CHAPTER V

CONCLUSION

This thesis has revealed the more precise predator-prey relationship between the social ants and bees. Each bee species which possess a biological activity from natural material to repel ants has developed a specific and singular way to repel the predatory ants. The number of bees on the sticky band of *A. florea* increased significantly after presentation of *O. smaragdina* and added material correlated with the exposure of *O. smaragdina*. The result indicated that *A. florea* recognize specifically *O. smaragdina* and strengthen the sticky band as the specific reaction to *O. smaragdina*. These results demonstrated that the dwarf honey bees invest high cost in defense against *O. smaragdina*. Apparently, they considered the weaver ants as a major enemy.

The material of nest entrances from *T. apicalis*, *T. terminata*, *T. melanocephala*, *T. laeviceps* and *T. minor* showed highly repellent to weaver ants. It seems that these groups build the entrance tube consistently related to at least some degree of specificity in defense to *O. smaragdina*. As pointed out by William and collaborators (1989), the recognition of the substance by predators might not be evident today, it is also possible that this substance is related to another predatory organism in the past. So the high recognition to the entrance tube material of *Trigona* is apparently not sufficient to explain the predator-prey specificity between *O. smaragdina* and *Trigona*. A more specific experiment, however, would still be needed to prove the hypothesis. In contrary, the entrance tube in *T. collina* showed less repellent property compared to other species of stingless bees in this study. This significant difference hinted that *O. smaragdina* have practised a weaker selective pressure in *T. collina*.

The interesting issue should be also mention that dwarf honey bees and *Trigona* species might use the physical properties (adhesion “sticky substrate”) of plant resins (bee material) to protect their nests as additional assets. This mechanism has the advantage that ants cannot reach the colony. "Getting stuck" seems to be a successful defense mechanism against many kinds of ants and other predatory arthropods (Betz and Kolsch, 2004). In this case, the evolution of highly derived sensory (Pasteels *et al.*, 1983) / or chemical equipment is not required. On the other hand, in weaver ants, the adhesive defense is effective only to some degree. Therefore, the social bees have evolved chemical repellents as an additional mode of defense. This idea is supported by the study of the separated fractions has shown clearly that the repellent activity of bee material came from chemical composition of resin. Nevertheless, the experiment with the physical adhesion used by social bees to defend against predatory ants should still be mentioned carefully. It would also be interesting to investigate the co-ordination between the physical and chemical functions of compositions in bee material.

In relation to the degree of repellent activity, *O. smaragdina* might be the main selective force responsible for acquisition of the resin from plants in social bees. In this study, the sticky band of *A. florea* is specifically employed to prevent weaver ant's attack. But still the intriguing question performed in the other bees, *Trigona* spp; Are the resins collected due to other kinds of selective pressure such as the physical protection (barrier of water influx) and / or the other kinds of predators? Moreover, the sympatric occurrence between prey and predators could be pointed out for the ecological relevance. The observation of responses of bee species / other similar organisms to ant predators would add valuable information. In groups such as *Trigona*, we found that entrance tube from *T. collina*, which nest on the ground, was significantly less effective to weaver ants. This indicated that *Trigona species* have a high variety of entrance tube structures and this exhibited also in its components. Further investigation would be needed to explore reasons for differences among the entrance tubes.

In *A. mellifera*, propolis (resinous material) was used to fill all crevices, which in the warmth and humidity of a hive are potential sites for starting infections of fungi and bacteria (Seeley, 1985, Burdock, 1998). No distinct structure of using resins against ant predator was observed. The propolis exhibited the ant repellent property was found in both weaver ant and red wood ant, showing that it has low specific property against ants. The repellent revealed in propolis of *A. mellifera* may be the defensive analogy of the plants in the same regions. To abridge, propolis from *A. mellifera* repel European red wood ant "stronger" than materials from Asian bees. Although, it would appear that the level of predator-prey "arms race" between social bees and ants in tropical regions is greater than that in temperate region. This is in agreement with the conclusion that resins in nests of social bees are derived as ant specific defense. The intensive interaction resulted in higher specific (tropical forest, Thailand and Malaysia) while weaker interaction resulted in less specific defense (temperate region, Germany). Apparently, the repellent index is higher against sympatric predatory ant species.

Generally pentane extracts had a higher repellent index compared to raw material. We conclude that none or very low repellent index in acetone and methanol extracts. Moreover, the thesis has shown that the common substances found in the fractions exhibited property of ant repellent were terpenoids, long chained hydrocarbons, phenol derivatives and naphthalene derivatives. Some terpenoids (Chen *et al.*, 1984 Shory *et al.*, 1992), phenolic compounds (Pasteels *et al.*, 1986) and naphthalenes and derivatives (Bolton and Eaton, 1968 cited in Daisy *et a.l*, 2002) are reported as repellents in insects/or ants. Moreover, terpenoid was found as the main component in the ant repellent fraction of the two tested *Apis* species. In *Trigona* species terpenoid do not play a dominant role in active fractions. We found a high diversity in proportion of terpenoids, hydrocarbons phenol and naphthalene derivatives. Furthermore, seven compounds so far not present in library database were found in significant proportion. The repellent properties of these unknown compounds are still unpredictable. However, bee behavior responding to ant enemies is not always related to all chemical compounds in the active fractions (Trigo, 2000). It is necessary to isolate the chemicals from the biological substrate and test them back against the ants to reveal repellent effects. Another interesting point is: What functional group in the compound is really active against ants? Is there any synergistic interaction among them? The relationship of the structure and activity of chemical substances against ant predation should also be studied. Another questions concerning to the chemical substances, Are there any chemical transformation of resin from plant to defensive material in bee nests? To find the answer, a comparison between the resins from original plant source and the defensive material in bee nests should be undertaken. Although, many literatures have revealed that many arthropods use the chemical defense against their enemies (see 2.4, 2.6). To date, only a small part of predatory defensive chemicals in resins from bee nest has been discovered. Finally, the medical and pharmaceutical application focuses more on the natural substances. As our results have shown about the chemical substances which repel the ants. In the future, we should investigate more and find the substances that protect items such as food and storage from ants.