Diversity of Bees (Hymenoptera: Apoidea) as Insect Pollinators on Physic Nuts (Euphorbiaceae: *Jatropha curcas* L.) in Thailand

C. Inson and S. Malaipan*

Department of Entomology, Faculty of Agriculture,
Kasetsart University, Chatuchak, Bangkok 10900, Thailand

**Corresponding author. Email: agrstm@ku.ac.th*

Abstract

Insect pollinators are very important for fruit setting of *Jatropha curcas* L. All insect pollinators were surveyed and identified in 20 provinces of Thailand during from April to August 2009. The results revealed 311 species, 138 genera and 64 families in eight orders namely Hymenoptera, Lepidoptera, Diptera, Coleoptera, Hemiptera, Mantodea, Orthoptera and Blattodea. All insect species were segregated into major and minor groups according to their behavioral activities and importance to *J. curcas*. The insect pollinators in each province were compared by species diversity index and distribution. The highest species diversity index was observed in the north while the lowest values were found in the northeast and the south. Sixty species of superfamily Apoidea were identified. The most distributed species were *Apis cerana indica* Fabricius, *A. florea* Fabricius and *Trigona pagdeni* Schwarz. These bees were considered to be the most common and effective pollinators.

Keywords: insect pollinators, bees, *Jatropha curcas* L., physic nuts, species diversity

Introduction

The important problem of *Jatropha curcas* L. is in its limited or low productivity (Jones and Miller, n.d.). Various factors such as variety, cultivation, irrigation, season and pollination are the causes of problem. *J. curcas* flowers flowers are unisexual (monoecious), that is both male and female flowers occur on the same inflorescence (Jones and Miller, n.d.; Gurcharan, 2004). The male flower has large and sticky pollen grains for insect-pollination (Ashoke et al., 2005) and the insect pollinators are essential for carrying the pollen grains from male flowers to the stigma of female flowers. Successful pollination results in seeds or fruits that can be collected for bio-diesel production.

On Asia there have been only limited investigations of the diversity of insect pollinators on *J. curcas*. The first observation (of more than fifty species of insect pollinators) were obtained in Thailand (Malaipan et al., 2002). Later, 12 species were reported in India by Raju et al. and Ezradnama (2002). Ashoke et al. (2005) also surveyed *J. curcas* in India but discovered just six species of insect pollinators.

The aims of the project reported on the present paper were to survey, identify and categorize *Jatropha* pollinatiors in Thailand, and compare species diversity indices among the provinces. The project also sought to assess whether insect pollinators were adequate for *J. curcas* pollination.

Materials and Methods

Study Sites

Surveys of insect pollinators were undertaken at *J. curcas* plantations in 20 provinces, in five regions as follows: Region 1 (north): Chiang Mai, Chiang Rai, Lampang, Lamphun, Nan and Phayao; Region 2 (northeast): Kalasin, Khon Kaen, Maha Sarakham, Nakhon Ratchasima, Sakon Nakhon and Udon Thani; Region 3 (central): Chai Nat, Kamphaeng

Phet, Nakhon Pathom and Suphan Buri; Region 4 (east): Chon Buri and Rayong; Region 5 (south): Chumphon and Phangnga. At each site, at least 100 m^2 was sampled.

Sampling Methods

The sampling methods followed Malaipan et al. (2002) and Kwaiser and Hendrix (2008). Twenty quadrants (each of 100 m^2) were selected from the large area in each province. Wherever *J. curcas* flowers were observed, pollinators were caught by sweep-net during the period 08.00-12.00 a.m., from April to August 2009. All specimens were preserved and maintained in the laboratory of Kasetsart University, Bangkok.

Identification and Grouping of Insect Pollinators

All insect specimens were identified into species or family and were divided into two groups. Identifications were performed by employing the taxonomic keys from Triplehorn and Johnson (2005), Michener (2000), Sakagami et al. (1985), Schwarz (1937, 1939), Osamu and Tasen (2009), Ekamnuay (2002), Insect Museum of Entomology Department, Kasetsart University (2006), Beaver et al. (2009), and Neal and Patrick (2002). The specimens were grouped by their colonizing behavior and the frequency of occurrence.

Data Analysis

Data were compared among twenty provinces in Thailand. Species diversity of insect pollinators was analyzed using the Shanon-Weiner diversity index (Ḣ) from the statistical package "Species Diversity and Richness", while diversity percentages were calculated using MS Excel.

Results

Diversity of Insect Pollinators

A total of 762 insect specimens were collected, representing 311 species, 138 genera and 64 families, and eight orders, namely Hymenoptera, Lepidoptera, Diptera, Coleoptera, Hemiptera, Orthoptera, Mantodea and Blattodea (Table 1). Based on the number of species Hymenoptera (with 45.02% of the species) exhibited the highest diversity followed by Lepidoptera (20.58%), Diptera (15.43%), Coleoptera (9.97%), Hemiptera (7.40%), Mantodea and Orthoptera (0.64%) while the lowest diversity was found in Blattodea (0.32%) (Table 2).

Table 1 Species list of insect visitors found on *Jatropha curcas* L. flowers in Thailand from April to August 2009.

Order	Family	Scientific Name
Blattodea	Blattellidae	Unidentified (1 sp.)
Coleoptera	Brentidae	*Eubactrus* sp.
	Bruchidae	Unidentified (2 spp.)
	Cerambycidae	*Chlorophorus annularis* Fabricius, *Polyzonus obtusus* Bates, *Polyzonus* sp.
	Chrysomelidae	*Aulacophora* sp., *Chrysochus* sp., *Donacia aenaria* Baly, *Galerupipla* sp., *Luperomorpha* sp.
	Cleridae	Unidentified (1 sp.)
	Curculionidae	*Ectatorhinus* sp., *Episomus* sp.
	Elateridae	*Alaus* sp., *Diploconus* spp. (2 spp.)
	Lycidae	*Lycostomus* spp. (4 spp.)
	Cantharidae	Unidentified (1 sp.)
	Nitidulidae	Unidentified (1 sp.)
	Scarabaeidae	*Gametis histrio* Olivier, *Glycyphana nicobarica* Janson, *Glycyphana horsfield* Hope, *Glycyphana quadricolor quadricolor* Wiedemann, *Ixorida mouhotii* Wallace, Unidentified (1 sp.)
	Staphylinidae	Unidentified (1 sp.)
Diptera	Asilidae	*Proctacantella* sp., *Promachus* sp.
	Bombyliidae	*Systropus* spp. (3 spp.)
	Calliphoridae	*Chrysomyia megacephala* Fabricius, *Chrysomyia* spp. (2 spp.), *Hypopygropsis* sp., Unidentified (1 sp.)
	Dolichopodidae	*Chrysosoma* sp.
	Drosophilidae	*Drosophila* sp., Unidentified (1 sp.)
	Empididae	*Hilara* sp.
	Muscidae	*Musca* spp. (7 spp.)
	Sarcophagidae	*Parasarcophaga* sp.
	Stratiomyidae	*Hermetia* sp., *Ptecticus* sp., *Stratiomys* sp., Unidentified (1 sp.)
	Syrphidae	*Eristalis arvorum* (Fabricius), *E. obscuritarsis* Meijere, *Helophilus bengalensis* Wiedemann, *Helophilus* spp. (2 spp.), *Megapis* sp., *Physocephala* sp., *Rhingia* spp. (4 spp.), *Syrphus* spp. (2 spp.), Unidentified (1 sp.)

Table 1 (Cont.)

Order	Family	Scientific Name
	Tabanidae	*Chrysops dispar* (Fabricius), *C. fasciata* Wiedemann
	Tachinidae	*Drino* spp. (3 spp.)
	Tephritidae	*Bactrocera* sp.
	Therevidae	Unidentified (1 sp.)
	Tipulidae	*Tipula* sp.
Hemiptera	Coreidae	*Clavigralla* sp., *Riptortus linearis Fabricius, Serinetha abdominalis* Fabricius, Unidentified (3 spp.)
	Lygaeidae	*Geocoris* sp., *Graptostethus servus* Fabricius, Unidentified (1 sp.)
	Miridae	Unidentified (1 sp.)
	Pentatomidae	*Eocanthecona furcellata* (Wolff), *Erothesima fullo* Thunberg, *Eusarcocoris guttiger* Thunberg
	Reduviidae	*Chitapa* sp., *Ectomocoris* sp., *Rhynocoris* spp. (2 spp.), *Sycanus collaris* Fabricius, Unidentified (1 sp.)
	Scutelleridae	*Chrysocoris grandis* Thunberg, *C. stollii* Wolff, *Callidea* sp.
Hymenoptera	Apidae	*Amegilla* sp., *Apis andreniformis* Smith, *A. cerana indica* Fabricius, *A. dorsata* Fabricius, *A. florea* Fabricius, *A. mellifera ligustica* Linnaeus, *Ceratina* spp. (3 spp.), *Pithitis smaragdula* Fabricius, *Podalirius crocea* Bingham, *Thyreus* sp., *Trigona collina* Smith, *T. laeviceps* Smith, *T. melanoleuca* Cockerell, *T. pagdeni* Schwarz, *T. ventralis* Smith, *Trigona* spp. (4 spp.), *Xylocopa aestuans* (Linnaeus), *X. collaris* Cockerell, *X. latipes* (Drury)
	Chrysididae	*Stilbum cyanarum* (Förster), *Stilbum* sp.
	Evaniidae	*Evania* sp.
	Formicidae	*Anoplolepis gracilipes* (Smith), *Camponotus* spp. (4 spp.), *Coleopter* sp., *Iridomyrmex* sp., *Meranoplus* sp., *Monomorium* spp. (2 spp.), *Ochetellus* spp. (2 sp.), *Oecophylla smaragdina* Fabricius, *Paratrechina* spp. (3 spp.), *Solenopsis geminata* (Fabricius), *Tetraponura rufonigra* (Jerdon), Unidentified (1 sp.)
	Halictidae	*Halictus* spp. (3 spp.), *Lasioglossum* spp. (4 spp.), *Nomia albofasciata* Smith, *Nomia* spp. (5 spp.), Unidentified (1 sp.)
	Megachilidae	*Coelioxys* sp., *Euaspis* spp. (2 spp.), *Lithurge* sp., *Megachile hera* Bingham, *M. disjuncta* (Fabricius), *M. ampulata* Smith, *Megachile* spp. (15 spp.), Unidentified (1 sp.)
	Mutillidae	*Trogaspidia* sp.
	Pompilidae	*Pompilus* spp. (2 spp.)
	Scoliidae	*Camsomeris collaris* 4-*fasciata* Fabricius, *Camsomeris phalerata* Saussure, *Liacos* sp., *Megascolia* azurea *rubiginosa* Fabricius, *Scolia quadripustulata humeralis* Saussure, *Scolia* spp. (4 spp.), Unidentified (5 spp.)
	Sphecidae	*Chalybion bengalense* (Dahlbom), *Chlorion lobatum* (Fabricius), *Chlorion* spp. (2 spp.), *Episylon* sp., *Liris* sp., *Sceliphron javanum* (Lepeletier), *Sphex argentatus* Fabricius, *S. sericeus lineolus* Lepeletier, *S. viduatus* Christ, *Sphex* spp. (2 spp.)
	Vespidae	*Apodynerus* sp., *Auterhynchium* sp., *Delta esuriens* Fabricius, *Delta* spp. (5 spp.), *Eumenes conica* Fabricius, *Eumenes* spp. (3 spp.), *Phimenes* spp. (2 spp.), *Polistes stigma* (Fabricius), *Polistes* spp. (5 spp.), *Rhynchium haemorrhoidala* (Fabricius), *R. quinquecinctum* (Fabricius), *Vespa affinis* (Linnaeus), *Vespa* spp. (5 spp.)
Lepidoptera	Acraeidae	*Acraea violae* Fabricius
	Arctiidae	*Amata sperbius* Fabricius, *Amata* sp., *Argina* sp., *Euchromia elegantissima* Wallgram, Unidentified (2 spp.)
	Danaidae	*Danaus chrysippus chrysippus* (Linnaeus), *D. genutia genutia* (Cramer), *Euploea aglae limborgii* Moore, *E. core godartii* (Lucas), *E. klugii erichsonii* Felder, *Euploea* sp., *Ideopsis* sp.
	Gelechiidae	Unidentified (1 sp.)
	Geometridae	Unidentified (1 sp.)
	Hesperiidae	*Caltoris bromus bromus* Leech, *Spialia galba* (Fabricius), *Telicota linna* Evans, Unidentified (4 spp.)
	Lycaenidae	*Amblypodia anita anita* Hewitson, *Cyclosia panthona* Cramer, *Everes lacturnus rileyi* Godfrey, *Loxura atymnus continentalis* Fruhstofer, *Rapala pheretima petosiris* (Hewitson), *Spindasis syama terana* (Fruhstorfer), *Surendra quercetorum quercetorum* (Moore), *Zizina otis sangra* (Moore), Unidentified (1 sp.)
	Noctuidae	Unidentified (1 sp.)
	Nymphalidae	*Cethosia cyane euanthus* Fruhstorfer, *Cirrochoa tyche mithila* Moore, *Junonia* sp., *Neptis hylas kamarupa* Moore, *Tanaecia* sp., Unidentified (1 sp.)
	Papilionidae	*Chilasa clytia clytia* (Evans), *Graphium agamemnon agamemnon* Linnaeus, *G. doson axion* (Felder), *Lamproptera meges virescens* (Butler), *Pachliopta aristolochiae goniopeltis* (Rothschild), *Papilio demoleus malayanus* Wallace, *P. memnon agenor* Linnaeus, *P. polytes romulus* Cramer, *Pathysa antiphates pompilius* (Fabricius), *Troides aeacus aeacus* Felder
	Pieridae	*Appias albina darada* (Felder), *A. olferna olferna* Fruhstorfer, *Catopsilia pomona pomona* (Fabricius), *Ixias pyrene yunnanensis* (Druce), *Leptosia nina nina* (Fabricius)
	Pyralidae	Unidentified (2 spp.)
	Satyridae	*Mycalesis* sp., *Ypthima* sp.
	Sessidae	*Melitta* spp. (3 spp.)
	Sphingidae	*Cephonodes hylas hylas* (Linnaeus)
	Tortricidae	Unidentified (1 sp.)
Mantodea	Mantidae	*Mantis religiosa* Linnaeus, Unidentified (1 sp.)
Orthoptera	Acrididae	Unidentified (1 sp.)
	Tettrigoniidae	Unidentified (1 sp.)

Table 2 Number of families, genus, species and diversity percentage of insect pollinators found on Jatropha curcas flowers in Thailand from April to August 2009.

Order	Family	Genera	Species	Diversity (%)
Blattodea	1	1	1	0.32
Coleoptera	12	15	31	9.97
Diptera	15	19	48	15.43
Hemiptera	6	14	23	7.40
Hymenoptera	11	47	140	45.02
Lepidoptera	16	39	64	20.58
Mantodea	1	1	2	0.64
Orthoptera	2	2	2	0.64
Total	64	138	311	100

Grouping of Insect Pollinators

The insect pollinators were divided by their behavior and the frequency of their occurrence on flowers of *J. curcas*. The "major" group includes all of the species commonly encountered on *J. curcas*. The group includes species of colonial and social bees (*Apis* spp. and *Trigona* spp.: Apidae, Hymenoptera) and several species of syrphid and calliphorid flies. The bees and their broods depend on both nectar and pollen, although not necessarily on *J. curcas*. The flies (Diptera), such as the syrphids (*Eristalis obscuritarsis*, *E. arvorum*, *Helophilus bengaliensis* and *Rhingia* spp.) calliphorid blow fly (*Chrysomyia megacephala*) were observed in this study to gather only nectar but it is known that some feed on both nectar and pollen. The insects in this group were the most abundant insects in physic nut plantations. The "minor" group, which was not so often encountered on the physic nut flowers included other species of Apidae, Chrysididae, Evaniidae, Formicidae, Halictidae, Megachilidae, Pompilidae, Scoliidae, Sphecidae and Vespidae. Other insects of Diptera, Lepidoptera, Coleoptera, Hemiptera, Orthoptera and Blattodea also belong to this group. They were found positively gathering in both nectar and pollen. Some of the species in the "minor" group are pest of physic nuts (e.g. the plant-sucking, scutellarids). The "minor" group also includes some predators of the insect pollinators, such as some species of Reduviidae and Mantidae (Figure 1).

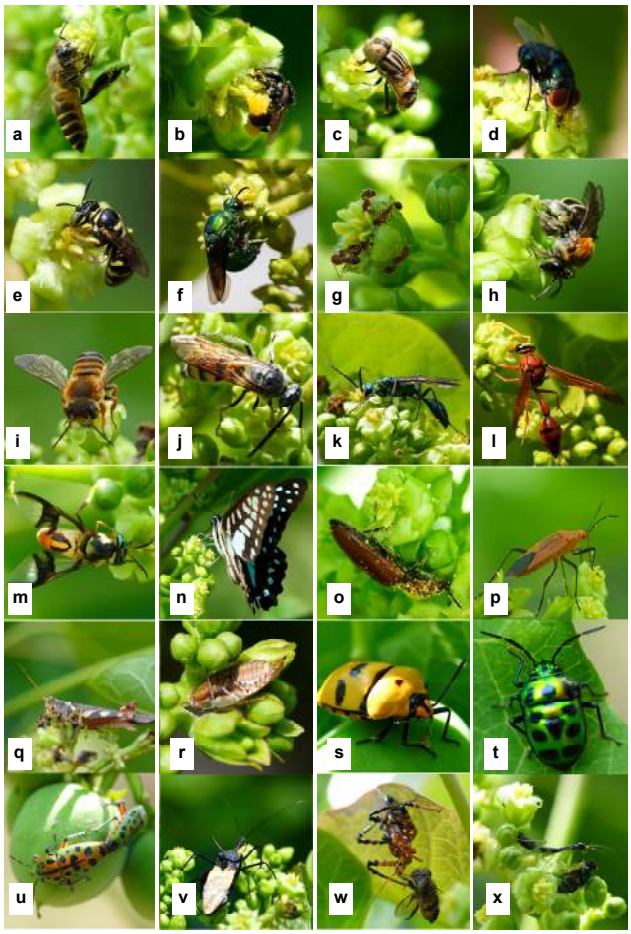

Figure 1 Grouping of insect pollinators visited *Jatropha curcas* flowers from 20 provinces in Thailand during the period April-August 2009, "Major" group: *Apis cerana indica* (a), *Trigona pagdeni* (b), *Eristalis obscuritarsis* (c), *Chrysomyia megacephala* (d); "Minor" group: *Ceratina* sp. (e), *Stilbum cyanarum* (f), *Solenopsis geminata* (g), *Nomia albofasciata* (h), *Megachile ampulata* (i), *Camsomeris collaris 4-fasciata* (j), *Chlorion* sp. (k), *Eumenes conica* (l), *Chrysops fasciata* (m), *Graphium doson axion* (n), *Diploconus* sp. (o), *Serinetha abdominalis* (p), Acrididae (q), Blattellidae (r), *Chrysocoris grandis* (s), *Chrysocoris stollii* (t), *Callidea* sp. (u), *Sycanus collaris* (v), Reduviidae & *A. cerana indica* (w), Mantidae & *Chrysomyia megacephala* (x). Diameter of *J. curcas* flowers is 0.7±0.1 cm.

Species Diversity Indices

The species diversity indices (H') were different among study sites. The highest value was observed in Chiang Rai (4.5), followed by Chiang Mai (4.3), Lampang (4.1), Lamphun, Nan and Phayao (3.8), Chai Nat and Kamphaeng Phet (3.4), Rayong (3.3), Nakhon Pathom (3.2), Kalasin (3.1), Chon Buri (3.0), Nakhon Ratchasima, Phangnga and Suphan Buri (2.9), Sakon Nakhon and Udon Thani (2.8). The lowest values were found in Chumphon, Khon Kaen and Maha Sarakham (2.5) (Table 3).

Distribution of Bees (*Apis* spp. and *Trigona* spp.)

A total of 311 species of insect visitors were collected from 20 provinces in Thailand. Figure 2 depicts the frequencies at which 10 colonial/social bees occurred across the provinces. *Apis cerana indica* occurred in the most provinces (11), followed by *A. florea* (present in 9 provinces) and *Trigona pagdeni* (present in 6 provinces).

Discussions

Diversities of insect pollinators on *J. curcas* flowers were investigated in 20 provinces of Thailand. The study yielded 311 species, a much larger tally than six species recorded on *J. curcas* flowers in India by Ashoke et al. (2005), 13 species recorded also in India by Raju and Ezradanam (2002), and the 50 species recorded in Thailand by Malaipan et al. (2002). This might be because the present study was undertaken during the rainy season (April to August) when insect pollinators in general tend to be abundant and diverse on flowers and because a large number of sites were surveyed; all previous studies were performed during the dry season and included only a few sampling sites. Thysanoptera were not recorded in the present study but thrips were found on *J. curcas* flowers in previous surveys (Malaipan et al., 2002; Raju and Ezradanam, 2002). The large number of species and the abundance of some in the present study suggested that *J. curcas* flowers were attractive to insects and provided suitable nectar and/or pollen.

All insect pollinators (311 species) at the sampling sites in the 20 provinces of Thailand were clearly different from that found at sites in National

Table 3 Species diversity indices of insect pollinators on *Jatropha curcas* flowers in Thailand from April to August 2009.

Thailand region	Province	Species diversity index (H')
North	Chiang Mai	4.3
	Chiang Rai	4.5
	Lampang	4.1
	Lamphun	3.8
	Nan	3.8
	Phayao	3.8
Northeast	Kalasin	3.1
	Khon Kaen	2.5
	Maha Sarakham	2.5
	Nakhon Ratchasima	2.9
	Sakon Nakhon	2.8
	Udon Thani	2.8
Central	Chai Nat	3.4
	Kamphaeng Phet	3.4
	Nakhon Pathom	3.6
	Suphan Buri	2.9
East	Chon Buri	3.0
	Rayong	3.3
South	Chumphon	2.5
	Phangnga	2.9

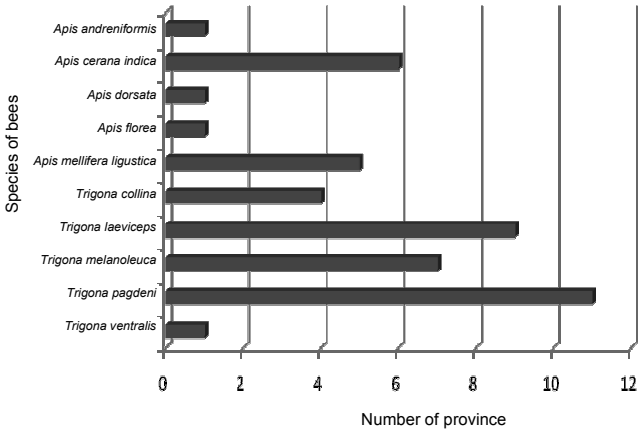

Figure 2 Frequency of occurrence in visiting *Jatropha curcas* flowers from 20 provinces in Thailand from April to August 2009.

Botanic Garden, Lucknow (Ashoke et al., 2005), the Eastern Ghats in India (Raju and Ezradanam, 2002) and previously surveyed site in Thailand (Malaipan et al., 2002). Very rare insect pollinators were observed on *J. curcas* flowers at the Lop Buri Campus, of Kasetsart University (Malaipan et al., 2002). Perhaps, the Lop Buri site was too dry, lacked of alternate host plants for insect pollinators or was too windy for insect pollinators. In the absence of pollination *J. curcas* flowers failed to set fruit.

The insect pollinators recorded during the present study can be divided into "major" and "minor" groups as in Malaipan et al. (2002) reported that some social bees such as *Apis* spp. and *Trigona* spp. and large populations of Diptera such as Syrphidae (*Eristalis obscuritarsis*, *E. arvorum*, *Helophilus bengaliensis* and *Rhingia* spp.) and Calliphoridae (*Chrysomyia megacephala*) were found in major group. The minor group consisted of some insect pollinators belonging to the Hymenoptera, Diptera, Lepidoptera, Coleoptera, Hemiptera and Thysanoptera. Raju and Ezradanam (2002) reported that bees were the most abundant pollinators. When floral structure and the adaptive features of the insects are considered, honeybees (*Apis dorsata*, *A. florea* and *A. mellifera*) were considered to be the most effective pollinators. Species of *Eumenes* and *Vespa* and the beetles are not considered as effective pollinators since the pollination syndromes of these visitors do not match with *J. curcas* flowers. The bees encountered in their study mostly collected floral rewards on different, conspecific plants and thus promoted cross (or xenogamous) pollination over pollination within the same, individual plant (geitonogamous pollination).

The relatively widespread occurrence on *J. curcas* of several species of social bees (Figure 2) is consistent with Ashoke et al.(2005) who suggested that, *Apis dorsata*, *A. florea* and *A. mellifera* were the most common and effective pollinators. The present survey found 60 species of Apiformes in the superfamily Apoidea on *J. curcas*. Of these, *Apis cerana indica*, *A. florea*, *A. mellifera ligustica* and *Trigona pagdeni* would be the most appropriate subjects for more detailed studies to determine efficiency pollination in *J. curcas* plantations. The present study has revealed that most *J. curcas* plantation in each province have a high diversity of insect pollinators and that there are marked differences among 20 provinces. This indicates that an intensive, various provinces investigation is needed to confirm the hypothesis that insect pollinators are an important factor for the successful pollination of *J. curcas*.

Conclusions

311 species of insect pollinators were found on *Jatropha curcas* flowers. Species diversity indices of insect pollinators showed response to differed the 20 provinces especially the highest in the north region of Thailand. The bees (*Apis* spp. and *Trigona* spp.) are likely to be the most important pollinators and could be chosen for further studies.

Acknowledgments

This work was supported by the TRF/BIOTEC Special Program for Biodiversity Research and Training grant BRT T_ 352025.

References

Ashoke, B., K. Datta and S. K. Datta. 2005. Floral biology, floral resource constraints and pollination limitation in *Jatropha curcas* L. Pakistan Journal of Biological Sciences. 8(3): 456-460.

Beaver, R.A., A. Mantilleri and L.-Y., Liu. 2009. Checklist and illustrated key to species of Brentidae from Fiji (Coleoptera: Curculionoidea). Arthropods XII. Bishop Museum Occasional Papers 102: 3-26.

Triplehorn, C.A. and N.F. Johnson. 2005. Borror and DeLong's Introduction to the Study of Insects. 7th ed. Thomson Brooks/Cole, USA.

Gurcharan, S. 2004. Plant Systematics An Intergrated Approch. Science Publishers, Inc. Enfield, NH, USA.

Insect Museum of Kasetsart University. 2006. Butterflies and Moths. Auk-sorn Siam Printing, Bangkok.

Jones, N. and J.H. Miller. N.d. *Jatropha curcas* A Multipurpose Species for Problematic Sites. The World Bank, Asia Technical Department, Agriculture Division.

Malaipan, S., C. Inson and P. Pobsuk. 2002. Study on species diversity and behavior of insect pollinators on *Jatropha curcas* L. Plantations, pp. 73-77. Proceeding of The 1st Meeting of *Jatropha curcas* L. Thailand.

Kwaiser, K.S. and S.D. Hendrix. 2008. Diversity and abundance of bees (Hymenoptera: Apiformes) in native and ruderal grasslands of agriculturally dominated landscapes. Agriculture, Ecosystems and Environment 124: 200-204.

Michener, C.D. 2000. The Bees of the World. The Johns Hopkins University Press, Maryland.

Neal, L.E. and G. Patrick. 2002. Annotated checklist of the Dolichopodidae (Diptera) of Singapore with descriptions of a new genus and new species. Raffles Bulletin of Zoology 50: 301-316.

Osamu, S. and W. Tasen. 2009. Bees of natural forest, teak plantations and agricultural fields in Thailand. Esakia 49: 7-13.

Ekamnuay, P. 2002. Beetles of Thailand. Amarin Printing and Publishing Public Co., Ltd., Bangkok.

Sakagami, S.F., T. Inoue and S. Salmah. 1985. Key to the stingless bees species found or expected from Sumatra, pp. 37-43. In R.I. Ohgushi, ed., Evolutionary Ecology of Insect in Humid Tropics, Especially in Central Sumatra. Kanasawa University, Japan.

Schwarz, H.F. 1937. Results of the Oxford University Sarawak (Borneo) Expedition: Bornean stingless bees of the genus *Trigona*. Bull. Amer. Mus. Nat. Hist. 73: 281-328.

Schwarz, H.F. 1939. The Indo-Malayan species of *Trigona*. Bulletin of the American Museum of Natural History 76: 83-141.

Raju, A.J.S. and V. Ezradanam. 2002. Pollination ecology and fruiting behavior in a monoecious species, *Jatropha curcas* L., (Euphorbiaceae). Current Science 83: 1395-1398.

Manuscript received 24 July 2011, accepted 30 December 2011