ABUNDANCE OF ANTS (HYMENOPTERA: FORMICIDAE) AT THE FACULTY OF SUSTAINABLE AGRICULTURE, UNIVERSITI MALAYSIA SABAH, SANDAKAN

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ABSTRACT

This study was conducted at the Faculty of Sustainable Agriculture (FSA), Universiti Malaysia Sabah (UMS) to determine the abundance of ants in FSA. FSA covers 244.64 acres of land and most of the area will be or had been used for planting purpose. Ants can be differentiated into beneficial ants and pest ants to plants. In this study, the genera and the abundance of the ants in FSA were determined and this study will provide a primary reference to FSA about the information of the ants in FSA. Hence, FSA may take control over the pest ants and maintain the population of beneficial ants. The ants were sampled from four plots in FSA using pitfall traps for duration of eight days. Pitfall trap baited with honey, tuna, meat, tofu and control were used to attract different ant species. The diversity of ants in FSA was determined by using software 'Species Diversity and Richness' version 4.1.2 designed by Dr R. M. H. Seaby and Dr P. A. Handerson, 2007, published by Disces Conservation Ltd. In total, 45879 individuals of ants were collected by using pit fall traps baited with honey, meat, tuna, tofu and control in this study. Meat had attracted the highest number of individuals, 20373 followed by tuna (13783 individuals), honey (9260 individuals), tofu (2080 individuals) and control (383 individuals). In this study, ten genus of ants were identified, which belonged to three subfamilies (Dolichoderinae, Formicinae and Myrmicinae). Three out of the ten genus of ants found in this study were identified as beneficial to agriculture, which are *Chimaeridris, Crematogaster* and *Oecophylla.* Others (seven genus of ants) included *Cardiocondyla, Dolichoderus, Lepisiota, Loweriella, Pseudolasius, Tapinoma,* and *Tetramorium* were identified as pest or non-beneficial to agriculture. There was no significant difference among baits honey, meat, tuna, tofu and control for Shannon Wiener's Index (Figure 4.1; H' : $F_{4,19} = 1.82$, $p = 0.18$), Margalef's Index (Figure 4.2; D_M : $F_{4,19} = 0.31$, $p = 0.87$), and Simpson's Index (Figure 4.1; D_S : $F_{4,19} = 0.84$, $p = 0.52$). This indicated that there no difference on ant genus diversity, richness and evenness regardless of the baits used in this study.

KELIMPAHAN SEMUT (HYMENOPTERA: FORMICIDAE) DI FAKULTI PERTANIAN LESTARI, UNIVERSITI MALAYSIA SABAH, SANDAKAN.

ABSTRAK

Kajian ini telah dijalankan di Fakulti Pertanian Lestari (FPL), Universiti Malaysia Sabah untuk mengkaji kelimpahan semut di FPL. FPL mempunyai 244.64 ekar tanah dan sebahagian besarnya akan ditanam ataupun telah ditanam pokok-pokok. Semut boleh dibezakan kepada semut berfaedah dan semut perosak. Dalam kajian ini, genera dan kelimpahan semut di FPL telah dipastikan dan kajian ini akan memberi satu rujukan asas kepada FPL terhadap informasi semut di FPL. Dengan itu, FPL dapat mengambil tindakan untuk mengawal semut perosak dan mengekalkan populasi semut berfaedah. Semut-semut telah disample dari empat plot terpilih di FPL dengan mengunakan "pitfall trap" untuk lapan hari berturut-turut. Empat jenis umpan (madu, tuna, daging dan tofu) dengan kawalan telah digunakan dengan "pitfall trap" untuk menarik semut-semut. Kelimpahan semut di FPL telah ditentukan dengan mengunakan software 'Species Diversity and Richness' versi 4.1.2 direka oleh Dr R. M. H. Seaby dan Dr P. A. Handerson, 2007, diterbitkan oleh Disces Conservation Ltd. Secara keseluruhan, 45879 ekor semut telah dikumpulkan dengan penggunaan "pitfall trap" yang berumpan dengan madu, daging, tuna, tofu dan kawalan dalam kajian ini. Daging menarik bilangan semut paling banyak iaitu 20373 individu, diikuti oleh tuna (13783 individu), madu (9260 individu), tofu (2080 individu) dan kawalan (383 individu). Dalam kajian ini, sepuluh genus semut telah dikenal pasti dan dimiliki oleh tiga subfamili semut (Dolichoderinae, Formicinae dan Myrmicinae). Tiga daripada sepuluh genus semut dijumpai dalam kajian ini telah dikenal pasti bermanfaat kepada pertanian iaitu Chimaeridris, Crematogaster dan Oecophylla. Tujuh genus semut yang lain termasuk Cardiocondyla, Dolichoderus, Lepisiota, Loweriella, Pseudolasius, Tapinoma, and Tetramorium telah dikenal pasti sebagai perosak atau tidak memberi manfaat kepada pertanian. Tidak ada perbezaan yang signifikan di antara umpan madu, daging, tuna, tauhu dan kawalan dalam Indeks Shannon Wiener (Rajah 4.1; H ': $F_{4,19} = 1.82$, $p = 0.18$), Indeks Margalef (Rajah 4.2; DM: $F_{4, 19} = 0.31$, $p = 0.87$), dan Indeks Simpson (Rajah 4.1; DS: $F_{4,19} = 0.84$, $p = 0.52$). Ini menunjukkan tidak ada perbezaan terhadap kepelbagaian, kekayaan dan keseragaman genus semut tanpa mengira umpan yang digunakan dalam kajian ini.

TABLE OF CONTENTS

LIST OF TABLES

Table **Page**

LIST OF FIGURES

Figure **Page**

LIST OF SYMBOLS, UNITS AND ABBREVIATIONS

FPL	Fakulti Pertanian Lestari
FSA	Faculty of Sustainable Agriculture
UMS	Universiti Malaysia Sabah

CHAPTER 1

INTRODUCTION

1.1 Introduction

Ant is classified under family Formicidae in the order Hymenoptera. Formicidae family comprised of 22 subfamiflies, 299 genera and 14,095 described species of ants worldwide (Bolton, 2010). Borneo's ant fauna includes 12 subfamilies, with at least 97 genera and 769 species and subspecies (Pfeiffer *et al.*, 2011). Thus, Borneo has representatives of about a third of the world's genera and about 5.5 percent of its species, though Borneo represents only about 0.5 percent of the earth's land surface (Pfeiffer *et al.*, 2011). In Malaysia the largest ant subfamily is Myrmicinae (Maryati *et al.,* 2004). Aenictinae and Dorylinae are included in smaller subfamilies (Maryati *et al.,* 2004). The subfamily Ponerinae is the most primitive ant whereas subfamily Formicinae is the most advanced ant in Malaysia (Maryati *et al.,* 2004). With this information, we can expect the subfamily of ants in FPA.

Many terrestrial invertebrates had been used as bioindicators due to their dominant biomass and diversity and their fundamental importance in ecosystem function (Disney, 1986). According to Maryati *et al.* (2004), ants have the potential to yield more meaningful biodiversity data than many other organisms as ants are one of the most abundant and diverse animal groups in tropical ecosystem. In tropical ecosystem, ants represents up to 80% of animal biomass (Hölldobler and Wilson, 1990) Besides that, ants have relatively perennial nests and limited foraging ranges make them have a potential role as environment change indicators (Maryati *et al.,* 2004). Ants are important in underground process such as soil modification. Ants can be easily sampled with various methods such as baiting technique, pitfall traps, hand collection and soil core samples (Folgarait, 1998). According to

Woodcock (2005), pitfall trap is the most frequently used sampling technique to collect epigeal invertebrates such as ants. Ants have wide preference of foods and bait is used to attract rare and aggregated species (Woodcock, 2005). Baiting ants is commonly used to estimate the composition and richness of ground-foraging ant fauna (Greenslade, 1972). Pitfall trap baited with tuna, tofu, honey and meat will be used to sample ants at the Faculty of Sustainable Agriculture (FSA).

FSA comprised of 244.64 acres and most of the area will be or had been used in planting purpose. So far, there have no study have been done about the abundance, species and food preference of ants in FSA. Hence, this study will provide primary data about the ants in FSA. Ants may serve as beneficial ants and pests ants to plants. By knowing the ant species, habitat and abundance, we will be able to identify their roles and their effects to plants in FSA.

1.2 Justification of study

This study was carried out at the Faculty of Sustainable Agriculture (FSA), Universiti Malaysia Sabah. Previously, no study has been done in FSA and ants genera / species and abundance of ants in FSA are not known. The roles of ants as bio-indicator and predators to other insects are well-known; however, there are also ants that act as pest and damaging plants in agriculture. Through this study, not only the abundance of the ants can be determined, the ant pests and beneficial ants can also be identified. Thus, Identification of ants may allow the Faculty to apply several methods to control the population of pest ants and to conserve the beneficial ants.

1.3 Objectives

1. To determine the abundance and food preferences of ants in Faculty of Sustainable Agriculture (FSA).
2. To compare the diversity of ants among pitfall traps baited with honey, tuna, meat, tofu and control.
3. To identify the genus of ants and relate them with its behaviour and habitat characteristics through information obtained from scientific publications.

1.4 Hypothesis

H_0: There was no significant difference in abundance of ants among pitfall traps baited with honey, tuna, meat, tofu and control.

H_A: There was a significant difference in abundance of ants among pitfall traps baited with honey, tuna, meat, tofu and control.

CHAPTER 2

LITERATURE REVIEW

2.1 Hymenoptera

Hymenoptera is one of the four diverse orders of insects, the other three being Coleoptera, Lepidoptera, and Diptera (David, 2012). In worldwide, there are more than 100,000 species included in order Hymenoptera. In general the species included in order Hymenoptera have two pairs of membranous wings, chewing mouth parts, compound eyes. The female of the species under order Hymenoptera normally have ovipositor and may modified for sawing, piercing and stinging.

Order Hymenoptera and be further divided into two suborder, which are suborder Symphyta and suborder Apocrita. The only characteristic that differentiates Apocita and Symphyta is the presence of petiole in Apocrita. Symphyta have no petiole. The ovipositor of most Symphyta species had modified to saw-look like marginal teeth which used to pierce plant tissue (Henri and John, 1993). On the other hands, Apocrita have long, thin and cylindrical ovipositor. According to Henri and John (1993), the fluids in the ovipositor of Apocitra have an additional aggressive function of paralyzing or killing the prey. Ants, bees and wasps are included in suborder Apocitra.

2.2 Formicidae

Ants are classified in Formicidae family, within the order Hymenoptera. In worldwide, there are 22 subfamilies of ants make up one super family Formicidae (Bolton, 2010). According to Bolton (2003), the subfamilies of ants included Nothomymeciinae, Myrmeciinae, Ponerinae, Dorylinae, Aneuritinae, Aenicitimae, Ecitoninae, Myrmicinae, Pseudomyrmecinae, Cerapachyinae, Leptanillinae, Leptandloidinae, Dolichoderinae and Formicinae.

2.3 Ant taxonomy

Kingdom: Animalia

Phylum: Arthropoda

Class: Insecta

Order: Hymenoptera

Family: Formicidae

2.4 Ant diversity in Borneo Island

The ant fauna of Borneo Island is very diverse and unique (Maryati *et al.*, 2004). According to Pfeiffer *et al.* (2011), Borneo's ant fauna includes 12 subfamilies, with at least 97 genera and 769 species and subspecies. In worldwide, there are 22 subfamilies, 299 genera and 14,095 described species of ants (Bolton, 2010). Twelve subfamilies of ant fauna in Borneo included Myrmicinae, Formicinae, Ponerinae, Dolichoderinae, Ectatommatinae, Pseudomyrmecinae, Aenictinae, Proceratiinae, Cerapachyinae, Amblyoponinae, Leptanillinae and Dorylinae (Pfeiffer *et al.*, 2011).

Table 2.1 Diversity of Bornean subfamilies of ants with the respective number of genera (Adapted from Pfeiffer *et al.*, 2011)

Subfamily	Genera	Species	Subspecies	Species + subspecies	Percentage of taxa
Myrmicinae	42	315	17	332	43.2
Formicinae	19	213	21	234	30.4
Ponerinae	14	59	10	69	9.0
Dolichoderinae	6	49	4	53	6.9
Ectatommatinae	2	22	0	22	2.9
Pseudomyrmecinae	1	16	0	16	2.1
Aenictinae	1	14	0	14	1.8
Proceratiinae	3	12	0	12	1.6
Cerapachyinae	1	10	0	10	1.3
Amblyoponinae	4	3	0	3	0.4
Leptanillinae	1	2	0	2	0.3
Dorylinae	3	2	0	2	0.3
Total	97	717	52	769	100

2.4.1 Myrmicinae

According to John and Nigel (1987), subfamily Myrmicinae can live in various range of habitat. There are 140 genera in this subfamily and some of them may still have functional sting. For example, one of the species from genera *Solenopsis* is aggressive fire ants which use their sting to protect their nest from being stepped by farmers (John and Nigel, 1987).

The size of Subfamily Myrmicinae ant is about 5mm long (Norshazreen, 2010). The genus that normally found in Malaysia included *Tetramorium, Crematogaster* and *Myrmicaria* (Bolton, 1994).

2.4.2 Formicinae

According to Bolton (1994), there are 28 genera recorded for Subfamily Formicinae in worldwide. Ants from Subfamily Formicinae do not have sting but able to store acids in their gaster. They sprayed their acid such as formic acid or others in high concentration to fight against the enemy or to kill preys (John and Nigel, 1987).

According to Maryati (1997), the genus normally found in Malaysia included *Camponatus, Anoplolepsis* and *Oecophylla.*

2.4.3 Ponerinae

The ants from Subfamily Ponerinae have length about 8-12 mm long (Norshazreen, 2010). Most of them are prey to others whereas some are not. For example, genus *Leptogens* will attack termite's nest. According to John and Nigel (1987), Ponerinae ants search for humus and preys underground by attack nests of other ants.

There are 40 genus recorded worldwide (Bolton, 1994) and the genus commonly found in Malaysia included *Diacamma, Odontomachus* and *Odontoponera* (Maryati, 1997).

2.4.4 Dolichoderinae

Dolichoderinae ants do have petiole but not post-petiole. They do not have sting as protection weapon. According to Bolton (1994), there are 19 genera Dolichoderinae recorded in worldwide. Common genus found in Malaysia included *Tapinoma* and *Dolichoderus* (Maryati, 1997).

2.4.5 Pseudomyrmecinae

Pseudomyrmecinae ants are small in size and ramping. They do have poisonous sting. There are only three genera made up this subfamily which are *Myrcidris, Pseudomyrmex* and *Tetraponera* (Bolton, 2003).

2.4.6 Aenictinae

According to John and Nigel (1987), Aenictinae ants are also known as army ants which can be found in Africa, Asia and Queensland. They do not have fixed nests and search foods by attack others.

2.4.7 Cerapachyinae

There are about 200 species of ants under Subfamily Cerapachyinae (Norshazreen, 2010). John and Nigel (1987) reported that Cerapachyinae ants do not have dorsal structure on head but they do have short and thick antennae. Besides that, Cerapachyinae ants normally hunt other ant species as foods.

2.4.8 Leptanillinae

Leptanillinae have teeth that are not sharp on mandible. They do have petiole with combined tergosternal.

2.4.9 Dorylinae

Dorylinae ants are also known as army ants. The ant colony of Dorylinae usually will attack surrounding environment for foods when the eggs and pupae hatched (John and Nigel, 1987). The foods obtained will be then given to the queen, larvae and pupae.

2.5 Ant anatomy

Ants, composed of three body segments (the head, thorax and abdomen), have jointed legs, a pair of antennae and a hard exoskeleton (Clark and Holbrook, 2009). The function of the exoskeleton is to provide support and protection to the ant as well as a barrier to prevent water loss. The colour of ants range from yellow to brown and red to black. Although ants do have head, thorax and abdomen, but the thorax and abdomen are not obvious (Clark and Holbrook, 2009).

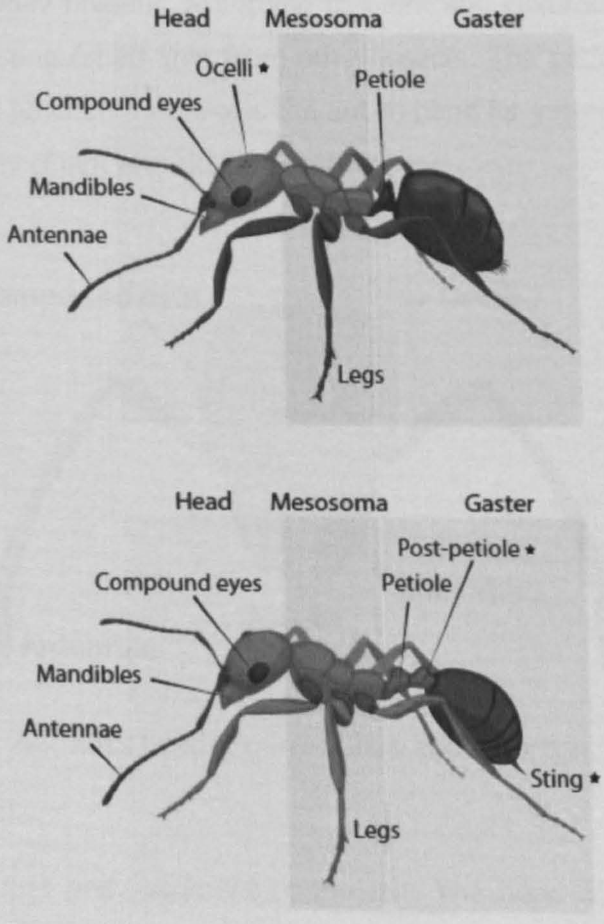

Figure 2.1: Ant anatomy (Source: Clark and Holbrook, 2009)

The ant's mesosoma comprised of the thorax and front part of the abdomen. Both the thorax and the front part of the abdomen fused together. The rest of the abdomen can be further divided into the petiole, post-petiole (if present), and gaster (Clark and Holbrook, 2009).

Mesosoma is the second body segment of the ant. Mesosoma is fully packed with muscle and is the segment where three pairs of legs attached. The legs of ant are designed for running purpose and at the end of each leg, there is a hooked claw that used for climbing or hand onto things (Clark and Holbrook, 2009).

Third body segment of the ant is gaster. Gaster consists of the ant's digestive system and chemical weapon. According to Clark and Holbrook (2009), some ants have sting as weapon which used to inject venom into enemy. On other hands, some ants have a tiny opening at the tip of their gaster which the tunnel of the ants used to spray acid to the enemy and defend themselves (Clark and Holbrook, 2009).

Petiole is the body part of the ant between mesosoma and gaster. In some ant species, post-petiole may present. According to Clark and Holbrook (2009), petiole is the body part that distinguished ants from other insects. The petiole and post-petiole functions as a flexible junction that allows the ant to bend its gaster forward to sting or spray acid to its enemy (Clark and Holbrook, 2009).

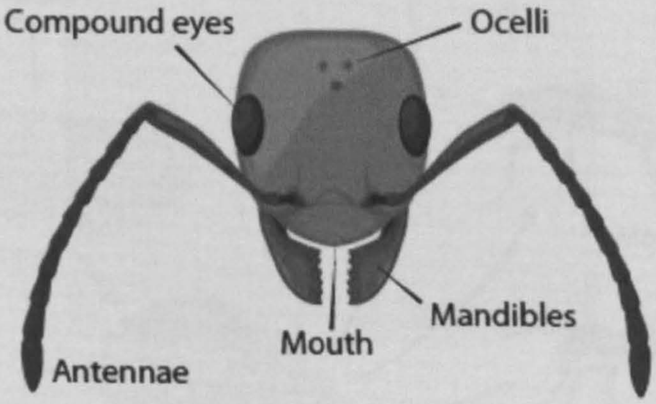

Figure 2.2: Ant's head (Source: Clark and Holbrook, 2009).

Head is the first body segment of the ant. The head of the ants is used to sense the surrounding information. Clark and Holbrook (2009) reported that ants mainly communicate through the detection and releases of the chemicals among themselves. Ants have a pair of antennae that sense these chemical and the nest mates from the same colony recognized their partners by the chemicals on their bodies (Clark and Holbrook, 2009). Ants can also use touch and vibration to communicate.

Besides that, ants have a pair of compound eyes that made up of hundreds of lenses that combine to form a single image in the ant's brain. However, for some ants that lives in dark places may have reduced vision or even blind (Clark and Holbrook, 2009). Some ants may also have ocelli (three simple eyes) that detect light.

Mandible is one of the most important body parts for ants. As ants do not have grasping forelegs, mandible is used by the ants to hold and carry stuffs. Mandibles can also be used to bitting, cutting, crushing, digging, hunting and fighting (Clark and Holbrook, 2009). Mouth is located behind the mandible which used by the ants to eat and clean themselves and nest mates.

2.6 Life cycle of ants

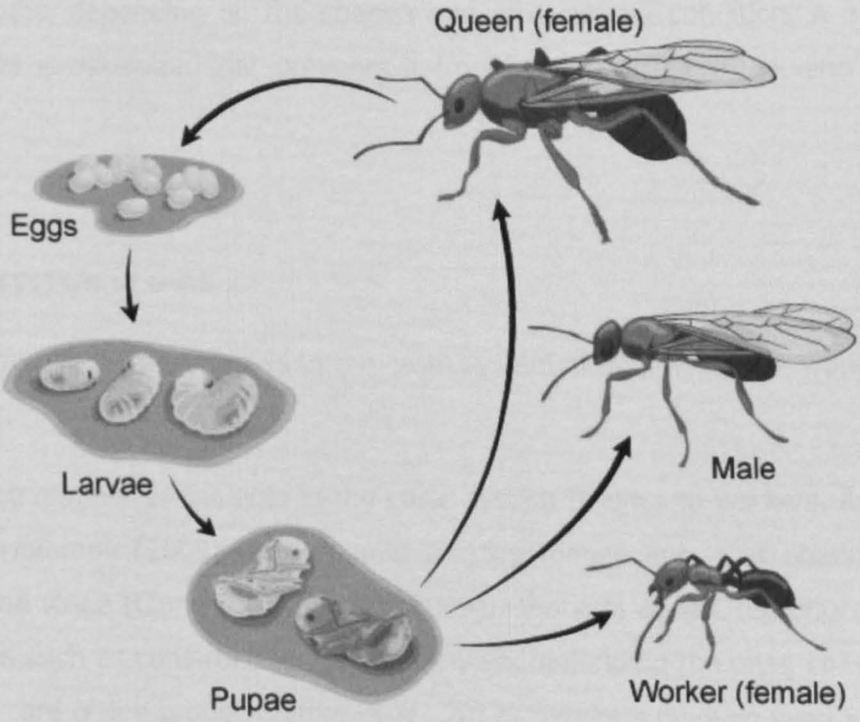

Figure 2.3: Life cycle of ants (Source: Clark and Holbrook, 2009).

Ants undergo complete metamorphosis throughout their life cycle, starting with egg, larvae, pupae and then adult.

An ant's life starts with an egg. Ant eggs are soft, oval and tiny. Not all eggs are able to emerge to an adult, as some of the eggs may be consumed by nest mates for extra nourishment (Clark and Holbrook, 2009).

An egg hatches into a worm-shaped larva with no eyes or legs. Larvae need to consume large amount of foods and rely on constant supply of foods from the adults. Larvae grow rapidly and moulting.

Larvae metamorphoses into a pupa when it is large enough. According to Clark and Holbrook (2009), physical appearance of pupae look similar to the adult but their legs and antennae are folded against their bodies. Pupae are whitish in colour at the initial stage and gradually become darker as they develop (Clark and Holbrook, 2009). The pupae of some species spin a cocoon for protection, while others remain uncovered, or naked.

Finally, the pupa emerges as adult. Young adults are often lighter in colour, and darken as they grow older. According to Clark and Holbrook (2009), the process of development from an egg to an adult takes a period of time from several weeks to several months, depending on the species and environment condition. A fully grown ant will have exoskeleton that prevents it from getting larger (Clark and Holbrook, 2009).

2.7 Caste system of ants

Generally, there are three classes in the caste system of ants which are workers, males and queens.

Large number of the ants in the caste system belongs to workers. According to Clark and Holbrook (2009), worker ants are the female ants that obtain less food during larvae stage (Clark and Holbrook, 2009). Workers do not reproduce but share other duties such as constructing, maintaining and defending the nest, collecting food, and taking care of the brood (Chittka *et al.*, 2012). Workers have no wing and only live for few months.

In most species, all the workers are almost the same size. However, some ant species harbour special castes of particularly large workers, 'soldiers' or 'majors'. Soldiers are larger in size than minor workers and have large heads (Clark and

Holbrook, 2009). They preferentially play roles in colony defence or for cutting up or carrying large objects, including prey (Chittka *et al.*, 2012). According to Clark and Holbrook (2009), a soldier can have 100 times the body mass of a minor worker.

Similar to queen, males have wings and muscular mesosomas to fly and mate with the queen (Clark and Holbrook, 2009). Male ants often have only one role which is mating with the queen (National Geographic, 2015). The male ants may die after their mating with the queen. Males never help with the chores of the colony (Clark and Holbrook, 2009). The size of males usually smaller than queens and have smaller heads with bigger eyes and straighter antennae.

Queens are female that had consumed more food compared to workers during larvae stage (Clark and Holbrook, 2009). They are large than worker and the only duty is to lay eggs in a colony. A queen may lay up to million eggs in some species. According to Clark and Holbrook (2009), queen initially has wings to fly and find male for mating process. They tear off the wings before they start a new colony. A queen can live for decades under suitable conditions.

2.8 Colony life cycle of ants

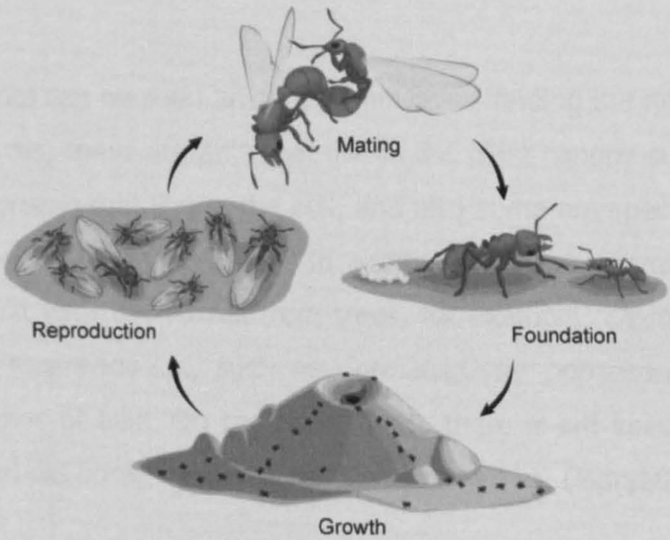

Figure 2.4: Colony life cycle of ants (Source: Clark and Holbrook, 2009).

Colony life cycle refers to the sequences of changes of an ant colony. There are three stages of colony life cycle which are founding stage, growth stage and reproduction stage.

References

Adgaba, A., Shenkute, A.G., Al-Ghamdi, A.A., Assefa, A., Mohammad J. A., Brian,T. and Sarah R. 2014. *Crematogaster chiarinii* ants as a potential biological control agent for protecting honeybee colonies from attack by *Dorylus quadratus* driver ants in Ethiopia (Hymenoptera: Formicidae). *Agricultural and Forest Entomology.*

Andersen, A. and McKaige, M.E. 1987. Ant Communities at Rotamah Island, Victoria, With Particular Reference to Disturbance and *Rhytidoponera tasmaniensis*. *Proceedings of the Royal Society of Victoria* **99**: 141-146.

Andersen, A.N. 1993. Ants as Indicators of Restoration Success at a Uranium Mine in Tropical Australia. *Restoration Ecology* **93**: 156-167.

Andersen, A.N. 1997. Measuring Invertebrate Biodiversity Surrogates of Ant Species Richness in the Australian Seasonal Tropics. *Memoirs of Museum Victoria* **56**: 355-359.

Andersen, A.N. and Sparling, G.P. 1997. Ants as Indicators of Restoration Success: Relationship with Soil Microbial Biomass in the Australian Seasonal Tropics. *Restoration Ecology* **7**: 109-114.

Azhar, I. 1988. *Mengenalpasti Serangga Perosak Koko Melalui Kesan dan Simptom Serangan.* Terbitan MARDI.

Batten, M. 1976. *The Tropical Forest.* London: Faber & Faber Ltd.

Benckiser, G. 2010. Ants and Sustainable Agriculture. *Agronomy for Sustainable Development* **30:** 191–199

Benzing, D.H. 1983. Vascular Epiphytes. Dalam: Sutton, S.L; Whitemore, T.C. and Chadwick, A.C (pnyt). Tropical Rain Forest: *Ecology and Management*. 11-24.

Bestelmeyer, B.T. and Wiens, J.A. 1996. The Effects of Land Use Structure of Ground Foraging Ant Community in the Argentinean Chaco. *Ecology. Application* **6**: 1225-1240.

Bolton, B. 1994. *Identification Guide to the Ants Genera of the World,* Harvard University Press, Cambridge, Massachussetts, London, England.

Bolton, B. 2003. Synopsis and Classification of Formicidae. *Memoirs of the American Entomological Institute* **71**: 1-370.

Bolton, B. 2010. The World Species List. Downloaded from http://www.antweb.org/taxonomicPage. do?rank=species&project=worldants on 3.4.2015.

Brian, M.V. 1978. *Production Ecology of Ants and Termites*. IBP 13, Cambridge, UK: Cambridge University Press.

Cherret, J.M. 1989. Leaf-cutting Ants. *Biogeographical and Ecological Studies.* In *Ecosystem of the World, Tropical Rain Forest Ecosystem.* (H. Leith and M.J. Werger, eds.) New York: Elsevier.

Chittka, A., Wurm, Y.and Chittka, L. 2012. Epigenetics: The Making of Ant Castes. *Current Biology* **22(19)**: R835–R838

Chung, Y. C. 1995. *Common Lowland Rainforest Ants in Sabah.* Forestry Department, Sabah.

Clark, R. and Holbrook, T. 2009. Ant Farm: Ask A Biologist Activity for the Classroom and Home. http://askabiologist.asu.edu/sites/default/files/resources/activities/ant_farm/ant_farm_activity_packet.pdf. Access on 5 April 2015.

David, B. 2012. Ants, Wasps, Bees and Sawflies: Order Hymenoptera. Australia Museum: Natural Culture Discover. http://australianmuseum.net.au/sawflies-wasps-bees-ants-hymenoptera. Access on 25 April 2015.

de la Fuente, M.A.S. and Marquis, R.J. 1999. The Role of Ant-Tended Extrafloral Nectaries in the Protection and Benefit of a Neotropical Rainforest Tree. *Oecologia* **118**: 192-202.

Decaens, T., Lavelle, P., Jimenez-Jaen, J.J., Escobar, G. and Rippstein, G. 1994. Impact of Land Management on Soil Macrofauna in the Oriental Llanos of Colombia. *European Journal of Soil Biology* **30**: 157-168.

Delabie, J.H.C., J.E. Mantovani and I.C. Mauricio. 1990. Observações sobre a biologia de duas espécies de *Acropyga* (Formicidae, Formicinae, Plagiolepidini) assodadas a rizosfera do cacaueiro. *Brazilian Journal of Medical and Biological Research* **51**: 185-192.

Detrain C., Deneubourg J.L. 2006. Self-organized structures in a superorganism: do ants "behave" like molecules? *Physiological Life Review* **3**: 162–187.

Disney, R.H.L. 1986. Assessments using invertebrates: posing the problem. In M.B. Usher, editor. *Wildlife conservation evaluation.* Chapman and Hall, London, England.

Dumpert, K. 1981. *The Social Biology of Ants.* Verlag. Paul Parey, Berlin.

Farb, P. 1978. *Serangga.* Pustaka Time Life. Jakarta.

Faridah Binti Yusof. 2010. *Kajian Tentang Populasi Semut (Hymenoptera; Formicidae) di Ladang Koko, Ranau.* Bachelor of Agricultural Science Dissertation. Universiti Malaysia Sabah.

Folgarait, P. J. 1998. Ant Biodiversity and Its Relationship to Ecosystem Functioning: A Review. *Biodiversity and Conservation* **7**: 1221-1244.

Folgarait, P.J., Gorosito, N. and Zipeto, G. 1997. Reduction of Biodiversity by *Camponotus Punctulatus* Ants Mediated by Human Disturbance. Association for Tropical Biology Annual Meeting. Symposium on Tropical diversity, origins, maintenance and conservation. June 15-20, San Jose, Costa Rica. pp. 57.

Friese, C.F. and Allen, M.F. 1993. The Interaction of Harvester Ants and Vesicular-Arbuscular Mycorrhizal Fungi in Patchy Semi-Arid Environment: The Effects of Mound Structure on Fungal Dispersion And Establishment. *Functional Ecolology* **7**: 13-20.

Greenslade, P. J. M., 1972. Comparative ecology of four tropical ant species. *Insectes Sociaux,* **19**: 195–212.

Hashimoto, Y. and Homathevi, R. 2003. Inventory & Collection. Research and Education Component of BBEC Programme, Institute for Tropical Biology and Conservation. UMS. 81-144

Henri, G and John, T. H. 1993. Hymenoptera of the world: an identification guide to families. Canada Communication Group.

Hermen, R. and Klaus, J. 1989. A Comparison of Methods for Sampling Ants (Hymenoptera, Formicidae) in Savannas. *Biotropica* **21(4)**: 348-352.

Hölldobler B., Wilson E.O. 1990. *The Ants.* Harvard University Press, Cambridge, MA.

Hölldobler, B. and Wilson, E.O. 2009. *The Superorganism.* Norton. New York: London

John, H. S. and Nigel, R. F. 1987. *The Behavioural Ecology of Ants.* Blackie & Son Limited.

Kannowski, P.B. 1956. The Ants of Ramser Country, North Dakota. *The American Midland Naturalist* **56**: 168-185.

Khoo, B. and Ho, C.T. 1992. The Influence *of Dolichoderus thoracicus* (Hymenoptera: Formicidae) on Losses Due to *Helopeltis thievora* (Heteroptera: miridae). Black Pod Disease, and Mammalian Pests in Cocoa in Malaysia. *Bulletin of Entomological Research* **82**: 485-491.

Lavelle, P. and Pashanasi, B. 1989, Soil Macrofauna and Land Management in Peruvian Amazonia (Yurimaguas, Loreto). *Pedobiologia* **33**: 283-291.

Majer, J.D. 1985. Recolonisation by Ants of Rehabilitated Mineral Sand Mines on North Stradbroke Island, Queensland, with Particular Reference to Seed Removal. *Australian Journal of Ecology* **10**: 31-48.

Majer, J.D. 1991. Ants: Bioindicators of Minesite Rehabilitation, Land use, and Land Conservation. *Environment Management* **(4)**: 375-383.

Majer, J.D. and Beeston, G. 1996. The biodiversity Integrity Index: An Illustration Using Ants in Western Australia. *Conservation Biology*. **10**: 65-73.

Majer, J.D. Sartiori, M., Stone, R. and Perriman, W.S. 1982. Recolonization by Ants and Other Invertebrates in Rehabiliated Mineral Sand Mines near Enebba, Western *Australia Reclamation and Revegetation Research* **1**: 63-81.

Majer, J.D. 1983. Ants: Bioindicators of Mine Site Rehabilitation, Land Use and Land Conservation. *Environmental Management* **7**: 375-383.

Mark, A.J. 2005. *Insects as Natural Enemies; A Practical Perspective.* Springer, The Netherlands.

Maryati, M. 1997. *Siri Haiwan Di Persekitaran Kita: Semut.* Dewan Bahasa dan Pustaka

Maryati, M., Homathevi, R., Tachi, T., and Mahadimenakbar, D. 2004. *Introduction to Entomology*. Research and Education Component of BBEC Programme, Institute for Tropical Biology and Conservation. UMS. 13-42

McGinley, M.A., Dhillion, S.S. and Neumann, J.C. 1994. Environmental Heterogeneity and Seeding Establishment: Ant-Plant-Microbe Interactions. *Functional Ecology* **8**: 607-615.

Merickel F.W. and Clark W.H. 1994. *Tetramorium caespitum* (Linnaeus) and *Liometopum luctuosum* WM Wheeler (Hymenoptera: Formicidae): New state records for Idaho and Oregon, with notes on their natural history. *Pan-Pacific Entomologist* **70**: 148-158.

National Geographic. Ant: *Formicidae.* 2015. http://animals.nationalgeographic.com/animals/bugs/ant/. Access on 5 April 2015.

Nixon, G.E. 1951. *The Association of Ants with Aphids and Coccids.* Commonwealth Institute of Entomology, London.

Nor' Aini, D. 1992. *Memahami Ekologi Kuala Lumpur*: BB & Perpustakaan.

Norshazreen Bt Sheh Muhammad Abidin. 2010. *Kajian Populasi Semut Pada Pokok Koko di Ladang Koko, Hilir Perak.* Bachelor of Agricultural Science Dissertation. Universiti Malaysia Sabah.

North, R. 1996. *Ants.* Whittet Books Ltd, London.

Nur-Zati A. M, Hannah M. W. S., Fletcher, C., Abd Rahman, K. and Matthew D. P. 2011. Taxonomic And Functional Diversity Of Ants (Hymenoptera:Formicidae) In An Upper Hill Dipterocarp Forest In Peninsular Malaysia. *The Raffles Bulletin of Zoology* **59(2)**: 181–194.

Perfecto, I., and R. Snelling. 1995. Biodiversity and the Transformation of the Tropical Agroeco-System: Ants In Coffee Plantations. *Ecological Applications* **5**: 1084-1097.

Petal, J. 1978a. Adaptation of Ants to Industrial Pollution. *Memorabilia Zoology* **29**: 99-108.

Petal, J. 1978b. The Role of Ants in Ecosystems. In *Production Ecology of Ants and Termites*. (M.V. Brain, ed.). pp. 293-325. Cambridge, UK: Cambridge Univ. Press.

Petal, J. 1980. Ant Populations, Their Regulation and Effect on Soil in Meadows. *Ekologia Polska* **28**: 297-326.

Petal, J., Jakubczyk, H., Chmielewski, K. and Tatur, A. 1975. Response of Ants to Environmental Pollution. *Progress in Soil Zoology* (J. Vabek, ed.) pp. 363-373. Prague: Czechoslovakia Academy of Sciences.

Petal, J., Nowak, E., Jakubczyk, H. and Czerwinski, Z. 1977. Effect of Ants and Earthworms on Soil Habitat Modification. *Ecological Bulletins* **25**: 501-503.

Pfeiffer, M., Mezger, D., Hosoishi, S., Bakhtiar, B. Y., and Kohout, R.J. 2011. The Formicidae of Borneo (Insecta: Hymenoptera): A Preliminary Species List. *Asian Myrmecology* **4**: 9–58.

Philpott, S.M. and Armbrecht, I. 2006. Biodiversity in Tropical Agroforests and the Ecological Role of Ants and Ant Diversity in Predatory Function. *Ecological Entomology* **31**: 369-377.

Rizali,A., Bos, M.M, Buchori, D., Yamane, S. and Schulze, C.H. 2008. Ants in Tropical Urban Habitats: The Myrmecofauna in a Densely Populated Area of Bogor, West Java, Indonesia. *HAYATI Journal of Biosciences* **15(2)**: 77-84.

Roberts, D.L., Cooper, R.J. and Petit, L.J. 2000. Use of Premontane Moist Forest and Shade Coffee Agroecosystems by Army Ants in Western Panama. *Conservation Biology* **14**: 192-199.

Romeser, S.W. 1981. *The Science of Entomology,* 2nd Edition. Microbiology and Zoology Department: University Ohio.

Schmitz, O.J., Hamback, P.A. and Beckerman, A.P. 2000. Trophic Cascades in Terrestrial Systems: A Review of the Effects of Carnivore Removals on Plants. *American Naturalist* **155,** 141-153.

Shattuck, S.O. and Marsden, S. 2013. Australian species of the ant genus Dolichoderus (Hymenoptera: Formicidae). *Zootaxa,* **3716(2)**:101-143.

Stork, N.E. 1987. Insect Diversity: Facts, Fiction and Speculation. *Biological Journal of the Linnean Society* **35**: 321-33

Stradling, D.J. 1978. *Production Ecology of Ants as Termites.* Cambridge Press: 82-91. Sukarman

Symondson, W.O.C, Sunderland, K.D. and Greenstone, M.H. 2002. Can generalist predators be effective biocontrol agents? *Annual Review of Entomology,* **47**: 561-594

Torossian, C. and Causse, R. 1968. Effets des radiations gamma sur la fertlité et la longévité des colonies de *Dolichoderus quadripunctatus.* Compte rendu du Colloque "Isotopes and radiation in entomology". International Atomic Energy Agency, Vienna. pp. 155-164.

Tyler, V. and Andrea, L. 2014. Featured Creatures. University of Florida. http://entnemdept.ufl.edu/creatures/misc/ants/pavement_ant.htm#top. Access on 7 November 2015.

Way, M.I. and Khoo, K.C. 1992. Role of Ants in Pest-Management. *Annual Review of Entomology* **37**: 479-503.

Way, M.I. 1963. Mutualism between ants and honeydew-producing Homoptera. *Annual Review of Entomology,* **8**: 307-344.

Weber, N.A. 1972. Gardening Ants, The Attines. *Memoirs of the American Philosophical Society* **92**: 1-146.

Wiens, J.A. 1977. On Competition and Variable Environments. *American Scientist.* **65**: 590-597.

Williams, D.F. 1994. *Exotic Ants Biology, Impact, and Control of Introduced Species.* San Francisco: Westview Press.

Woodcock, B.A. 2005. *Insect Sampling in Forest Ecosystems*: Chapter 3. Pitfall Trapping in Ecological Studies. Blackwell Science Ltd

Yong, Ed. 2013. Ant Bodyguards Get Exclusive Contract from Trees. *National Geographic.*