**Title**

Catch a free ride with me: A report on ant hitchhiking on vehicles in Taiwan and its ecological implications

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**Abstract**

Species hitchhiking on human transportation objects can facilitate long-distance dispersal of organisms, allowing them to colonize new areas and thus increasing the probability of biological invasions. In Taiwan, there have been multiple observations of ants actively hitchhiking in motor vehicles, yet no study has examined this behavior. Here, we provide the first quantitive and qualitative report on ant hitchhiking using citizen science data collected from the social media Facebook. In total, 52 cases of ant hitchhiking on a car or scooter were reported between 2017 and 2023, and nine ant species were involved with seven being exotic. In particular, the invasive black cocoa ant (*Dolichoderus thoracicus*) is attributed to over half of the reported cases. The parking duration of the vehicles on which the ants hitchhiked ranged from several hours to over a month (30 cases occurred within a day). Moreover, more cases were reported in warm seasons (i.e., spring and summer) than in cold seasons (i.e., fall and winter). To our knowledge, this study is the first to document species, ant hitchhiking on vehicles and further examine this phenomenon. We encourage future studies to explore the abiotic and biotic factors that determine the success of hitchhiking events to better predict the spread of exotic ants and to develop effective management strategies for preventing their biological invasions.

**Keywords**

arboreal ants, biological invasions, citizen science, exotic species, human-mediated dispersal, species hitchhiking, transportation

**Introduction**

The increases in human transportation activities over the past few decades have had a wide range of impacts on human societies, living organisms, and the environment (Hulme 2009, Banks et al. 2015). One of the ecological consequences of human transportation is the transfer of organisms to a new area through mobile vehicles. Such “hitchhiking” can lead to long-distance dispersal of species beyond their natural ranges and potentially facilitate biological invasions (Ward et al. 2006, Von der Lippe and Kowarik 2007, Wilson et al. 2009, Auffret et al. 2014, Gippet et al. 2019).

Various terrestrial organisms, including both animals and plants, have been documented to hitchhike on vehicles. For example, plant seeds can disperse to new places by attaching to car and tire surface (Von der Lippe and Kowarik 2007, Ansong and Pickering 2013), and the seeds can remain on the vehicles for hundreds of kilometers under certain conditions (Taylor et al. 2012). Exotic earthworms have been introduced into the boreal forests of western Canada through vehicle transportation (Cameron et al. 2007). Many insects also hitchhike on vehicles. For instance, gypsy moth (*Lymantria dispar*) may lay eggs on the surface of shipping containers and trucks, and later arrive at the destination as larvae (Gray 2017, Meurisse et al. 2019). The tiger mosquito (*Aedes albopictus*) can travel in cars and move across provinces (Eritja et al. 2017).

Fire ants and Argentine ants are easily transported by agricultural machineries, and this is movement control is all about – but how prevailing does such thing happen is something untested.<< this could be a good line to guide your readers to your idea, In recent years, observations of ants actively hitchhiking on vehicles in Taiwan have been reported. These observations have shown that hitchhiking could potentially facilitate the spread of ants to new areas. However, no previous studies have ever investigated such active hitchhiking behavior of ants. To better understand this phenomenon, we collected ant hitchhiking cases from the social media Facebook via citizen science efforts and examined the spatial and temporal patterns of ant hitchhiking in Taiwan. Our aim is to provide the first official report of ant hitchhiking on vehicles and discuss its potential ecological implications.

**Materials and Methods**

*Data collection and analysis*

In the initial phase of data collection (2017–2022), cases of ant hitchhiking on vehicles were gathered from Facebook group where general public shares a case involving their own vehicle intruded by ants. When a user responded, we asked the person to provide the parking date and location of the vehicles, the parking duration (the period between the time when the vehicle was parked and when the ant hitchhiking was observed), the vehicle type (car or scooter), the intended destination, the weather conditions, the surrounding environment (e.g., whether there was any tree nearby), and a photo of the ants for species identification. In the second phase of this study (2023), a dedicated Facebook group (https://www.facebook.com/groups/577051257470900) was established to systematically collect ant hitchhiking data from users. A post listing standardized survey questions was pinned on the top of the group page so that the observers can report the aforementioned information on hitchhiking cases in their posts in a consistent format. The data collected from the two phases were combined as the final data for subsequent analysis.

We categorized ant species as “arboreal”, “semi-arboreal”, or “ground-dwelling” based on their nesting sites and foraging habits. The difference in the number of reported cases in the four seasons (spring: March–May; summer: June–August; fall: September–November; winter: December–February) was analyzed using the Pearson's chi-square test. All recorded cases and the associated variables were provided in the Supplementary Data.

**Results**

In total, we received 52 cases of ant hitchhiking on cars (*n* = 44) and scooters (*n* = 8) between 2017 and 2023, with the majority of them reported from central and northern Taiwan (Fig. 1). Nine species were recorded, among which two were native and seven were exotic (Table 1). Besides, among the recorded species, eight of them were arboreal or semi-arboreal ants (Table 1). One species in particular, the black cocoa ant (*Dolichoderus thoracicus*), constituted approximately 60% the reported cases (*n* = 31). The parking duration of the vehicles on which the ants hitchhiked ranged from less than half a day to over a month; more than half of the hitchhiking events (*n* = 30) occurred within a day. The number of reported cases differed significantly among the four seasons (χ2 = 25.69, *df* = 3, *P* < 0.001) and were higher in the spring and summer compared to the fall and winter (Fig. 2).

**Discussion**

Ant hitchhiking on vehicles can be a potential pathway for the spread of exotic species. In some cases, the travel distance between the parking location and the intended destination can be as long as a few hundred kilometers (e.g., from Nantou County in central Taiwan to Pingtung County in southern Taiwan), largely exceeding the dispersal distance achievable through natural movements. Furthermore, hitchhiking events can take place within several hours, during which the workers may carry eggs and larvae, along with queen(s), and move together to the vehicles. This suggests that ant hitchhiking is not a foraging behavior but rather a colonization attempt, potentially driven by high population pressure. In fact, the most frequently reported hitchhiking species, the black cocoa ant (*D*. *thoracicus*), exhibits notably high local densities in central Taiwan, which may act as a driving force underlying their dispersal and colonization of artificial structures (e.g., vehicles). Of particular significance is the black cocoa ant populations in central Taiwan has been demonstrated to be non-native (Hsu et al. 2022). Therefore, the role of vehicles in facilitating biological invasions cannot be underestimated, emphasizing the need for comprehensive monitoring and management efforts to mitigate the impact of invasive populations.

Various factors determine a successful ant hitchhiking event (Fig. 3). First, ants need to encounter vehicles, which largely depends on their searching or exploring behavior. Ants are generally more active under warmer conditions (Parr and Bishop 2022), potentially leading to more hitchhiking cases in spring and summer compared to fall and winter (Fig. 2). Moreover, species with different habitat associations may differ in their probability of encountering vehicles. Because of resource limitations within tree canopies (particularly nitrogen availability), arboreal ants typically exhibit frequent foraging activities and territorial patrolling (Yanoviak and Kaspari 2000, Hahn and Wheeler 2002, Hashimoto et al. 2010). Furthermore, there were plenty of instances where the vehicle's surface came into contact with the leaves and twigs of trees, thereby creating pathways for ants to move onto a vehicle and subsequently increasing the opportunities for hitchhiking.

Second, ants need to climb onto vehicles after locating them. The metallic paint of vehicle surface could present a slippery barrier to ants, and only species with good climbing abilities are able to overcome this hurdle. The climbing performance of ants is determined by the morphological characteristics of the leg segments (Beutel et al. 2020). For instance, the fine hair arrays on the tarsus can increase the friction forces during vertical climbing (Endlein and Federle 2015). Arboreal ants have hooked pretarsal claws, well-developed adhesive pads, and fine tarsal hairs, allowing them to walk on smooth vertical substrates. On the other hand, ground-dwelling ants have straight pretarsal claws and lack adhesive pads as well as tarsal hairs, and therefore they are less capable of moving on smooth vertical surfaces (Orivel et al. 2001, Billen et al. 2017).

Third, ants need to be capable of colonizing the vehicles after moving onto them. The thermal tolerance of species plays a critical role in this because ants need to tolerate the high temperature on the surface and in the interior of the vehicles before arriving at the destination and dispersing to new areas. Arboreal ants are generally more heat- and drought-tolerant compared to ground-dwelling ants (Hood and Tschinkel 1990, Bujan et al. 2016, Leahy et al. 2022), and therefore they are more likely to survive throughout the parking duration of the vehicles. Vehicle color may also be an important factor influencing the ants’ colonization attempt and success, as it affects the temperature of the vehicles, particularly in direct sunlight.

To our knowledge, this is the first report of ant hitchhiking on vehicles via citizen science. The overrepresentation of *D*. *thoracicus* in the recorded ant hitchhiking cases is mainly attributed to its high population densities in Taiwan (driving its tendency to colonize artificial structures), high exploratory behavior, good climbing ability, and high thermal tolerance. Our study nonetheless serves as the first efforts to characterize the patterns of ant presence in vehicles, and we have endeavored to engage the wider community in citizen science work as a cost-effective method for collecting hitchhiking data. We encourage future studies to examine the behavioral, morphological, physiological, and ecological traits of exotic species versus their native relatives to better understand the determinants underlying the success of hitchhiking events. Hopefully, this can help to predict the spread of exotic ants and to develop effective management strategies for preventing their biological invasions.

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**Conflict of interest**

The authors declare no conflict of interest regarding this manuscript.

**Author contributions**

Feng-Chuan Hsu and Gen-Chang Hsu conceived the ideas, collected the data, analyzed the data, and wrote the first draft of the manuscript; all authors revised the manuscript and approved the final version for publication.

**Data availability statement**

Data and code used in this manuscript are publicly available on Dryad Digital Repository: DOI (citation).

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**Tables and Figures**

Table 1. The status, habitat association, and the number of hitchhiking cases of the recorded ant species in this study

|  |  |  |  |
| --- | --- | --- | --- |
| Species | Status | Habitat association | Number of cases |
| *Polyrhachis dives* | Native | Arboreal | 2 |
| *Nylanderia* sp. | Native | Ground-dwelling | 1 |
| *Dolichoderus thoracicus* | Exotic  (cryptic invasion) | Arboreal | 31 |
| *Tapinoma melanocephalum* | Exotic | Semi-arboreal | 5 |
| *Paratrechina longicornis* | Exotic | Semi-arboreal | 5 |
| *Technomyrmex albipes* | Exotic | Arboreal | 4 |
| *Technomyrmex brunneus* | Exotic | Arboreal | 2 |
| *Anoplolepis gracilipes* | Exotic | Semi-arboreal | 1 |
| *Trichomyrmex destructor* | Exotic | Semi-arboreal | 1 |

Figure 1. (a) A map of the ant hitchhiking cases in Taiwan and (b–c) example photos of ant hitchhiking on vehicles.

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Figure 2. The number of ant hitchhiking cases in each season (spring: March–May; summer: June–August; fall: September–November; winter: December–February). Do a box plot?

Illustration

Figure 3. The determinants of a successful ant hitchhiking event. See *Discussion* for more details.