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ROLE OF TROPICAL GREENHOUSES FOR INTRODUCTION AND ESTABLISHMENT OF FOREIGN ANT SPECIES (HYMENOPTERA: FORMICIDAE) IN CENTRAL EUROPE

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Abstract Introduction of exotic ants to Central Europe plays an increasing role for the last twenty years caused by the growing world trade and short transportation routes. Particularly tropical greenhouses offer ideal conditions for ant species with high temperature and humidity preferences and with ability to withstand cold and dry conditions during transportation. The colonies are found in the soil, in rotten wood and leaves but also well hidden in cavities of plant bulbs. Thirteen foreign and five European ant species belonging to the subfamilies Formicinae, Dolichoderinae, Myrmicinae and Ponerinae were identified from samples which were sent from 24 botanical and zoological gardens. Most of these ant species feed on sweet nutrition and tend aphids which may be defended against predators/parasitoids and distributed over the cultivated area. White footed ants (*Technomyrmex vitiensis*) were found in many green house localities, often in high populations. *Plagiolepis* sp. is also common in many greenhouses with tropical climate. A few species are of medical importance like species of the genus *Cardiocondyla* which live in small colonies in the foliage. Two *Cardiocondyla* species were found in separate greenhouses. The workers may sting people severely, when they are pruning the plants. Instructions for control of these species are presented with regard to the special circumstances in greenhouses with a sensitive flora and the use of beneficial insects.
Key words Invasive ants, Formicinae, Dolichoderinae, Myrmecinae

INTRODUCTION

Ants are one of the most successful insect families worldwide. They have developed an impressive diversity of species and occupy many ecological niches (Hölldobler and Wilson 1990, 2010). All ant species live in social communities and most of them play an important beneficial role in natural ecosystems (Klotz et al 2008). However, a few species have a detrimental impact in urban areas. Some may become passive carriers of pathogens in hospitals (Beatson, 1972; Fowler et al., 1993; Moreira et al., 2005; Pospisch,il 2010), while others cause nuisance by biting or stinging people (Blum and Hermann, 1978; Klotz et al., 2008; Schmidt, 1986). Some invasive species like the Argentine ant repress other indigenous species which is an unwanted ecological impact. This has happened along the Mediterranean coasts of Spain, France and Italy (Giraud et al., 2002). Some subtropical and tropical species are common in buildings with tropical climate and high humidity since more than 100 years (McGlynn, 1999; Boer and Vierbergen, 2008). During the last 20 years a strong increase of species was observed in Central Europe which cause tremendous problems in urban areas and tropical greenhouses (Giraud et al., 2002; Heinze et al., 2006; Pospischil, 2010; Ugelvig et al., 2008).

METHODS

Ant samples were collected in different zoological and botanical gardens or sent to the authors. Identification was carried out according to Bolton (2007), Bolton et al (2006), Kutter (1977), Czechowski et al. (2002), Klotz et al. (2008), and Seifert (2007). The classification follows Bolton et al. (2006) (Table 4). Several taxa were recently revised or may be revised in the near future. The specimens were therefore preserved by pinning and stored for further identification. Small colonies were cultured for further observation to get some information of the behavior, nutrition requirements and possible nesting sites.

Some genera were revised since 2005. Three species of the genus *Tetramorium* were described in Central Europe until 10 years ago (*T. caespitum, T. impurum* and *T. rhenanum*). Since 2006 *T. caespitum* and *T. impuru,m* are seen as

complex of at least 7 species which were specified with code names and identified using biochemical and genetic assays (Schlick-Steiner et al., 2006). Two tropical species were found in tropical green houses (*T. bicarinatum* and *T. insolens*). Another black *Tetramorium* species was selected from a tropical house together with *Technomyrmex vitiensis*. One dark-brown specimen belongs to the Central European complex and was not specified further.

Technomyrmex albipes was split into three species (*T. albipes*, *T. vitiensis* and *T. difficilis*) by Bolton (2007). The specimens, which were sampled by the authors, were all identified as *T. vitiensis*. The genus *Cardiocondyla* was determined according to the key in Seifert 2007. Further species determination followed Seifert (2003). The genus *Plagiolepis* is well characterized according to Seifert (2007). Species with Central European origin are described in Seifert (2007). But identification of (sub)tropical species is uncertain until this genus is revised. One yellow species was distributed with potted plants world wide and is present in many European heated green houses for about 20 years. The origin of this species and its name are uncertain. In some publications this species is called *Plagiolepis alluaudi* but its status is not yet proven.

A pictural key on ants in European tropical green houses was created as identification guide for technicians in zoological and botanical gardens.

RESULTS

Ant samples were received from 24 botanical and zoological gardens (19 in Germany and 5 in Switzerland) (Table 1). In some gardens samples were taken from different buildings which were separated from each other (44 buildings from German locations and 8 buildings from Swiss locations) (Table 2). 18 ant species were selected from these locations, 13 species with (sub) tropical origin and 5 belonging to the Central European fauna. In 12

Table 1. Ant species found in buildings with (sub) tropical climate in 14 botanical and zoological gardens (2000-2011).

Species	Germany buildings	Bot./zool. Gardens	Switzerland buildings	Bot./zool. Gardens
Formicidae				
Plagiolepis sp.	11	9	1	1
Plagiolepis taurica	2	1		
Lasius neglectus	1	1		
Lasius niger	3	2		
Lasius platythorax			1	1
Lasius emarginatus	1	1		
Dolichoderinae				
Tapinoma melanocephalum	1	1	1	1
*Tapinoma sessile**			1	1
Technomyrmex vitiensis	18	5	6	4
Myrmicinae				
Monomorium pharaonis	1(until 2002)	1	1	1
Tetramorium bicarinatum	9	1		
Tetramorium insolens	1	1	2	2
Tetramorium sp. (black)			1	1
Tetramorium sp.	1	1		
Pheidole sp	2	1		
Cardiocondyla cf. *wroughtoni* Forel 1881	1	1		
Cardiocondyla cf. *obscurior*	1	1		
Ponerinae				
Hypoponera sp.**	1	1		

locations only one ant species was present as a nuisance. The remaining 12 locations had 2 ant species (4 locations), 3 species (5 locations), 4 species (2 locations) and 5 species (1 location).

Detailed information of the ant distribution in one garden was received from 19 samples belonging to buildings which were not directly connected and had different equipment. Some of these houses were used as greenhouses with different climate, one was a vivarium for Lepidoptera and other buildings included birds or reptiles (Table 3). *Technomyrmex vitiensis* and *Tetramorium bicarinatum* were present in half of the greenhouses but only sporadically in other buildings. *Pheidole* sp. was found in both greenhouses and animal houses with tropical climate. Both *Lasius* species were only found in one greenhouse.

The species which were found in German and Swiss heated greenhouses, belong to the subfamilies Formicinae, Dolichoderinae, Myrmicinae and Ponerinae. Both exotic and endemic species were found in the glasshouses. The subfamily Formicinae was present with the genera *Plagiolepis* and *Lasius*. The *Plagiolepis* species have a small body size, ranging from 1.2 to 2 mm. Their native habitats are subtropical and tropical regions. Only a few species live in Europe. Their body is compact and arc-shaped when viewed from the side. They have a smooth, rounded propodeum. The antennae are 11-segmented, and most species are yellow to light brown (Shattuck and Barnett, 2001). One species has been introduced into central Europe on tropical plants and spread to many tropical greenhouses. In this survey *Plagiolepis* sp. is present in 10 green houses. Their nests are usually less than 20 millimeters in diameter and found typically between roots and inside bark crevices and flowerpots, but also in cavities of the bulb of *Myrmecodia platyrea*. This species usually requires high humidity; however, colonies may survive in a dry room if water is available. The workers forage for nectar, juice of overripe fruits and honeydew, although due to their small size tending aphids may be difficult. The species is primarily active at night, with some activity during the day (Klotz et al., 2008).

The second species *Plagiolepis taurica* was found in only one botanical garden. It is a European species which feeds on honeydew, overripe fruits and sweet excretions of nectaries. The species was probably introduced with soil from South Europe. These ants nest in the soil under logs, rotten wood, and stones, and in cavities beneath bark.

Table 2. Number of botanical/zoological gardens and buildings and ant species recorded from the different locations.

Germany		**species/location**				
		1	2	3	4	5
Botanical/ zoological gardens	19	10	4	3	1	1
				Species /building		
		1	2	3		
buildings	47	35	6	3		
Species (total)	15					
Switzerland		**species/location**				
		1	2	3	4	
Botanical/ zoological gardens	5	2	0	2	1	
				Species /building		
		1	2	3		
buildings	8	5	1	2		
Species (total)	9					

Three endemic *Lasius* species were collected in greenhouses, *Lasius niger* in 4 locations, *Lasius platythorax* in 1 location and *Lasius emarginatus* in 1 location. The invasive *Lasius neglectus*, which is spread by man with plants and soil is mentioned from only one botanical garden with nests also outside of the tropical greenhouses (Seifert, 2007; Ugelvig et al., 2008).

The Dolichoderinae are now the most prominent subfamily in tropical greenhouses and zoological gardens. Introductions of the invasive Argentine ant *Linepithema humile* are known since more than 100 years. The species forms large colonies in the south of Europe but was thought to be restricted to buildings with tropical climate in Central Europe (Giraud et al., 2002). It was found in tropical greenhouses in the first half of last century in the Netherlands (Boer and Vierbergen, 2008), and mentioned from a heated green house in Poland (Czechowski et al 2002). In this survey colonies of *Linepithema humile* were not found in houses with tropical climate. The ghost ant *Tapinoma melanocephalum*, is now a pest in many central heated houses in Central Europe (Deconinck et al 2006). In this study it is present in 3 locations. The odorous house ant *Tapinoma sessile* is only mentioned from 1 zoological garden in Switzerland (Koerber, personal communication).

Table 3. Distribution of exotic ants in buildings of a garden with different tropical houses Samples were sent from 24 different places (11. 2008)

Location	**Greenhouse**	**Zoological hot house**	**Office**	**Service area**	**Total**
No. of locations	18	4	1	1	24
Species					
Lasius emarginatus	1				1
Lasius niger	1				1
Technomyrmex vitiensis	9		1		10
Tetramorium bicarinatum	8	1		1	10
Pheidole sp.	2	3			5

The white footed ant *Technomyrmex vitiensis* was introduced into tropical greenhouses at the end of last century and is now the most common ant species in buildings with tropical climate. It is present in 12 of the 24 localities which are included into this survey. The species has decentralized colonies over large territories with regular exchange of workers. Inseminated queens are only found in new colonies and then eventually replaced by intercastes which can hardly be differentiated from workers (Yamauchi et al., 1991). Transfer of nutrients occurs through trophic eggs rather than trophallaxis. The species tends aphids, and large colonies may interfere with the biological control programs to control aphids (Klotz et al., 2008).

The subfamily Myrmicinae is present in tropical houses with more species than the Dolichoderinae, but with lower pest status. Pharaoh's ants *Monomorium pharaonis* are rare in buildings with tropical climate with 2 records in zoological gardens. Numerous colonies were found in the insectarium of another zoological garden in the second half of the last century which disappeared 10 years ago and seemed to be replaced by *Tapinoma melanocephalum*.

The genus *Tetramorium* is represented in greenhouses with several species of tropical origin since more than 100 years. *Tetramorium bicarinatum* and *T. insolens* were found in two locations each. A black *Tetramorium* species, which could not be identified yet, was observed in a tropical green house in Switzerland, where it occurred together with *Technomyrmex vitiensis*. A dark brown species belonging to the *Tetramorium caespitum*/*obscurum* complex was received from a German tropical greenhouse. Bigheaded ants (*Pheidole* sp.) are sporadically introduced to Central Europe, but only one case was recorded in a tropical greenhouse.

Two different species of the genus *Cardiocondyla* were sent from tropical greenhouses in 2008 and 2010. The nests are tiny and often well hidden, and the observed colonies were active during the night. Workers are very small and forage solitarily. They sting severely when they are disturbed. The nests of *Cardiocondyla*

wroughtoni are found in the dermatiae of leaves from *Tococa guianense* (Melastomataceae) (dermatiae = thick, hollow stems at the base of leaves). The dermatiae can be entered by the ants through small holes. Infested dermatiae are recognized by small dark brown particles, which are deposited by the ants on the leaf near the exit of the dermatiae. Leaves, which are not inhabited by *Cardiocondyla*, are clean. Nests of *Cardiocondyla obscurior* were first found in crevices of trunks and branches or below bark of the Weeping Fig or Benjamin's Fig (*Ficus benjamina, Moraceae*). Later other plants were also infested by this species. Stings were reported during the work in the top of infested trees.

Small populations of the Ponerinae (*Hypoponera* spp.) which live in soil and feed on Arthropods are often hidden and not recognized. They are therefore underrepresented in this study. *Hypoponera* sp. was only recorded from one botanical garden.

DISCUSSION

Ants were originally not seen as a nuisance in tropical greenhouses in contrast to cockroach species like *Periplaneta australasiae* or *Pycnoscelus surinamensis*. Sometimes they were even understood as beneficial insects in the fight against harmful pests of tropical plants. This situation changed with the introduction of new ant species in the last three decades (Klotz et al., 2008).

The introduction of exotic ant species is not a new problem, but their frequency is increasing with globalization and urbanization (Klotz et al., 2008; Vierbergen and Boer, 2008). In 1999 already 147 species of ants have been recorded living in non native habitats (McGlynn, 1999). Ant species which are able to establish in a new country after introduction have to fulfill special requirements (Klotz et al., 2008; McGlynn, 1999; Tsutsui and Suarez, 2003). Workers are often of small size and inconspicuous color. Nuptial flights do not occur and reproduction takes place by budding. Both workers and queens have a high foraging mobility and no specific requirements to the nesting sites. The colonies are polydomous and polygynous. In many species members of different colonies are not aggressive. Tramp ants live close to people, but they do not expand actively (McGlynn, 1999; Klotz et al., 2008). Invasive species spread actively after introduction in urban and rural areas and displace native species (Giraud et al., 2002; Holway et al., 2002; Tsutsui and Suarez, 2003).

The introduction and distribution of exotic species happens often with world trade. In the past trade with logs and lumbers (*Solenopsis invicta* and *Linepithema humile*) but also dead freight (in sailing-vessels) (*Tetramorium caespitum* and *Myrmica rubra*) were the means of displacement of species even between continents (Klotz et al., 2008). Nowadays travelling between continents is much faster with aircrafts and modern container ships with fruits and vegetables, in roots and soil of plants or in flower pots (*Plagiolepis* sp, *Pheidole* sp), or in dermatiae of leaves or in cavities inside of bulbs (*Cardiocondyla* spp., *Technomyrmex vitiensis* or *Tetramorium insolens*). With container traffic ant colonies are often not detected in the harbour and arrive at their final destination without being noticed. Small colonies which are well hidden in plant tissues are distributed through exchange of plants by tropical greenhouses (Vierbergen & Boer 2008). Rearing exotic ant species as pets or food for reptiles and amphibians should not be underestimated (*Atta* spp., *Pheidole* spp.) (Buschinger 2004, Klotz et al 2008).

The ant fauna of heated green houses consists of species with different habitat requirements. Native species are introduced with soil, plants, roots or with container-plants which are kept outdoors during summer. Species like *Lasius niger, L. platythorax,* and *L. emarginatus* belong to this group. Colonies of the European fire ant *Myrmica rubra* were also found in potted plants which were stored in a winter garden for hibernation. These species do not survive for a long time under the temperature conditions of hot houses. The three *Lasius* species are monogynous and introduced colonies can only survive when the queen is present, too.

Tropical species like *Technomyrmex vitiensis*, *Tetramorium bicarinatum*, *T. insolens*, *Cardyocondyla* sp. and *Plagiolepis* sp. do not tolerate the Central European climate conditions with cold temperatures. They can only survive in permanently warm greenhouses. However, they tolerate cold temperatures during transportation and stay in central heated rooms for several weeks or even month depending on humidity.

Some introduced species have been reported to be restricted in Central Europe to buildings with tropical climate, e.g. *Linepithema humile* (Czechowski et al., 2002). Outdoor populations of *Linepithema humile* have been found now even in winter in the Netherlands and two locations in Germany (Pospischil and Brooks, 2008). Similar observations on the cold resistance of *L. humile* were reported by Yoshifumi et al. (2004) and Seifert (2007). Active allates of the South European acrobat ant *Crematogaster scutellaris*, a species of the subfamily Myrmicinae, which is common in South Europe, were selected in Germany from the outside of a roof construction in the beginning of February 2011 at a temperature of ~5° celsius. The nest itself was in the

insulation of the flat roof and also exposed to winter temperatures, but above freezing point. This species is not native in Central Europe, but frequently introduced with trade (Seifert, 2007). Cold resistance is also known from other insect species like the litterbeetle *Alphitobius diaperinus* (Salin et al., 1998). These examples demonstrate well, that even exotic species with tropical origin may be tolerant to cold temperatures at least for a short time.

A detailed survey on the introduction of exotic ant species was given for the Netherlands with special regard to heated green houses in botanical and zoological gardens (Vierbergen and Boer, 2008). The infestation of hot houses in 9 botanical and zoological gardens over the last century was presented. *Plagiolepis* sp. started to be a nuisance in 4 botanical gardens in the second half of last century. A first record of *Technomyrmex albipes* was dated on the second half of last century, but between 2000 and 2006 8 of the 9 gardens were infested by this species. These data are similar to our results from Germany and Switzerland. *Linepithema humile, Tapinoma melanocephalum* and *Monomorium pharaonis* were only recorded from heated green houses in the Netherlands before 1945. *L. humile* was also not found recently in German or Swiss greenhouses, and mentioned only once in the first half of last century from a tropical greenhouse in Poland (Czechowski et al., 2002). *M. pharaonis* was present in one zoological garden until 2000 and was then probably replaced by *T. melanocephalum*. Our results for *Tetramorium bicarinatum* and *T. insolens* are similar to the observations from the Netherlands. *Cardiocondyla* species were not mentioned for tropical greenhouses in the Netherlands (Vierbergen and Boer, 2008).

The history of ant infestations in buildings with tropical climate demonstrates a fluctuation of exotic ant species during the past 100 years, which may be caused by introduction of new invasive species like *Technomyrmex vitiensis*. Further studies are needed to assess the potency of new exotic species to replace already established ant populations.

Food preferences may also play a role for the occurrence of ant species in different kinds of tropical buildings. Some species are typical inhabitants of tropical greenhouses like *Technomyrmex vitiensis* and *Plagiolepis* sp. These species feed primarily on honeydew from homopterans, sweet excretions from nectaries and overripe fruits. *Monomorium pharaonis* and *Tapinoma melanocephalum* prefer nutrition sources with protein and infest more often animal houses, insect breedings, food preparation in zoological gardens etc. Ponerinae are carnivorous and forage in the soil (Klotz et al., 2008).

Some exotic ant species have become a nuisance in buildings with tropical climate, because they may tend aphids and interfere in biological aphid control with beneficial insects, other ant species sting severely when they are disturbed, or they may transmit plant diseases (Pospischil, 2010). Ant management strategies should therefore be implemented, to prevent infestations of exotic ants in tropical greenhouses. New plants should be thoroughly inspected, and placed in quarantine for several weeks. Additional measures include reducing aphid populations and eliminating decaying fruit, which serve as food sources for the ants.

The components of an effective ant control program include the identification of the ant species and localization of the main and satellite nests and trails of the workers. Different baits can be used depending on the ant species with special regard to its nutritional preferences (Klotz et al., 2008). The control strategy depends also on the equipment of the tropical green house (e.g. exotic plants, aquatic systems, beneficial insects for aphid control (e.g. Australian ladybird beetle and animals). Sunbirds and humming birds may be attracted by sweet liquid baits. In this case baits should be offered to the ants in tubes which do not give the birds access to the bait. Documentation of the ant management programs is an important tool to avoid new ant introductions.

CONCLUSIONS

Central European buildings with tropical climate are infested by exotic ants since they exist. However in the past ants were not of major concern because the species mainly had nests in the soil and were active at night. With the modern trade new invasive species arrived, which cause major concern because they produce large colonies, tend and fend off aphids and displace beneficial insects for biological control. The most common ant pests *Plagiolepis* sp and *Technomyrmex vitiensis* (Syn: *T. albipes*) are now found in many botanical and zoological gardens in Europe, e.g. Germany, Switzerland, United Kingdom (Boase personal communication), Netherlands (Vierbergen and Boer, 2008) and Belgium. The ant management programs are therefore an important tool in houses with tropical climate to overcome damage of exotic plants and to avoid further accidental distribution of these ant species.

Table 4. Classification of ant species according to Bolton et al (2006) ant Bolton (2007)

Subfamily	Genus	Species
Formicinae	*Lasius*	emarginatus (Olivier, 1792)
		neglectus Van Loon, Boomsma & Andrasfalvy,1990
		niger (Linnaeus, 1758)
		platythorax Seifert, 1991
	Plagiolepis	*alluaudi* Emery 1894
		taurica Santschi, 1920
	Paratrechina	*longicornis* (Latreille, 1802)
Dolichoderinae	*Linepithema*	*humile* (Mayr, 1868)
	Tapinoma	*melanocephalum* (Fabricius, 1793)
		sessile (Say, 1836)
	Technomyrmex	*albipes* (Smith, F., 1861)
		vitiensis (Mann, 1921)
		difficilis (Forel, 1892)
Myrmicinae	*Cardiocondyla*	*obscurior* Wheeler, W.M., 1929
		wroughtoni Forel, 1881
	Crematogaster	*scutellaris* (Olivier, 1792)
	Monomorium	*pharaonis* (Linnaeus, 1758)
	Myrmica	*rubra* (Linnaeus, 1758)
	Pheidole	*megacephala* (Fabricius, 1793)
	Solenopsis	*invicta* Buren, 1972
	Tetramorium	*caespitum* (Linnaeus, 1758)
		impurum (Foerster, 1850)
		rhenanum Schulz, 1996
		insolens (Smith, F., 1861)
		bicarinatum (Nylander, 1846)
Ponerinae		
	Hypoponera	*punctatissima* (Roger, 1859)

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