Serangga 14(1-2): 67-92
ISSN 1394-1530 © 2009, Centre for Insect Systematics,
Universiti Kebangsaan Malaysia & Department of Museums Malaysia

A REVIEW OF FLORA AND FAUNA IN MALAYSIA THAT INTERACT WITH ANTS

Bakhtiar, E. Y.[1] & Maryati Mohamed[2]
Institute for Tropical Biology and Conservation
Universiti Malaysia Sabah
Email: bakhtiareffendi@yahoo.co.uk[1], dmaryati@ums.edu.my[2]

ABSTRACT

This paper compiles reports on interactions of ants with other organisms in Malaysia. Interaction involving ants is diverse and complex. With approximately 20,000 known ant species so far, interactions among ants include commensalisms and parasitism. A great number of myrmecophiles organisms (insect and other arthropods) live together with ants in a symbiotic relationship. There are also ants that act as myrmecophiles with plants. These ants protect plants from pests and obtain shelter in hollow spaces and chambers of the plants in return. All 12 ant subfamilies that exist in Malaysia interact with other organisms in one way or another. Being the largest ant group, Myrmicinae recorded the highest number of genera that interact with six plants and 20 other fauna, respectively, followed by Ponerinae (12 with fauna; 0 with flora), Formicinae (11 with fauna; 4 with flora), Proceratiinae (3 with fauna; 0 with flora), Dolichoderinae (2 with fauna; 3 with flora), Leptanillinae (2 with fauna, 0 with flora), Ectatomminae and Dorylinae (1 with fauna each), and Pseudomyrmecinae (0 with fauna; 1 with flora).

It is believed that there are many more ants that interact with other organisms in Malaysia that have not been recorded.

Information of such interactions is crucial in order to further understand the role of ants in the natural ecosystem. Information on ant interactions can be utilized in other areas such as pest control.

Keyword: Ant, Formicidae, interactions, ant plant, symbiosis, parasitism, trophobiosis, functional group

ABSTRAK

Kertas ini menggabungkan beberapa laporan berkaitan dengan tindak balas antara semut dengan makhluk hidup lainnya di Malaysia. Tindak balas yang membabitkan semut dengan persekitarannya adalah beragam dan rumit. Setakat ini spesies semut yang diketahui hampir mencapai 20,000 spesies, dan tindak balas yang berkaitan dengannya termasuklah komensalisme dan parasitisme. Sejumlah besar daripada organisma myrmekofilia (serangga dan arthropoda lainnya) hidup bersama dengan semut dalam hubungan simbiotik. Ada juga semut yang bertindak sebagai myrmecofilia dengan tanaman. Semut tersebut melindungi tanaman daripada perosak dan mendapat tempat berteduh dalam ruang berongga dan ruang pada tanaman secara bersamaan. Kesemua 12 subfamili daripada semut yang ada di Malaysia berinteraksi dengan organisma lainnya dengan pelbagai cara. Sebagai kumpulan semut yang terbesar Myrmicinae direkodkan sebagai genus yang terbanyak berinteraksi dengan enam jenis tanaman dan 20 fauna lainnya, diikuti oleh Ponerinae (12 dengan fauna; 0 dengan flora), Formicinae (11 dengan fauna; 4 dengan flora), Proceratiinae (3 dengan fauna; 0 dengan flora), Dolichoderinae (2 dengan fauna; 3 dengan flora), Leptanillinae (2 dengan fauna, 0 dengan flora), Ectatomminae and Dorylinae (masing-masing 1 dengan fauna), and Pseudomyrmecinae (0 dengan fauna; 1 dengan flora). Dipercayai bahawa masih banyak jenis semut yang berinteraksi dengan pelbagai organisma di Malaysia yang belum direkodkan Maklumat tentang interaksi ini penting di masa hadapan bagi memahami peranan semut dalam ekosistem semulajadi. Maklumat tersebut dapat juga digunakan dalam bidang lainnya seperti pengendalian perosak.

Kata kunci : Semut, Formicidae, interaksi, simbiosis semut tanaman, simbiosis, parasitisma, trofobiosis, kumpulan fungsi.

INTRODUCTION

The ant society is more open system than those of a lower unit of biological organization such as the organism or cell. Ants have opened themselves to alien species by adopting aphids, mealybugs and other homopterans as cattle to provide a steady source of honeydew. There has been very few or nonexistence of true interspecific cooperation among ant species. Almost every ant interactions encompass almost every conceivable mode of commensalisms and parasitism. There are ant species that raid colonies of other species to acquire workers as domestic slaves, or utilize the odor trails or colony identification of other species or defend common nest sites (social parasitism) (Holldobler & Wilson 1990). Some ants also predate specially on a number of animals.

Huge diversity and sheer abundance of the ants have produced a spectacular array of interactions between ants and other organisms (Schultz & McGlynn 2000). Trophobiosis is a symbiosis in insects in which food is obtained from one species (the trophobiont) by another in return for protection (Lincoln *et al*. 1998). This interaction may involve plants or other animals. Bluthgen *et al*. (2006) studied parter specificity, ant recruitment, temporal continuity and monopolization in 218 trophobioses that comprise 58 ant species and 62 hemipteran and over 31 plant species. Of all trophobises cases, 96% were monopolized by only a single ant species at a time. Occasionally these guards were replaced by another ant species after a few weeks (11%) or during the night (34%).

Many insect species and other arthropods live with ants and have developed thriving symbiotic relationships with them during part or all of their life cycles. Perhaps 80,000 – 100,000 insect species possess myrmecophilous adaptations enabling them to interact and coexistwith ants (Holldobler & Wilson 1990). Very occasionally that ants function as casual predators or temporary nest commensals. These ant guests (myrmecophiles) include a great variety of beetles, mites, collembolans, flies and wasps. These myrmecophiles make their home in nest of the ants and enjoy all the social benefits of their hosts. This is done by penetrating social immune barrier of the ant colonies.

Beccari (1884) pioneered the monograph on myrmecophilous plants from East Indian pitcher plants *Nepenthes bicalcarata*. The ants risk being eaten by the plant but they get a home; the plants surrender some tissue space and insect prey to the ants but they gain some protection from herbivores (Holldobler & Wilson 1990). This ant plant relationship represents a tiny fraction of the interactions documented for the past 150 years of research. It has been the subject of rich and informative reviews in the 80's including systematic accounts of plants and an ecological analysis of ant-plant mutualism.

In Australia and North America, ants have been classified into 9 functional groups based on their interactions with other organisms and climatic adaptability (Andersen 1997). Nine ant functional groups have been classified. They are 1) Dominant Dolichoderinae; 2) Subordinate Camponotini; 3) Hot Climate Specialists; 4) Cold Climate Specialists; 5) Tropical Climate Specialists; 6) Cryptic Species; 7) Opportunists; 8) Generalized Myrmicine, and 9) Specialized predators.

Most of these relationships bring advantage to the ants as well as to the myrmecophiles. This paper attempted to list and identify all reported ant interactions with other organism in Malaysia through literature review.

Ant – fauna Interactions

Large numbers of ants interact with many fauna. These fauna include bees (Schatz & Wcislo 1999), beetles (Abera-Kalibata *et al*. 2008, Akino 2002, Geiselhardt *et al*. 2007, Henin & Paiva 2004, Liebherr & Krushelnycky 2007, Orivel *et al*. 2004, Stoeffler *et al*. 2007, Taniguchi *et al*. 2005), caterpillars (Axen 2000, Devries 1988, Maschwitz *et al*. 1986, Schonrogge *et al*. 2004, Seufert & Fiedler 1996), crustaceans (Witte *et al*. 2008), heteropterans (Altfeld 2008, Bluthgen *et al*. 2006, Gibernau & Dejean 2001, Hubner 2000, Kaneko 2007, Kindlmann *et al*. 2007, Majerus *et al*. 2007, Malsch *et al*. 2001, Maschwitz *et al*. 1987, Matsuura & Yashiro 2006, Mondor & Addicott 2007, Moog *et al*. 2005, Ness & Bronstein 2004, Reithel & Billick 2006, Sakata & Hashimoto 2000, Stuart & Polavarapu 2002, Yamazaki 2008), hoppers (Sanders *et al*. 2008), mites (Witte *et al*. 2008), mollusks (Witte *et al*. 2008), nematodes (Poinar Jr. *et al*. 2007), sawflies (Carita *et al*. 2006), spiders (Elgar & Allan 2004, Witte *et al*. 2008) and wasps (LaPierre *et al*. 2007). Generalist ants are aggressive towards foreign insects (Choe & Rust 2006). Many interspecific interactions have also been reported between ant species (Heterick *et al*. 2000, Johnson *et al*. 2001, Ruano & Tinaut 2005).

Many other organisms live with ants. These myrmecophiles develop symbiotic with the hosts. More than half of the lycaenid butterflies associate with ants during development (Fiedler 1991, Pierce *et al*. 2002). Species that require specific ants for their survival, as protectors against enemies or as a food source, are obligate myrmecophiles. Species that can thrive with or without ants are facultatively myrmecophilous. Caterpillar-ant interactions are mediated by several glandular organs (Malicky 1969, Cottrell 1984, Kitching & Luke 1985).

In Malaysia, 11 out of 12 ant subfamilies (Aenictinae, Amblyoponinae, Cerapachyinae, Dolichoderinae, Dorylinae, Ectatomminae, Formicinae, Leptanillinae, Myrmicinae, Ponerinae and Proceratiinae) have been reportedto have interactions with other fauna (Table 1).

The ant of the subfamily Myrmicinae recoded the most number of genera (20 or 32% of all Myrmicinae) that interact with other organisms. This is followed by Ponerinae (12 or 80% of all Ponerinae), Formicinae (11 or 48% of all Formicinae), Proceratiinae (3 or 100% of all Proceratiinae), Dolichoderinae (2 or 14% of all Dolichoderinae), Leptanillinae (2 or 67% of all Leptanillinae), Ectatomminae (1 or 50% of all Ectatomminae) and Dorylinae (1 or 100% of all Dorylinae).

Often the relationship between ants and homopterans appears to be a highly evolved symbiosis, and most myrmecophilous homopterans have various morphological and behavioral adaptations that appear to facilitate ant attendance. These include modified cornicles, cauda, was filaments, and setae, as well as specialized postures and honeydew exretion mechanism (Stuart & Polavarapu 2002).

Table 1: List of fauna that interact with ants

No	Ant (Genus)	Fauna	Authority
A. Aenictinae			
1.	*Aenictus*	Predator to unnamed fauna	Brown Jr. 2000
B. Amblyoponinae			
1.	*Amblyopone*	1. Chilopoda	Brown Jr. 2000
2.	*Myopopone*	Predator to unnamed fauna	Brown Jr. 2000
3.	*Mystrium*	1. Chilopoda	Brown Jr. 2000
4.	*Prionopelta*	Predator to unnamed fauna	Brown Jr. 2000
C. Cerapachyinae			
1.	*Cerapachys*	Predator to unnamed fauna	Brown Jr. 2000
D. Dolichoderinae			
1.	*Dolichoderus*	1. Aphidae	Bluthgen *et al*. 2006
		2. Cicadellidae	Bluthgen *et al*. 2006
		3. Coccidae	Bluthgen *et al*. 2006
		4. Delphacidae	Bluthgen *et al*. 2006
		5. Lepidoptera	Seufert & Fiedler 1996
		6. Membracidae	Bluthgen *et al*. 2006
		7. Pseudococcidae	Bluthgen *et al*. 2006
		8. Psyllidae	Bluthgen *et al*. 2006
2.	*Technomyrmex*	1. Aphidae	Bluthgen *et al*. 2006
		2. Cicadellidae	Bluthgen *et al*. 2006
		3. Coccidae	Bluthgen *et al*. 2006
		4. Coreidae	Bluthgen *et al*. 2006
		5. Delphacidae	Bluthgen *et al*. 2006
		6. Membracidae	Bluthgen *et al*. 2006
	Undetermined Dolichoderinae	1. Tortricidae	Maschwitz *et al*. 1986

Table 1 continue…

...Table 1 continued

E. Dorylinae			
1.	*Dorylus*	Predator to unnamed fauna	Brown Jr. 2000
F. Ectatomminae			
1.	*Gnamptogenys*	Predator to unnamed fauna	Brown Jr. 2000
G. Formicinae			
1.	*Acropyga*	1. Coccidae	Brown Jr., W. L 2000
2.	*Anoplolepis*	1. Aphidae	Bluthgen *et al*. 2006
		2. Coried bugs (Coreidae) – *Cloresmus*, *Hygia*, *Notobitus*	Maschwitz *et al*. 1987
3.	*Camponotus*	1. Aphidae	Bluthgen *et al*. 2006
		2. Cicadellidae	Bluthgen *et al*. 2006
		3. Coccidae	Bluthgen *et al*. 2006
			Maschwitz *et al*. 1996b
		4. Coreidae	Bluthgen *et al*. 2006
		5. Cicadellidae	Bluthgen *et al*. 2006
		6. Delphacidae	Bluthgen *et al*. 2006
		7. Membracidae	Bluthgen *et al*. 2006
		8. Pseudococcidae	Bluthgen *et al*. 2006
		9. Psyllidae	Bluthgen *et al*. 2006
4.	*Cladomyrma*	1. Coccidae	Moog *et al*. 2001
		2. Lepidoptera	Seufert & Fiedler 1996
5.	*Myrmoteras*	Predator to unnamed fauna	Brown Jr. 2000
6.	*Oecophylla*	1. Lepidoptera	Seufert & Fiedler 1996
		2. Predator to unnamed fauna	Brown Jr. 2000
7.	*Paratrechina*	1. Aphidae	Bluthgen *et al*. 2006
		2. Cicadellidae	Bluthgen *et al*. 2006
		3. Coreidae	Bluthgen *et al*. 2006
		4. Delphacidae	Bluthgen *et al*. 2006
		5. Membracidae	Bluthgen *et al*. 2006
		6. Pseudococcidae	Bluthgen *et al*. 2006
8.	*Plagiolepis*	1. Aphidae	Bluthgen *et al*. 2006

Table 1 continue...

...Table 1 continued

9.	*Polyrhachis*	1. Aphidae	Bluthgen *et al*. 2006
		2. Cicadellidae	Bluthgen *et al*. 2006
		3. Coccidae	Bluthgen *et al*. 2006
		4. Coreidae	Bluthgen *et al*. 2006
		5. Delphacidae	Bluthgen *et al*. 2006
		6. Membracidae	Bluthgen *et al*. 2006
		7. Pseudococcidae	Bluthgen *et al*. 2006
10.	*Pseudolasius*	1. Pseudococcidae	Malsch *et al*. 2001
11.	*Prenolepis*	1. Predator to	Brown Jr. 2000
		unnamed fauna	
	Undetermined Formicinae	1. Tortricidae	Maschwitz *et al*. 1986
H. Leptanillinae			
1.	*Leptanilla*	Predator to unnamed fauna	Brown Jr. 2000
2.	*Protanilla*	Predator to unnamed fauna	Brown Jr. 2000
I. Myrmicinae			
1.	*Cataulacus*	1. Delphacidae	Bluthgen *et al*. 2006
2.	*Colobostruma*	1. Collembola	Brown Jr. 2000
3.	*Crematogaster*	1. Aleyrodidae	Bluthgen *et al*. 2006
		2. Aphidae	Bluthgen *et al*. 2006
		3. Cicadellidae	Bluthgen *et al*. 2006
		4. Coccidae	Bluthgen *et al*. 2006,
			Maschwitz *et al*. 1991
		5. Coreidae, *Cloresmus*, *Hygia*, *Notobitus*	Bluthgen *et al*. 2006, Maschwitz *et al*. 1987
		6. Delphacidae	Bluthgen *et al*. 2006
		7. Lepidoptera–Lycaenidae	Seufert & Fiedler 1996
		8. Margarodidae	Bluthgen *et al*. 2006
		9. Membracidae	Bluthgen *et al*. 2006
		10. Pseudococcidae	Maschwitz *et al*. 1991
		11. Psyllidae	Bluthgen *et al*. 2006
		12. Predator to unnamed fauna	Brown Jr. 2000

Table 1 continue...

...Table 1 continued

4.	*Kartidris*	1. Predator to unnamed fauna	Brown Jr. 2000
5.	*Leptothorax*	1. Predator to unnamed fauna	Brown Jr. 2000
6.	*Lophomyrmex*	1. Membracidae	Bluthgen *et al*. 2006
4.	*Meranoplus*	1. Phloem-feeding plataspid bugs – (Plataspidae) – *Tropidotylus*	Maschwitz *et al*. 1987
7.	*Metapone*	1. Isoptera	Brown Jr. 2000
8.	*Monomorium*	1. Aphidae	Bluthgen *et al*. 2006
		2. Cicadellidae	Bluthgen *et al*. 2006
		3. Coccidae	Bluthgen *et al*. 2006
9.	*Myrmicaria*	1. Membracidae	Bluthgen *et al*. 2006
		2. Plataspididae	Bluthgen *et al*. 2006
10.	*Myrmecina*	1. Mites	Brown Jr. 2000
11.	*Oligomyrmex*	1. Predator to unnamed fauna	Brown Jr. 2000
12.	*Paratopula*	1. Aphidae	Bluthgen *et al*. 2006
		2. Cicadellidae	Bluthgen *et al*. 2006
13.	*Pheidole*	1. Aphidae	Bluthgen *et al*. 2006
		2. Cicadellidae	Bluthgen *et al*. 2006
		3. Coccidae	Bluthgen *et al*. 2006
14.	*Pheidologeton*	1. Delphacidae	Bluthgen *et al*. 2006
15.	*Pristomyrmex*	1. Predator to unnamed fauna	Brown J. 2000
16.	*Rhopalothrix*	1. Predator to unnamed fauna	Brown J. 2000
17.	*Rhoptromyrmex*	1. Cicadellidae	Bluthgen *et al*. 2006
18.	*Solenopsis*	1. Aphidae	Bluthgen *et al*. 2006
19.	*Strumigenys*	1. Predator to unnamed fauna	Brown Jr. 2000
20.	*Tetramorium*	1. Aphidae	Bluthgen *et al*. 2006
		2. Membracidea	Bluthgen *et al*. 2006
	Undetermined Myrmicinae	1. Tortricidae	Maschwitz *et al*. 1986

Table 1 continue...

...Table 1 continued

J. Ponerinae			
1.	*Anochetus*	1. Predator to unnamed fauna	Brown Jr. 2000
2.	*Cryptopone*	1. Predator to unnamed fauna	Brown Jr. 2000
3.	*Diacamma*	1. Predator to unnamed fauna	Brown Jr. 2000
4.	*Emeryopone*	1. Predator to unnamed fauna	Brown Jr. 2000
5.	*Harpegnathos*	1. Predator to unnamed fauna	Brown Jr. 2000
6.	*Leptogenys*	1. Coleoptera	Witte *et al*. 2008
		2. Collembola	Witte *et al*. 2008
		3. Diptera	Witte *et al*. 2008
		4. Mites	Witte *et al*. 2008
		5. Molluscs	Witte *et al*. 2008
		6. Oniscid woodlice	Witte *et al*. 2008
		7. Oonopid spider	Witte *et al*. 2008
		8. Silverfish	Witte *et al*. 2008
		Others	Brown Jr. 2000
7.	*Myopias*	1. Millipede	Brown Jr. 2000
8.	*Odontomachus*	1. Predator to unnamed fauna	Brown Jr. 2000
9.	*Odontoponera*	1. Predator to unnamed fauna	Brown Jr. 2000
10.	*Pachycondyla*	1. Predator to unnamed fauna	Brown Jr. 2000
11.	*Platythyrea*	1. Isoptera	Brown Jr. 2000
12.	*Ponera*	1. Predator to unnamed fauna	Brown Jr. 2000
K. Proceratiinae			
1.	*Discothyrea*	1. Predator to unnamed fauna	Brown Jr. 2000
2.	*Probolomyrmex*	1. Predator to unnamed fauna	Brown Jr. 2000
3.	*Proceratium*	1. Predator to unnamed fauna	Brown Jr. 2000

Ant – flora Interactions

Unlike highly specialized associations between hemipteran and plants, ants are more opportunistic in their choices of patterns although partitioning was also significant between ant versus hemipteran, and between ants versus plants. Relationships between ants and plants have been reported by many authors (Bluthgen *et al*. 2001, Cannicci *et al*. 2008, Dauber *et al*. 2006, Dejean *et al*. 2008, Edwards *et al*. 2007, Fiala *et al*. 1996, Heil *et al*. 2000, Larrea-Alcazar & Simonetti 2007, McKey & Davidson 1993, Ness & Bronstein 2004, Oliver *et al*. 2007, Paiva, E. A. S et al. 2007, Prinzing *et al*. 2008, Rico-Gray & Oliviera 2007, Solano *et al*. 2005, Tillberg 2004, Val & Dirzo 2003 and Zhongjian *et al*. 2008). McKey & Davidson (1993) reported that out of more than 2,178 plant genera, 52 plant genera are associated with plants with 32 are endemic to the Oriental and Indo-Australian regions.

In Malaysia, over 31 plant species have also been identified to have involved in trophobiotic interactions with ants and hemipterans (Bluthgen *et al*. 2006). Four subfamilies of ants (Dolichoderinae, Formicinae, Myrmicinae and Pseudomyrmecinae) have been reported to have the most interactions with plants (Table 2).

The ant of the subfamily Myrmicinae recoded the most number of genera (6 or 10% of all Myrmicinae) that interact with plants (Table 2). This is followed by Dolichoderinae (3 or 21% of all Dolichoderinae), Formicinae (4 or 17% of all Formicinae) and Pseudomyrmecinae (1 or 33% of all Pseudomyrmecinae). The plant from the family Euphorbiaceae interact the most with ants with 7 records. This is followed by Moraceae (5), Verbenaceae (4), Capparaceae (3), Caesalpiniaceae and Crypteroniaceae (2 each) and 1 for Acanthaceae, Fabaceae, Flacourtiaceae, Loganiaceae, Rubiaceae and Rutaceae (1).

Table 2: List of plants that interact with ants

No	Ant (Genus)	Host plant		Authority
		Family	Species	
A. Dolichoderinae				
1.	*Dolichoderus*	1. Acanthaceae	*Thunbergia grandiflora*	Fiala *et al*. 1996
2.	*Iridomyrmex*	1. Verbenaceae	*Clerodendrum fistulosum*	Maschwitz *et al*. 1994a
3.	*Technomyrmex*	1. Euphorbiaceae	*Macaranga caladiifolia*	Fiala *et al*. 1996
		2. Verbenaceae	*Clerodendrum fistulosum*	Maschwitz *et al*. 1994a
B. Formicinae				
1.	*Camponotus*	1. Capparaceae	*Capparis buwaldae* (climber)	Maschwitz *et al*. 1996[a]
		2. Euphorbiaceae	*Macaranga caladiifolia*	Fiala *et al*. 1996
			Macaranga	Maschwitz *et al*.
			lamellate	1996b
			Macaranga	Federle *et al*.
			puncticulata	1998, Fiala *et al*. 1996
			Macaranga sp.	Federle *et al*. 1997
		3. Moraceae	*Ficus obscura* var. *Borneensis*	Maschwitz *et al*. 1996b
		4. Verbenaceae	*Clerodendrum fistulosum*	Maschwitz *et al*. 1994[a]
2.	*Cladomyrma*	1. Caesalpiniaceae	*Saraca thaipingensis*	Maschwitz *et al*. 1991, Moog & Maschwitz 1994
		2. Crypteroniaceae	*Crypteronia griffithii*	Maschwitz *et al*. 1991, Moog *et al*. 1998, Moog & Maschwitz 1994
		3. Euphorbiaceae		Moog & Maschwitz 1994
		4. Fabaceae	*Millettia nieuwenhuisii*	Moog & Maschwitz 1994

Table 2 continue…

...Table 2 continued

			Spatholobus	Moog & Maschwitz 1994
		5. Flacourtiaceae		Moog & Maschwitz 1994
		6. Loganiaceae	*Strychnos vanprukii*	Moog & Maschwitz 1994
		7. Rubiaceae	*Neonauclea*	Maschwitz & Fiala 1995, Moog & Maschwitz 1994
		8. Rutaceae		Moog & Maschwitz 1994
		9. others		Brown Jr. 2000
3.	*Paratrechina*	1. Euphorbiaceae	*Macaranga caladiifolia*	Fiala *et al*. 1996
4.	*Polyrhachis*	1. Poaceae (Bamboo, Grass)		Liefke *et al*. 1998
		Other (herbs & dry leaves)		Liefke *et al*. 1998
C. Myrmicinae				
1.	*Cardiocondyla*	1. Moraceae	*Ficus obscura* var. *Borneensis*	Maschwitz *et al*. 1994b
2.	*Cataulacus*	1. Moraceae	*Ficus obscura* var. *Borneensis*	Maschwitz *et al*. 1994b, Brown Jr. 2000
3.	*Crematogaster*	1. Caesalpiniaceae	*Saraca thaipingensis*	Maschwitz *et al*. 1991
		2. Capparaceae	*Capparis buwaldae* (climber)	Maschwitz *et al*. 1996a
		3. Crypteroniaceae	*Crypteronia griffithii*	Maschwitz *et al*. 1991
		4. Euphorbiaceae	*Macaranga caladiifolia*	Fiala *et al*. 1996
			Macaranga sp.	Hashimoto *et al*. 1997; Federle *et al*. 1997; Fiala *et al*. 1989; Fiala *et al*. 1994; Fiala *et al*. 1999; Inui & Itioka

Table 2 continue...

...Table 2 continued

				2007; Maschwitz *et al*. 1984; Nomura *et al*. 2001
			Macaranga lamellata	Maschwitz et al. 1996b
		5. Moraceae	*Ficus obscura* var. *borneensis*	Maschwitz *et al*. 1994b
		6. Verbenaceae	*Clerodendrum fistulosum*	Maschwitz *et al*. 1994a
4.	*Monomorium*	1. Capparaceae	*Capparis buwaldae* (climber)	Maschwitz *et al*. 1996a
5	*Pheidole*	1. Euphorbiaceae	*Macaranga caladiifolia*	Fiala *et al*. 1996
6.	*Tetramorium*	1. Euphorbiaceae	*Macaranga caladiifolia*	Fiala *et al*. 1996
		2. Moraceae	*Ficus obscura* var. *borneensis*	Maschwitz *et al*. 1994b
D. Pseudomyrmecinae				
1.	*Tetraponera*	Unknown	Unknown	Personal observation

DISCUSSIONS

Ants interact with a large number of flora and fauna. This paper has compiled studies that looked into the interactions of Malaysian ants with other organisms. All 12 ant subfamilies that exist in Malaysia have interaction records with other organisms. This indicates the importance of ants in the ecosystem.

Many roles that ants play contribute to crucial ecological requirements and needs of the ecosystems. This includes the process of the decomposition of organic materials, protection against pests, nutrient supplier and pollination. However, not all of these processes have ever been reported from Malaysia.

All these interactions involve different kinds of strategies namely chemicals, tactile contacts that revolves around the process of adaptation (evolution). Ants and their partners do modify themselves in order to fit to each other's needs and adaptability.

Plants for example have evolved a multitude of adaptations to affect ant behaviour from food bodies and extrafloral nectarines (EFN) to provide food, domatias (nest sites) in hollow thorn or twigs, to elaiosomes, nutritious appendages on the seeds, that motivate ants to move seeds to their nest and thus aid the dispersal of plants (Rico-Gray & Oliviera 2007).

All these interactions benefit the ants or/and the host. However, the host can also receive negative effects from the interaction. Therefore, proper understanding of various interactions between ants and other organisms could be used to predict ecological conditions within a given habitat by the presence of a particular ant species (Schultz & McGlynn 2000).

There are still lots of scopes in ant interactions need to be studied and explored. For example, organisms that parasitize on ants may be used to control certain ant species that may harm others. Study by Poinar *et al*. (2007) on parasitizing nematode on fire ants in Argentina may be applied locally. On the other hand, repelling behaviour of certain ants to herbivores may also useful to be manipulated for insect pests control.

In conclusion, there are number of other studies indicates the ecological and economic importance of ants in Malaysia and that the opportunities to study it should not be missed out. Not only in Malaysia, research on interaction of ants with its environment is still widely available and open for debate.

REFERENCES

Abera-Kalibata, A. M., Gold, C. S. & Driesche, R. V. 2008. Experimental evaluation of the impacts of two ant species on banana weevil in Uganda. Biological Control 46: 147 – 157.

Akino, T. 2002. Chemical camouflage by myrmecophilous beetles *Zyras comes* (Coleoptera: Staphylinidae) and *Diaritiger fossulatus* (Coleoptera: Pselaphidae) to be intergrated into the nest of *Lasius fuliginosus* (Hymenoptera: Formicidae). Chemoecology 12: 83 – 89.

Altfeld, L. & Stiling, P. 2008. Effects of aphid-tending Argentine ants, nitrogen enrichment and early-season herbivory on insects hosted by a coastal shrub. Biol Invasions

Andersen, A. 1997. Functional groups and patterns of organization in North American ant communities: a comparison with Australia. Journal of Biogeography 24: 433 – 460.

Axen, A. H. 2000. Variation in behavior of lycaenid larvae when attended by different ant species. Evolutionary Ecology 14: 611 – 625.

Bluthgen, N., Mezger, D. & Linsenmair, K. E. 2006. Ant-hemipteran trophobioses in a Bornean rainforest – diversity, specificity and monopolization. Insectes Sociaux 53: 194 – 203.

Bluthgen, N., Schmit-Neuerburg, V., Engwald, S. & Barthlott, W. 2001. Ants as epiphyte garderners: comparing the nutrient quality of ant and termite canopy substrates in a Venezuelan lowland rainforest. Journal of Tropical Ecology 17: 887 – 894.

Brown Jr., W. L. 2000. Diversity of ants. In Agosti, D., Majer, J. D., Alonso, L. E. & Schultz, T. R. (eds.). Ants: Standard methods for measuring and monitoring biodiversity. Smithsonian Institution Press.

Cannicci, S., Burrows, D., Fratini, S., Smith, T. J., Offenberg, J. & Dahdouh-Guebas, F. 2008. Faunal impact on vegetation structure and ecosystem function in mangrove forests: A review

Carita, L., Johanna, M., Jussi, P. & Martti, V. 2006. Effects of group size and pine defence chemicals on Diprionid sawfly survival against ant predation. Oecologia 150: 519 – 526.

Choe, Dong-Hwan & Rust, M. K. 2006. Homopteran chemical signatures reduce aggression of tending ants. Chemoecology 16: 175 – 178.

Cottrell, C. B. 1984. Aphytophagy in butterflies: its relationship to myrmecophily. Zoological Journal of the Linnean Society 80: 1 – 57.

Dauber, J., Rommeler, A. & Wolters, V. 2006. The ant *Lasius flavus* alters the viable seed bank in pastures. European Journal of Soil Biology 42: 157 – 163.

Dejean, A., Djieto-Lordon, C., Cereghino, R. & Leponce, M. 2008. Ontogenetic succession and the ant mosaic: an empirical approach using pioneer trees. Basic and Applied Ecology 9: 316 – 323.

Devries, P. J. 1988. The larval ant-organs of *Thisbe irenea* (Lepidoptera: Riodinidae) and their effects upon attending ants. Zoological Journal of the Linnean Society 94(4): 379 – 393.

Edwards, D. P., Arauco, R., Hassall, M., Sutherland, W. J., Chamberlains, K., Wadhams, L. J. & Yu, D. W. 2007. Protection in an an-plant mutualism: an adaptation or a sensory trap? Animal Behaviour 74: 377 – 385.

Elgar, M. A. & Allan, R. A. 2004. Predatory spider mimics acquire colony-specific cuticular hydrocarbons from their ant model prey. Naturwissenschaften 91: 143 – 147.

Federle, W., Maschwitz, U. & Fiala, B. 1998. The two-partner ant-plant system of *Camponotus* (*Colobopsis*) sp. 1 and *Macaranga puncticulata* (Euphorbiaceae): natural history of the exceptional ant partner. Insectes Sociaux 45: 1 – 16.

Federle, W., Maschwitz, U., Fiala, B., Riederer, M. & Holldobler, B. 1997. Slippery ant-plants and skilful climbers: selection and protection of specific ant partners by epicuticular wax blooms in *Macaranga* (Euphorbiaceae). Oecologia 112: 217 – 224.

Fiala, B., Grunsky, H., Maschwitz, U. & Linsenmair, K. E. 1994. Diversity of ant-plant interactions: protective efficacy in *Macaranga* species with different degrees of ant association. Oecologia 97: 186 – 192.

Fiala, B., Jakob, A., Maschwitz, U. & Linsenmair, K. E. 1999. Diversity, evolutionary specialization and geographic distribution of a mutualistic ant-plant complex: *Macaranga* and *Crematogaster* in South East Asia. Biological Journal of the Linnean Society 66: 305 – 331.

Fiala, B., Krebs, S. A., Barlow, H. S. & Maschwitz, U. 1996. Interactions between the climber *Thunbergia grandiflora*, its pollinator *Xylocopa latipes* and the ant *Dolichoderus thoracicus*: the nectar-theif hypothesis refuted?. Malayan Nature Journal 50: 1 – 14.

Fiala, B. & Maschwitz, U. 1992. Domatia as most important adaptations in the evolution of myrmecophytes in the paleotropical tree genus *Macaranga* (Euphorbiaceae). Plant Systematic and Evolution 180: 53 – 64.

Fiala, B., Maschwitz, U. & Linsenmair, K. E. 1996. *Macaranga caladiifolia*, a new type of ant-plant among Southeast Asian Myrmecophytic *Macaranga* species. Biotropica 28(3): 408 – 412.

Fiala, B., Maschwitz, U., Tho Yow Pong & Helbig, A. J. 1989. Studies of a South East Asian ant-plant association: protection of *Macaranga* trees by *Crematogaster borneensis*. Oecologia 79: 463 – 470.

Fiedler, K. 1991. Systematic, evolutionary, and ecological implications of myrmecophily within the lycaenidae (Insecta: Lepidoptera: Papilionidae). Bonn. Zool. Monogr. 31.

Fiedler, K. & Maschwitz, 1988. Functional analysis of the myrmecophilous relationships between ants (Hymenoptera: Formicidae) and lycaenids (Lepidoptera: Lycaenidae). Oecologia 75(2): 1432 – 1939.

Geiselhardt, S., Peschke, K. & Nagel, P. 2007. A review of myrmecophily in ant nest beetles (Coleoptera: Carabidae: Paussinae): linking early observations with recent findings. Naturwissenschaften 94: 871 – 894.

Gibernau, M. & Dejean, A. 2001. Ant protection of a heteropteran trophobiont against a parasitoid wasp. Oecologia 126: 53 – 57.

Hashimoto, Y., Yamane, S. & Itioka, T. 1997. A preliminary study on dietary habits of ants in a Bornean rainforest. Japan Journal of Entomology 64(4): 688 – 695.

Heil, M., Staehelin, C. & McKey, D. 2000. Low chitinase activity in Acacia myrmecophytes: a potential trade-off between biotic and chemical defences? Naturwissenschaften 87: 555 – 558.

Henin, Jean-Marc & Paiva, M. R. 2004. Interactions between *Orthotomicus erosus* (Woll.) (Col., Scolytidae) and the Argentine ant *Linepithema humile* (Mayr) (Hym., Formicidae). Journal of Pest Science 77: 113 – 117.

Heterick, B. E., Casella, J. & Majer, J. D. 2000. Influence of Argentine and coastal brown ant (Hymenoptera: Formicidae) invasions on ant communities in Perth gardens, Western Australia. Urban Ecosystem 4: 277 – 292.

Holldobler, B. & Wilson, E. O. 1990. The Ants. The Belknap Press

Hubner, G. 2000. Differential interactions between an aphid endohyperparasitoid and three honey-collecting ant species: A field study of *Alloxysta brevis* (Thomson) (Hymenoptera: Alloxystidae). Journal of Insect Behavior 13(5): 771 – 784.

Inui, Y. & Itioka, T. 2007. Species-specific leaf volatile compounds of obligate *Macaranga* myrmecophytes and host-specific aggressiveness of Symbiotic *Crematogaster* ants. Journal of Chemical Ecology 33: 2054 – 2063.

Johnson, C. A., Meer, R. K. V. & Lavine, B. 2001. Changes in the cuticular hydrocarbon profile of the slave-maker ant queen, *Polyergus breviceps* Emery, after killing A *Formica* host queen (Hymenoptera: Formicidae). Journal of Chemical Ecology 27(9): 1787 – 1804.

Kaneko, S. 2007. Predator and parasitoid attacking ant-attended aphids: effects of predator presence and attending ant species on emerging parasitoid number. Ecology Research 22: 451 – 458.

Kindlmann, P., Hulle, M. & Stadler, B. 2007. Timing of dispersal: effect of ants on aphids. Oecologia 152: 625 – 631.

Kitching, R. L. & Luke, B. 1985. The myrmecophilous organs of the larvae of some British Lycaenidae (Lepidoptera): a comparative study. Jounal of Natural History 19(2): 259 – 276.

LaPierre, L., Hespenheide, H. & Dejean, A. 2007. Wasps robbing food from ants: a frequent behavior?. Naturwissenschaften 94: 997 – 1001.

Larrea-Alcazar, D. M. & Simonetti, J. A. 2007. Why are there few seedlings beneath the myrmecophyte Triplaris americana? Acta Oecologica 32: 112 – 118.

Liebherr, J. K. & Krushelnycky, P. D. 2007. Unfortunate encounters? Novel interactions of native *Mecyclothorax*, alien *Trechus obtusus* (Coleoptera: Carabidae), and Argentine ant (*Linepithema humile*, Hymenoptera: Formicidae) across a Hawaiian landscape. Journal of Insect Conservation 11: 61 – 73.

Liefke, C., Dorow, W. H. O., Holldobler, B. & Maschwitz, U. 1998. Nesting and food resources of syntopic species of the ant genus Polyrhachis (Hymenoptera, Formicidae) in West-Malaysia. Insectes Sociaux 45: 411 – 425.

Lincoln, R., Boxshall, G. & Clark, P. 1998. A dictionary of ecology, evolution and systematics. Cambridge University Press.

Majerus, M. E. N., Sloggett, J. J., Godeau, J. –F. & Hemptinne, J., -L. 2007. Interactions between ants and aphidophagous and coccidophagous ladybirds. Population Ecology 49: 15 – 27.

Malicky, H. 1969. Uebersicht ueber praimaginalstadien, bionomie und okologie der mitteleuropaischen Lycaenidae (Lepidoptera). Mitt. Entomol. Ges. Basel (N. F.) 19: 25 – 91.

Malsch, A. K. F., Kaufmann, E., Heckroth, H. –P., Williams, D. J., Maryati, M. & Maschwitz, U. 2001. Continuous transfer of subterranean mealybugs (Hemiptera, Pseudococcidae) by *Pseudolasius* spp. (Hymenoptera, Formicidae) during colony fission?. Insectes Sociaux 48: 333 – 341.

Maschwitz, U., Dumpert, K. & Tuck, K. R. 1986. Ants feeding on anal exudate from tortricid larvae: a new type of trophobiosis. Journal of Natural History 20(5): 1041 – 1050.

Maschwitz, U. & Fiala, B. 1995. Investigations on ant-plant associations in the South-East-Asian genus *Neonauclea* Merr. (Rubiaceae). Acta Ecologica 16(1): 3 – 18.

Maschwitz, U., Fiala, B. & Dolling, W. R. 1987. New trophobiotic symbioses of ants with South East Asian bugs. Journal of Natural History 21: 1097 – 1107.

Maschwitz, U., Fiala, B., Moog, J. & Saw, L.G. 1991. Two new myrmecophytic associations from the Malay

Peninsula: ants of the genus *Cladomyrma* (Formicidae, Camponotinae) as partners of *Saraca thaipingensis* (Caesalpiniaceae) and *Crypteronia griffithii* (Crypteroniaceae). Insectes Sociaux 38: 27 – 35.

Maschwitz, U., Fiala, B., Saw, L.G., Yusoff, N. R. & Idris, A. 1994b. *Ficus obscura* var. *borneensis* (Moraceae), a new non-specific ant-plant from Malesia. Malayan Nature Journal 47: 409 – 416.

Maschwitz, U., Dumpert, K., Moog, J., Lafrankie, J. V. & Azarae, I. HJ. 1996a. *Capparis buwaldae* Jacobs (Capparaceae) A New Myrmecophyte from Borneo. Blumea 41: 223 – 230.

Maschwitz, U., Fiala, B., Davies, S. J. & Linsenmair, K. E. 1996b. A south-east asian Myrmecophyte with two alternative inhabitants: *Camponotus* or *Crematogaster* as partners of *Macaranga lamellata*. Ecotropica 2: 29 – 40.

Maschwitz, U., Schroth, M., Hanel, H. & Tho Yow Pong. 1984. Lycaenids parasitizing symbiotic plant-ant partnership. Oecologia 64(1): 78 – 80.

Matsuura, K. & Yashiro, T. 2006. Aphid egg protection by ants: a novel aspect of the mutualism between the tree-feeding aphid *Stomaphis hirukawai* and its attendant ant *Lasius productus*. Naturwissenschaften 93: 506 – 510.

McKey, D. & Davidson, D. W. 1993. Ant-plant symbioses in Africa and the Neotropics: History, Biogeography and diversity. In Goldblatt, P. (ed.). Biological relationships between Africa and South America. Yale University Press

Mondor, E. B. & Addicott, J. F. 2007. Do exaptations facilitate mutualistic associations between invasive and native species? Biological Invasions 9: 623 – 628.

Moog, J., Drude, T. & Maschwitz, U. 1998. Protective function of the plant-ant Cladomyrma maschwitzi to its host, Crypteronia griffithii, and the dissolution of the mutualism (Hymenoptera: Formicidae). Sociobiology 31(1): 105 – 129.

Moog, J. & Maschwitz, U. 1994. Associations of Cladomyrma (Hymenoptera: Formicidae: Formicinae) with plants in SE Asia. Les Insectes Sociaux. 12th Congress of the International Union for the Study of Social Insects.

Moog, J., Saw, L. G., Hashim, R. & Maschwitz, U. 2005. The triple alliance: how a plant-ant, living in an ant-plant, acquires the third partner, a scale insect. Insectes Sociaux 52: 169 – 176.

Ness, J. H. & Bronstein, J. L. 2004. The effects of invasive ants on prospective ant mutualists. Biological Invasions 6: 445 – 461.

Nomura, M., Itioka, T. & Murase, K. 2001. Non-ant antiherbivore defences before plant-ant colonization in *Macaranga* myrmecophytes. Population Ecology 43: 207 – 212.

Oliver, T. H., Cook, J. M. & Leather, S. R. 2007. When are ant-attractant devices a worthwhile investment? *Vicia faba* extrafloral nectarines and *Lasius niger* ants. Population Ecology 49: 265 – 273.

Orivel, J., Servigne, P., Cerdan, P., Dejean, A. & Corbara, B. 2004. The ladybird *Thalassa saginata*, an obligatory myrmecophile of *Dolichoderus bidens* ant colonies. Naturwissenschaften 91: 97 – 100.

Paiva, E. A. S., Buono, R. A. & Delgado, M. N. 2007. Distribution and structural aspects of extrafloral nectaries in *Cedrela fissilis* (Meliaceae). Flora 202: 455 – 461.

Pierce, N. E., Braby, M. F., Heath, A., Lohman, D. J., Mathew, J., Rand, D. B. & Travassos, M. A. 2002. The ecology and evolution of ant association in the Lycaenidae (Lepidoptera). Annu. Rev. Entomol. 47: 733 – 771.

Poinar Jr., G. O., Porter, S. D., Tang, S. & Hyman, B. C. 2007. *Allomermis solenopsis* n. sp. (Nematoda: Mermithidae) parasitizing the fire ant Solenopsis invicta Buren (Hymenoptera: Formicidae) in Argentina. Syst Parasitol 68: 115 – 128.

Prinzing, A., Dauber, J., Hammer, E., Hammouti, N & Bohning-Gaese, K. 2008. Does an ant-dispersed plant, *Viola reichenbachiana*, suffer from reduced seed dispersal under inundation disturbances? Basic and Applied Ecology 9: 108 – 116.

Reithel, J. & Billick, I. 2006. Bottom-up mediation of an ant-membracid mutualism: effects from different host plants. Evolutionary Ecology 20: 27 – 38.

Rico-Gray, V. & Oliviera, P. S. 2007. The ecology and evolution of ant-plant interactions. Chicago University Press. 331 pp.

Ruano, F. & Tinaut, A. 2005. Mating behaviour in a slave-making ant, *Rossomyrmex minuchae* (Hymenoptera, Formicidae). Naturwissenschaften 92: 328 – 331.

Sakata, H. & Hashimoto, Y. 2000. Should aphids attract or repel ants? Effect of rival aphids and extrafloral nectarines on ant-aphid interactions. Population Ecology 42: 171 – 178.

Sanders, D., Nickel, H., Grutzner, T. & Platner, C. 2008. Habitat structure mediates top-down effects of spiders and ants on herbivores. Basic and Applied Ecology 9: 152 – 160.

Schatz, B. & Wcislo, W. T. 1999. Ambush predation by the Ponerine ant *Ectatomma ruidum* Roger (Formicidae) on a sweat bee *Lasioglossum umbripenne* (Halictidae), in Panama. Journal of Insect Behavior 12(5): 641 – 663.

Schonrogge, K., Wardlaw, J. C., Peters, A. J., Everett, S., Thomas, J. A. & Elmes, G. W. 2004. Changes in chemical signatures and host specificity from larval retrieval to full social integration in the myrmecophilous butterfly *Maculinea rebeli*. Journal of Chemical Ecology 30(1): 91 – 107.

Schultz, T. R. & McGlynn, T. P. 2000. The interactions of ants with other organisms. In Agosti, D., Majer, J. D., Alonso, L. E. & Schultz, T. R. (eds.). Ants: Standard methods for measuring and monitoring biodiversity. Smithsonian Institution Press.

Seufert, P. & Fiedler, K. 1996. The influence of ants on patterns of colonization and establishment within a set of coexisting lycaenid butterflies. Oecologia 106: 127 – 136.

Solano, P. –J., Belin-Depoux, M. & Dejean, A. 2005. Formation and structure of food bodies in Cordia nodosa (Boraginaceae). C. R. Biologies 328: 642 – 647.

Stoeffler, M., Maier, T. S., Tolasch, T. & Steidle, J. L. M. 2007. Foreign-language skills in rove-beetles? Evidence for chemical mimicry of ant alarm pheromones in Myrmecophilous *Pella* beetles (Coleoptera: Staphylinidae). Journal of Chemical Ecology 33: 1382 – 1392.

Stuart, R. J. & Polavarapu, S. 2002. On the relationship between the ant, *Acanthomyops claviger*, and the blueberry mealybug, *Dysmicoccus vaccinii*. Journal of Insect Behavior 15(2): 299 – 304.

Taniguchi, K., Maruyama, M., Ichikawa, T. & Ito, F. 2005. A case of Batesian mimicry between a myrmecophilous staphylinid beetle, *Pella comes*, and its host ant, *Lasius* (*Dendrolasius*) *spathepus*: an experiment using the Japanese treefrog, *Hyla japonica* as a real predator. Insectes Sociaux 52: 320 – 322.

Tillberg, C. V. 2004. Friend or foe? A behavioral and stable isotopic investigation of an ant-plant symbiosis. Oecologia 140: 506 – 515.

Val, E. D. & Dirzo, R. 2003. Does ontogeny cause changes in the defensive strategies of the myrmecophyte *Cecropia peltata*? Plant Ecology 169: 35 – 41.

Witte, V., Leingartner, A., Sabab, L., Rosli Hashim & Foitzik, S. 2008. Symbiont microcosm in an ant society and the diversity of interspecific interactions. Animal Behaviour 76: 1477 – 1486.

Yamazaki, K. 2008. Autumn leaf colouration: a new hypothesis involving plant-ant mutualism via aphids. Naturwissenschaften 95: 671 – 676.