V. bicolor workers frequently preyed on workers of the western honey bee, *A. mellifera*, and occasionally on hover flies. Attack behavior *V. bicolor* was similar to that of *V. velutina* (Chauzat and Martin 2009). A worker of *V. bicolor* usually hovered in front of the beehives and attacked a honey bee worker entering or leaving the hive (Fig. 2B). After capturing its prey, the wasp immediately flew away. Occasional observations found workers landing on tree leaves or on the ground nearby and decapitating the prey. During the observation, honey bee workers did not make any defense against foraging by hornets.

Discussion

Based on the facts that *V. bicolor* occurs in a small area in Taiwan and that we collected two mature nests and males in different localities, as well as that *V. bicolor* was not reported from Taiwan in previous studies (Sonan 1927, 1929; Matsuura 1973; Yamane 1977; Starr 1992; Chao et al. 2002), we conclude that *V. bicolor* is an alien hornet that has recently become established in Taiwan.

Although the possibility of natural dispersal cannot be rejected with certainty, the following circumstantial evidence suggests accidental artificial introduction of *V. bicolor* into Taiwan. First, hornets, especially inseminated gynes under hibernation, can be easily transported accidentally by human activities from their maternal localities to foreign localities, as already reported for *V. velutina* recently established in France and South Korea (Haxaire et al. 2006, Choi et al. 2011, Monceau et al. 2012). Second, Shengang, the first place where *V. bicolor* was collected in 2003, is only 5 km from Taichung Airport and 15 km from Taichung Harbor, both of which are major ports of import from continental Asia; and Sanyi, the locality where many individuals of *V. bicolor* were collected, is located next to the highway of busy traffic and is famous for woodcarving industry using material imported from continental Asia. However, specifying the original population(s) of *V. bicolor* that established in Taiwan may need a detailed phylogeographical study using molecular data.

The establishment of *V. bicolor* in Taiwan may impact local apiculture to some extent. However, as local beekeepers in Miaoli who had noticed *V. bicolor* for several years do not consider this hornet a major pest for their honey bees, establishment of *V. bicolor* in Taiwan may not create any serious impact on the apicultures in Taiwan, whereas other parts of eastern Asia may see either *V. mandarinia* or *Vespa soror* disruptively and massively foraging on honey bee colonies.

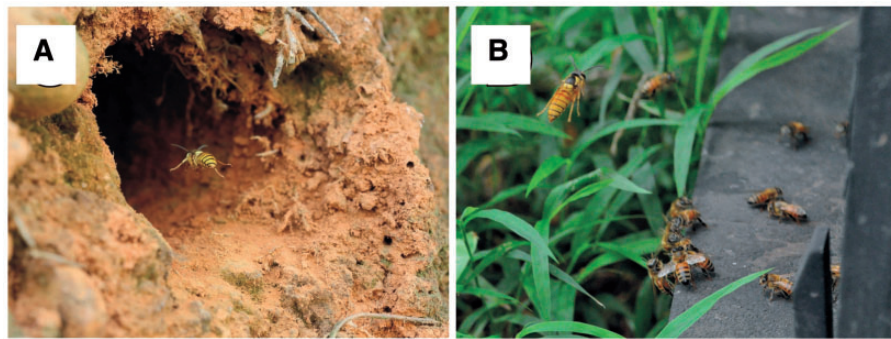


Fig. 2. (A) A *V. bicolor* flying back to the burrow (7–8 cm in diameter) of Nest 2. (B) A *V. bicolor* worker hovering in front of the beehive.

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