Thai J. For. 34 (3) : 1-15 (2015)

Original article

Diversity and Foraging Behavior of Dipteran Pollinators of Physic nut (*Jatropha curcas* L.) in Thailand

Pananya Pobsuk **Chama Phankaew**
Savitree Malaipan*

Department of Entomology, Faculty of Agriculture Kasetsart University, Chatuchak, Bangkok 10900, Thailand
*Corresponding Author, E-mail: agrstm@ku.ac.th

Received: Jun 18, 2015 Accepted: Jul 17, 2015

ABSTRACT

Insect pollinators increase fruit and seed setting of *Jatropha curcas* L. Therefore, it is important to understand the diversity of fly species as pollinators and their pollination effectiveness. This study was performed at 19 locations in 5 regions of Thailand from March 2012 to May 2014. In total, 491 individual flies were identified belonging to 30 species, 22 genera and 13 families in the order Diptera. The family Syrphidae was the most dominant representing 8 species followed by the Calliphoridae (6 species), Asilidae, Stratiomyidae, Tabanidae, Tachinidae and Tephritidae (2 species). The families with only 1 species each were the Bombyliidae, Drosophilidae, Muscidae, Sarcophagidae, Therevidae and Tipulidae. However, the family Calliphoridae comprised the highest number of individuals (284) contributing 57.84% of the fly pollinators collected. There were 2 peaks of greatest abundance in March to May and September to October which related to flowering periods at the Supan Buri location. Two species (*Eristalis obscuritarsis* and *Chrysomya megacephala*) showed the highest abundance during 08.00-10.00 h and numbers declined in the late afternoon on male flowers, whereas both species were found on female flowers at peak populations in the afternoon. Male and female fly preferences for floral sex characters differed. Both fly species preferred female flowers to male flowers. With regard to visiting male and female flowers, *E. obscuritarsis* produced male and female flies with ratios of 1:5 and 1:1, respectively, whereas, for *C. megacephala*, the ratios were 1:8 and 1:2, respectively. Overall, both flies spend less time on female flowers than on male flowers. Both sexes of *E. obscuritarsis* on male and female flowers showed different foraging rates, while for *C. megacephal*a, on average, both sexes visited female flowers more than male flowers with similar foraging rates.

Keywords: fly pollinators, Diptera, Dipteran, *Jatropha curcas* L., physic nuts, diversity

INTRODUCTION

Jatropha curcas L (physic nut), was introduced to Thailand and is valued as an oilseed crop since it is a non-consumable, bio-diesel alternative and is easily cultivated. In particular the pollination process is of great importance when developing a method to increase the productivity of *J. curcas* crops. Chang-wei *et al*. (2007) categorized physic nut as an out-crossing that is self-compatible and needs pollinators due to the adhesiveness of the pollen, while the smoothness of the stigma of 1.62 mm in diameter makes wind pollination almost impossible; so there is a reliance on insect pollination. The role of insects as a pollination agent in fruit and seed development is essential for increasing crop yields. Therefore, physic nut plants need cross-pollination by bees (Hymenoptera) and flies (Diptera), which make up the major pollinating groups of species commonly encountered on *J. curcas* (Malaipan *et al*., 2002; Raju and Ezradanam, 2002; Inson and Malaipan, 2011; Negussie *et al*., 2013). The characteristics of bees and flies are more valuable than other species of insects for pollinating crops. Most of the research on *J. curcas* indicated that honey bees and stingless bees were the most abundant and effective pollinators on physic nuts (Raju and Ezradanam, 2002; Bhattacharya *et al*., 2005; Chang-wei *et al*., 2007; Malaipan *et al*., 2007; Rianti *et al*., 2010; Inson and Malaipan, 2011). Flies may have a distinct advantage over bees in terms of being important pollinators. Flies are the most common visitors to the physic nut flower based on data collected from many locations in Thailand (Malaipan *et al*., 2007; Inson and Malaipan, 2011). They are more consistent at pollinating physic nut flowers, being present throughout the year under various climatic conditions. Flies can be used as alternate pollinators when honey bees are not available. Bees may be partly or completely absent in some areas under certain conditions and can be replaced by flies. Various crops, (strawberry, sweet pepper and onion) may be less attractive to honey bees than competing weed blossom. Flower flies and blowflies are necessary to produce an acceptable crop in terms of fruit and seed (Jarlan *et al*., 1997; Albano *et al*., 2009; Munawar *et al*., 2011). In tropical forest, Dipterans are the major visitors of teak flowers in Thailand (Tasen *et al.*, 2014) The objectives of this experiment were to study the diversity of the pollinating fly species and to observe their pollinating frequency on physic nuts. The fly pollinators primarily focused on were the blow fly (*Chysomya megacephala*) and the flower fly (*Eristslis obscuritarsis*). Their diurnal activity patterns and foraging behavior were investigated in relation to enhancing the crop yield.

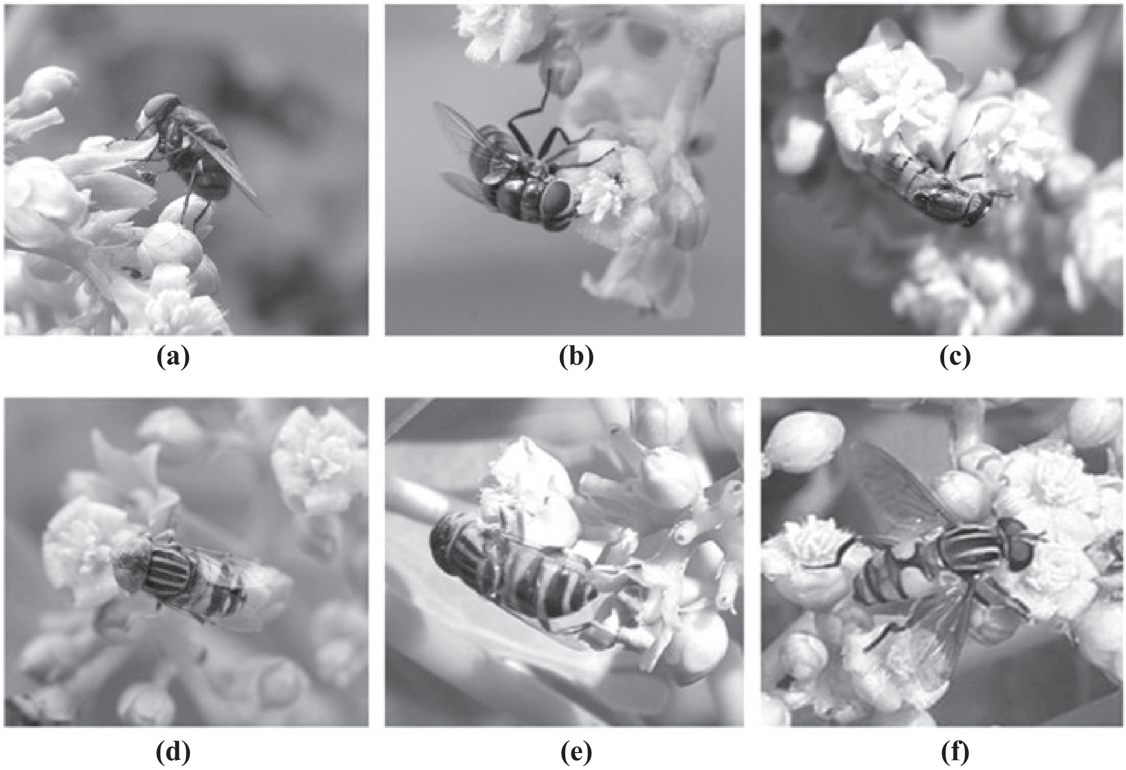

Figure 1 Dipteran pollinators on physic nut flowers from 19 locations in Thailand during March 2012 to April 2013, Family Calliphoridae: *Chrysomya megacephala* (a) *Chrysomya rufifacies* (b) *Stomorhina discolor* (c) Family Syrphidae: *Eristalis obscuritarsis* (d) *Eristalis arvorum* (e) *Helophilus bengalensis* (f)

MATERIALS AND METHODS

Study sites

Surveys of Dipteran pollinators were carried out at physic nut (*Jatropha curcas* L.) plantations in 19 locations, in provinces in five regions: 1) Central region: Chai Nat, Kamphaeng Phet, Nakhon Pathom and Suphan Buri; 2) North region: Chiang Mai, Chiang Rai, Lampang, Lamphun, Nan and Phayao; 3) Northeast region: Maha Sarakham, Nakhon Ratchasima, Sakon Nakhon, Mukdahan and Udon Thani; 4) East region: Chon Buri and Rayong and 5) South region: Chum Pon and Pang Nga. At each location, an area of 100 m^2 was sampled.

Sampling methods

Sampling methods used in the survey followed Malaipan *et al*. (2007) and Kwaiser and Hendrix (2008). Twenty quadrants (each 100 m^2) were selected from commercial plantations in each province. Wherever physic nut flowers were observed, pollinators were caught using a sweep-net during the period 08.00-18.00 h from March 2012 to April 2013. All specimens were preserved and maintained in the laboratory at Kasetsart University, Bangkok.

Fluctuation in abundance of Dipteran pollinators

This experiment was set up in a physic nut plantation at the Suphan Buri location from June 2013 to May 2014. Numbers and species of fly pollinators were monitored and recorded. The sampling flower method followed Malaipan *et al*. (2007). Flower visitors were observed and recorded from 08.00-18.00 h. The duration of each transect observation was 10 minutes. Insect visitors on physic nut flowers were caught and identified. The diversity of fly pollinators (species list and abundance) were recorded.

Fly behavior

Two Dipteran pollinators *Eristalis obscuritarsis* De Meijere and *Chrysomya megacephala* F. were selected and observed on physic nut flowers throughout the day from 08.00 h till 18.00 h. during March 2013 till April 2014, using the following criteria: 1) for diurnal activity, the behavior of fly species visiting dioecious flowers was counted using the number of flowers during 10 minute intervals every hour; and 2) fly preferences for both fly species regarding male and female flowers were estimated from each 100 flowers. The sex ratios of physic nut flowers (male and female) were randomly counted and classified into type of flower; and 3) fly foraging rates for both flies species were observed and counted for male and female flowers in a 2-minute period (Dafni, 1992) during the flowering period (08.00-14.00 h). Data on *Eristalis obscuritarsis* and *C. megacephala* were recorded from 10 individuals of each species. All visited inflorescence was bagged again with thin paper until fruit setting and yellow fruit were visible, in order to prevent fruit spoiling by *Chrysocoris stolii* (Scutelleridae) (Inson and Malaipan, 2011)

Data analysis

The number of fly species per family was calculated and compared among the Diptera identified. Data on foraging time was subjected to statistical analysis using analysis of variance (ANOVA). Means were separated using Fisher's least significant difference (LSD) at P = 0.05. Statistical tests were conducted using the software package SPSS ver.19.0 (Statistical Package of Social Sciences, 2009).

RESULTS AND DISCUSSION

Diversity of Dipteran pollinators

In total, 491 individual fly pollinators belonging to 30 species, 22 genera and 12 families were recorded during the study period (Table 1). On the basis of number of collected species, the family Syrphidae was the most abundant with 8 species. The family Calliphoridae was the second most abundant with 6 species followed by the Asilidae, Stratiomyidae, Tabanidae, Tachinidae and Tephritidae (2 species each). The lowest number (only 1 species) belonged to the families Bombyliidae, Drosophilidae, Muscidae, Sarcophagidae, Therevidae and Tipulidae. The percentage contribution of the relative number of individuals and species of different families of fly pollinators collected from the study area are presented in Table

2. The family Calliphoridae comprised the highest number of individuals (57.84%) with the family Syrphidae contributing the second highest (24.03%), followed by the Tachinidae, Muscidae, Sarcophagidae, Asilidae, Bombyliidae, Stratiomyidae, Drosophilidae, Tephritidae, Therevidae and Tipulidae with 4.28, 3.87, 2.65, 2.04, 1.22, 1.02, 0.81, 0.41,0.41 and 0.20%, respectively, of the total collected fly pollinators. *Chrysomya megacephala* from the family Calliphoridae, was the most dominant species, representing 59.62% of the total individuals of this family, followed by *Stomorhina discolor*, *Chrysomya rufifacies*, *Stomorhina* sp. *Sibomyia* spp. and *Lucila sericata* with 24.30, 6.92, 5.28, 0.77 and 0.38%, respectively. *Eristalis obscuritarsis* was the most dominant species in the family Syrphidae, with 55.93% of the total individuals in this family, followed by *Eristalis arvorum*, *Helophilus bengalensis*, *Eristalis cearalis*, *Helophilus insignis* with 22.03, 13.56, 3.39 and 2.54% respectively. *Helophilus* sp., *Megapis* sp. and *Phytomia errans* had the lowest numbers with 0.85%.

The results of the current study were consistent with other reports which have recorded as many as 48 species of fly pollinators from 20 provinces in Thailand (Malaipan *et al*., 2002; Inson, and Malaipan, 2011). The large numbers may have resulted as the present study was undertaken during the flowering period when a diverse range of insect pollinators were abundant. Moreover, areas all over Thailand were surveyed, whereas only one species was recorded in India and Indonesia by Raju and Ezradanam (2002) and Rianti *et al*. (2010), respectively. This might have been because of fewer sampling sites. Furthermore, the present results showed that the two major fly species (*Eristalis obscuritarsis* and *Chrysomya megacephala*) were considered the most dominant species due to their frequent appearance. Malaipan *et al*. (2002) and Inson and Malaipan (2011) reported that flies (Diptera) such as Syrphids (*E. obscuritarsis*) and Calliphorids (*C. megacephala*) were the major group of insect pollinators on physic nut flowers in Thailand. Similar results were obtained by Alamu *et al*. (2013), Rianti *et al*. (2010) and Negussie *et al*. (2013) who reported that *Chrysomya choropyga* (Calliphoridae) and *Eristalis tenax* (Syrphidae) were prominent pollinators on physic nut flowers in Nigeria and Indonesia.

Table 1 Species list of Dipteran pollinators found on *Jatropha curcas* L. flowers in five regions of Thailand during March 2012–April 2013.

Family	Scientific name	C	N	NE	E	S	Total
Asilidae	*Proctacantella* sp.	-	1	1	-	-	2
	Promachus sp.	-	8	-	-	-	8
Bombyliidae	*Systropus* sp.	2	2	1	1	-	6
Calliphoridae	*Chrysomya megacephala* F.	90	47	15	-	-	155
	Chrysomya rufifacies (Macquart)	2	-	6	10	-	18
	Lucila sericata (Meigen)	1	-	-	-	-	1
	Sibomyia spp.	-	2	-	-	-	2
	Stomorhina discolor F.	44	42	3	4	-	93
	Stomorhina sp.	2	12	1	-	-	15
Drosophilidae	*Drosophila* sp.	3	0	-	1	-	4
Muscidae	*Musca domestica* L.	10	4	4	1	-	19
Sarcophagidae	*Parasarcophaga ruficornis* Thomson	2	7	2	2	-	13
Stratiomyidae	*Hermetia illucens* L.	1	-	1	1	-	3
	Stratiomys sp.	-	-	-	2	-	2
Syrphidae	*Eristalis obscuritarsis* De Meijere	33	20	12	1	-	66
	Eristalis arvorum F.	10	-	6	-	-	16
	Eristalis cearalis F.	-	2	1	-	-	3
	Phytomia errans F.	-	1	-	-	-	1
	Helophilus bengalensis Wiedemann	9	12	5	-	-	26
	Helophilus insignis Doleschall	1	1	1	-	1	4
	Helophilus sp.	-	1	-	-	-	1
	Megapis sp.	-	1	-	-	-	1
Tabanidae	*Chrysops dispar* F.	-	3	-	-	-	3
	Chrysops fasciata Wiedemann	-	2	1	-	-	3
Tachinidae	*Exorista xanthaspis* Wiedemann	1	12	1	-	1	15
	Argyrophylax nigrotibialis Baranoff	2	2	1	-	-	5
Tephritidae	*Bactrocera dorsalis* (Hendel)	-	-	1	-	-	1
	Bactrocera correcta (Bezzi)	-	-	-	1	-	1
Therevidae	*Pandivirilia* sp.	-	1	-	-	1	2
Tipulidae	*Tipula* sp.	1	1	-	-	-	2
Total		214	184	63	24	6	491
Mean		54	31	13	12	3	

Notes: C = Central region; N = North region; NE = Northeast region; E = East region; S = South region

Table 2 Percentage contribution of relative number of individuals and species of different families of fly pollinators found on physic nut flowers in Thailand from March 2012 to April 2013.

Family	Genus	Species	% of species	Total individuals	Individuals (%)
Asilidae	2	2	6.67	10	2.04
Bombyliidae	1	1	3.33	6	1.22
Calliphoridae	4	6	20.00	284	57.84
Drosophilidae	1	1	3.33	4	0.81
Muscidae	1	1	3.33	19	3.87
Stratiomyidae	2	2	6.67	5	1.02
Syrphidae	4	8	26.67	118	24.03
Sarcophagidae	1	1	3.33	13	2.65
Tabanidae	1	2	6.67	6	1.22
Tachinidae	2	2	6.67	21	4.28
Tephritidae	1	2	6.67	2	0.41
Therevidae	1	1	3.33	2	0.41
Tipulidae	1	1	3.33	1	0.20
Total	22	30	100	491	100

Fluctuation in abundance of Dipteran pollinators

The results from Figure 2 show the different abundance levels among the 10 species representing 6 families and 8 genera of Diptera which were recorded from June 2013 to May 2014 at the Suphan Buri location. Across all months, the highest abundance was in May (15.57%) followed by April (14.15%), March (13.68%), June (10.85%), September (10.38%), October (8.96%), November (7.08%), August (4.25%), December (3.77%), July (4.21%), February (3.30%), and January (2.36%), respectively. The diversity of fly pollinators was represented mainly with visits by the Calliphoridae (44.34%) followed by the Syrphidae (36.32%), Stratiomyidae (6.13%), Tachinidae (4.72%), Sarcophagidae (4.72%) and Muscidae (3.77%) respectively. The families Calliphoridae and Syrphidae were the most abundant of all collected individuals.

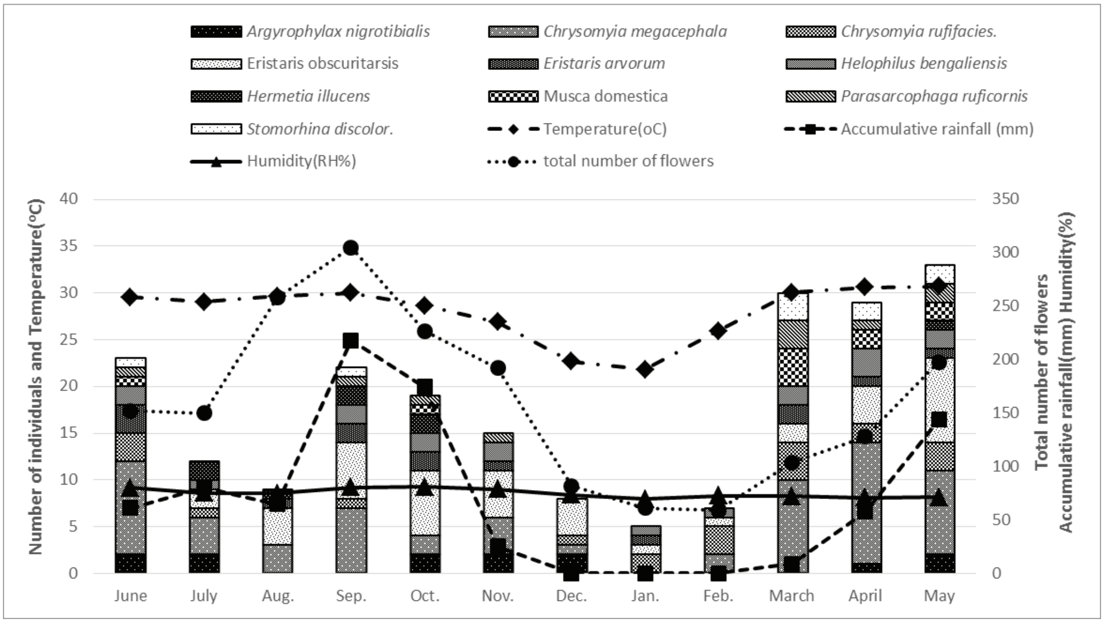

Figure 2 Abundance of 11 species of Dipterans on physic nut flowers and monthly rainfall, relative humidity and temperature from June 2013 to May 2014 in Supan Buri (Source: UThong Meteorological Station).

Visits by the family Calliphoridae occurred throughout the year. Abundance of the three most common species *Chrysomya megacephala* F. *Chrysomya rufifacies* (Macquart) and *Stomorhina discolor* F. occurred with a peak from March to May 2014. Similarly, Inson and Malaipan (2011) reported that *C. megacephala* was most abundant on physic nut flowers at a Kamphaengsean location, Thailand in May-June 2007. The family Syrphidae was also most abundant in March-May 2014. Among the Syphidae, *Eristalis obscuritarsis* De Meijere proved to be the most frequent floral visitor followed by *Helophilus bengalensis* Wiedemann and *Eristalis arvorum* F. The families Muscidae (*Musca domestica* L.) and Sarcophagidae (*Parasarcophaga ruficornis* Thomson) were most abundant in March and May. Of the Tachinidae, (*Argyrophylax nigrotibialis* F.) was most abundant in October and of the Stratiomyidae, (*Hermetia illucens* L.) was most abundant from September to October.

The abundance of fly species was related to the peak of natural and physic nut flowering during September to November 2013 (approximately during the rainy season) and from March to May 2014 (approximately during the hot season). However, there were lower numbers of flowers in the hot season than in the rainy season even though flies were abundant in both seasons, which seemed to be related to a lot of rotting food substrates including food waste, fish, meat and overripe fruit that rotted quickly in the hot season and most bacteria grow rapidly under conditions of high temperature and humidity. Thus, these influences resulted in high numbers of flies in these seasons. *Eristalis obscuritarsis* and *Chrysomya megacephala* were notable both by their predominance in the habitat and their frequency of visits to physic nut flowers. The vicinity of suitable habitat in such areas may support more frequent observation of the flies at this location.

Paddy fields may be suitable as a breeding ground for *Eristalis obscuritarsis*. The larva of these flies (rattail maggots) are scavengers feeding on organic matter from putrid water and the adult flies feed on nearby plant nectar of coat button (*Tridax procumbens* L.) flowers as this is a simple weed growing in the area and is an available food source for adult flies. The Suphan Buri location was located in an agricultural area with irrigated farmland where rice was cultivated 2-3 times per year. Thus, monthly fluctuations in the abundance of *E. obscuritarsis* were more related to the rice planting seasons. Paddy provided a wild habitat for *E. obscuritarsis* and these flies were abundant in October 2013 (first crop) and May 2014 (second crop). The larval growth stages were correlated to land preparation and transplanting periods when the whole field surface was covered with water, and manure and fertilizer were added to the soil. The level of water is maintained according to the rice growth stage. Presumably, these flies selected breeding sites when paddy fields were flooded but the populations decreased when the paddy fields were drained before harvesting.

Chrysomya megacephala, blow flies generally utilize garbage, decaying vegetable matter, dung material and castle manure for breeding sites. One location had a high number of blow flies because it was nearby a cattle pen which acted as a breeding site for these flies. Therefore, this external factor attracted a higher number of the flies so that they were present throughout the year. *Stomorhina discolor* adults have been habitually found on mango flowers but sometimes on physic nut flowers too. Nevertheless, there is limited information on the biology and ecology of this species.

Parasarcophaga ruficornis (Sarcophagidae), *Musca domestica* (Muscidae) and *Hermetia illucens* (Stratiomyidae) can lay eggs in feces, animal wounds and garbage but were only observed occasionally on flowers, and where these other resources were present nearby physic nut plantations. Wolda (1988) concluded that the population peaks of some pollinators are positively correlated with several factors other than climate that can influence the diversity of existing seasonal patterns, such as food abundance.

Activity of diurnal Dipteran pollinators

The abundance of Dipteran pollinators on physic nut flowers at the Suphan Buri location was mainly due to two fly species, *Eristalis obscuritarsis* and *Chrysomya megacephala* (Figure 3). Field observations were made during the blooming period in March 2013 and these species were recorded on physic nut flowers throughout the day from 08.00 h till 18.00 h. The diurnal abundance dynamics of flies had a peak in the population of *E. obscuritarsis* on male flowers during 08.00-10.00 h followed by a decline at noon and in the afternoon. Female flowers were visited by these flies mostly at noon and in the afternoon, peaking during 12.00-14.00 h and decreasing considerably afterward. The highest number of *C. megacephala* on male flowers occurred during 08.00-10.00 h and declined in the late morning. However, the peak time for visiting female flowers occurred during 16.00-18.00 h. with another minor peak during 10.00-12.00 h. These results were consistent with the findings of Alamu *et al.* (2013) who reported high activity in the morning and the afternoon for blow flies (*Chrysomya chloropyga*) on physic nuts flowers in Nigeria.

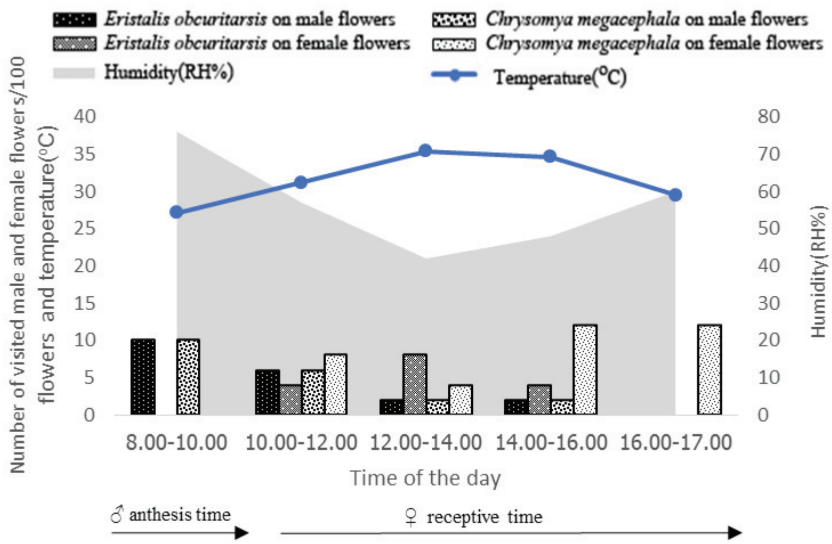

Figure 3 Diurnal activity pattern of *Eristalis obcuritarsis* and *Chrysomya megacephala* on 100 each of male and female flowers and individual visitors 08.00-18.00 h in March 2013 at Suphan Buri location.

The peak activity of fly pollinators was influenced by the nature of the bloom, possibly through anthesis and the receptive time including weather factors. Both flies species had peak male flower visitation usually in the morning probably because the anthesis time of the male flowers was during 08.30-9.30 h (Figure 3). These flies also foraged on male flowers soon after anther dehiscence and they preferred to feed on fresh pollen which might have influenced the timing of high foraging activity. In contrast, the flies visited female flowers mainly at noon and in the late afternoon which might have been associated with the receptive time of the female flowers occurring during 10.00-11.30 h (Figure 3). Moreover, the nectar concentration increased in the late afternoon which was when numbers of nectar foraging flies peaked. Similarly, Inson and Malaipan (2011) reported that the highest nectar concentration of physic nut flowers was found during 15.00-19.00 h. and the lowest was observed at 07.00-9.00 h in April based on the recorded nectar in the honey sacs of dwarf honey bees (*Apis florea*). Visitation by both species of flies corresponded with the high abundance of nectar secretion in the afternoon, but fewer individuals visited female flowers in the morning when there was less nectar.

Fly foraging preference

Fly preferences for floral sex characters were different between female and male flowers at the Suphan Buri location during 08.00-18.00 h on March 2013 as presented in Figure 4. Numbers of flower flies (*E. obscuritarsis*) and blow flies (*C. megacephala*) were significantly different for foragers on female and male flowers based on the 100 flower sample. The flower sex ratio (male: female) visited by *E. obscuritarsis* male and female flies was 1:5 and 1:1, respectively, whereas, the same ratio for *C. megacephala* was 1:8 and 1:2, respectively.

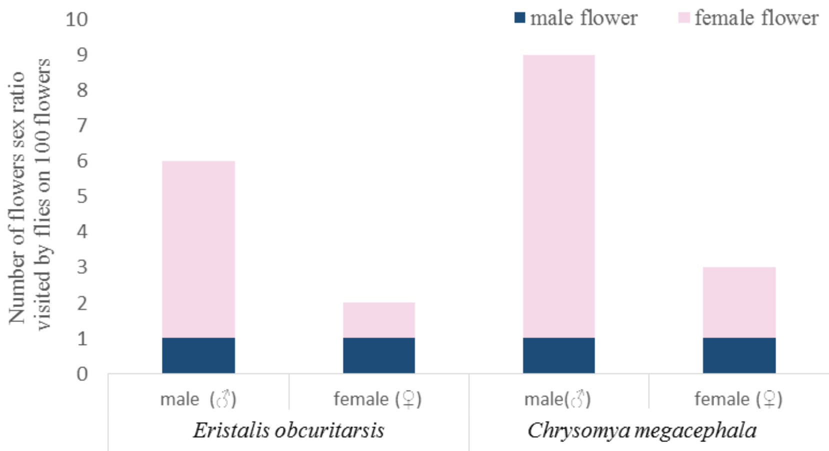

Figure 4 Floral sex characters influence on number of male and female fly foragers 08.00-14.00 h in March 2013 at Suphan Buri location.

The results showed that total visits were comparable to the proportion of male and female flowers of the physic nuts crop and that flies tended to showed a preference for female flowers. This was similar to the results reported by Inson and Malaipan (2011) that fly pollinators were observed on physic nut flowers only when gathering nectar. This finding is also consistent with Gilbert (1985) and Sajjad and Kown (2008) who stated that most flower flies and blow flies spent more time feeding on nectar. Contrariwise, Mazumdar *et al.* (2011) reported that flower flies were found mainly eating pollen probably due to the observation areas containing large numbers of male flowers in bloom. Therefore, fly pollinators seem to visit male flowers more frequently than female flowers because female flies need pollen as a protein source to develop their eggs (Gilbert, 1985), while male flies need more nectar as a carbohydrate source for their own energy needs mostly involving flying.

Eristalis obscuritarsis seemed to be a more efficient pollinator than *C megacephala* because the flowers of both sexes were visited equally by flies which were likely acting as pollinators. When flies walked on the inflorescence, their bodies always remained away from from the anthers, so that pollen grains might adhered to the bristles on the fly body or legs. During foraging activity, pollen grains were transferred to stigmas (Negussie *et al*., 2013). Alamu *et al.* (2013) concluded that the flower fly (*Eristalis tenax*) and blow fly (*Chrysomya chloropyga*) can easily move among flowers within the same tree and other trees which may result in effective pollination and a high yield of physic nut fruit.

Fly foraging rate

The fly foraging rates were studied for different flowers visited by flies of both sexes. Overall flies visited female flowers for a shorter duration than male flowers. The time spent by *E. obscuritarsis* on male flowers was significantly different by sex (male 1.46 and female 8.08 flowers/2 minutes), and similarly on female flowers, female *E. obscuritarsis* had a higher fly foraging rate (2.5 flowers/2 minutes compared to the male rate of 1.76). On average, both sexes of *C. megacephala* had similar foraging rates for female and male flowers (Table 3, Figure 5).

Table 3 Fly foraging rates on male and female flowers of physic nuts/2 minute during 8.00-14.00 h on March 2013 at Supan Buri location.

	Eristalis obscuritarsis		*Chrysomya megacephala*	
Number of flowers/ minute	female (♀)	Male (♂)	Female (♀)	Male (♂)
on male flowers	2.5[b]	1.46 [cd]	0.82[d]	0.92[d]
on female flowers	8.08[a]	1.76[bc]	1.62[cd]	1.42[cd]

The number of flowers visited was significantly different for male and females of fly species (df= 39, p=0.05).

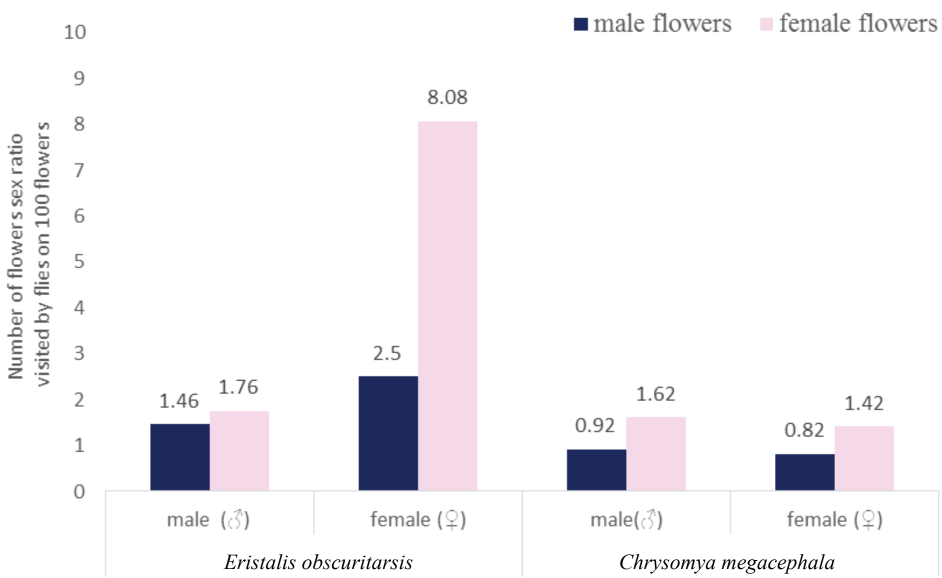

Figure 5 Number physic nuts flowers in 2 minutes visited by an individual fly 08.00-14.00 h. in March 2013 at Suphan Buri location.

The result revealed that *E. obscuritarsis* was the most effective fly pollinator of physic nuts due to its high foraging rates, especially for the female fly, compared with *C. megacephala* which had lower foraging rates. From observation *C. megacephala* spent a longer period on a flower, mostly resting and grooming rather than actively feeding. Similar results were also observed by Alamu *et al*. (2013) who reported that blow flies (*Chysomya choropyga*) spent most of the time foraging within physic nuts flowers on the same inflorescence. However, flower visit frequencies tended to be higher for females, indicating a somewhat higher energy intake efficacy and a higher probability of females acting as pollinators.

CONCLUSION

There were two peaks of fly pollination from March to May and from September to October at the Supan Buri location which correlated with flooding in paddy fields, rainfall and the flowering periods of physic nut and weeds. Two main Dipteran flies *Eristalis obscuritarsis* and *Chrysomya megacephala* were most abundant in the morning and numbers declined in the late afternoon on male flowers, whereas on female flowers the fly population peaked in the afternoon. Both flies tended to show a higher preference for female flowers. *Eristalis obscuritarsis* visited both male and female flowers in equal proportions, whereas the female flies of *C. megacephala* preferred female flowers more than twice as much as male flowers and male flies preferred female flowers more than eight times as much as male flowers. Overall, both flies spent less time per visit on female flowers than on male flowers. The foraging rate on female flowers by *E. obscuritarsis* was the most active which indicated that flower flies (*E. obscuritarsis*) and blow flies (*C. megacephala*) could become alternative insect pollinators for physic nuts to enhance the crop yield. In particular, in some areas under certain conditions these flies could play a critical role where there was failed insect pollination due to insufficient honey bees and stingless bees, resulting in low fruit setting. Flies can be used as alternate pollinators instead of honey bees and stingless bees in plantations. Furthermore, it is easy to do mass rearing of the flies for their introduction into physic nut plantation to act as pollinators.

ACKNOWLEDGEMENTS

This work was financially supported by the Promotion of Kasetsart University Research and Development Institute and KU Biodiesel Project.

REFERENCES

Alamu, O. T., A. O. Amao, O. A. Oke and R. A. Suleiman. 2013. Foraging behavior of three insect pollinators of *Jatropha curcas* in Samaru - Zaria, Nigeria. **IJAAR** (1): 87-91.

Albano, S., E. Salvado, S. Duarte, A. Mexia and P.A.V. Borges. 2009. Pollination effectiveness of different strawberry floral visitors in Ribatejo, Portugal: Selection of potential pollinators. Part 2. **Adv. Hort. Sci.** 23(4): 246-253.

Bhattacharya, A., K. Datta and S. K. Datta. 2005. Floral biology, floral resource constraints and pollination limitation in *Jatropha curcas* L. **Pak. J. Biol. Sci.** 8 (3): 456-460.

Chang-wei, L., L. Kun, C. You and S. Yongyu. 2007. Floral display and breeding system of *Jatropha curcas* L. **For. Stud. China.** 9 (2): 114-119.

Dafni, A. 1992. **Pollination Ecology: A Practical Approach.** Oxford University Press, New York 6 (5): 776.

Girlbert, S. 1985. Diurnal activity patterns in hoverflies (Diptera, Syrphidae). **Ecol. Entomol.** 10: 385-392.

Inson, C. and S. Malaipan. 2011. Diversity of Bees (Hymenoptera: Apoidea) as insect pollinators on Physic nuts (Euphorbiaceae: *Jatropha curcas* L.) in Thailand. **Thai J. Agric. Sci.** 44 (4): 263-269.

Jarlan, A., D. D. Oliveira and J. Gingras. 1997. Pollination by *Eristalis tenax* (Diptera: Syrphidae) and seed set of Greenhouse sweet Pepper. **J. Econ. Entomol.** 90 (6): 1646-1649.

Kwaiser, K. S. and S. Hendrix. 2008. Diversity and abundance of bees (Hymenoptera: Apiforms) in native and ruderal grasslands of agriculturally dominated landscapes. **Agric. Ecosyst. Environ.** 124: 200-204.

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. *In* **Proceeding of The 1st Meeting of Jatropha curcas L.**, Thailand.

_____. 2007. Some factors effected to pollen germination of physic nut (*Jatropha curcas* L.) and insect pollinators, pp. 618-626. *In* **Proceedings of 46th Kasetsart University Annual Conference: Plants.** 29 January-1 February 2007, Kasetsart University, Bangkok.

Mazumdar, S., B.A. Bhuiya and M.K. Pasha. 2011. Pollinating True Flies (Insecta: Diptara) and their foraging behaviour on seasonal crops of Bangladesh. **J. Taxon. Biodiv. Res.** 5: 5-8.

Mohammad Siddique, M., R. Shazia, N. Shahid and S. Ghulam. 2011. Comparative Periformance of Honey Bees (*Apis mellifera* L.) and Blow Flies (*Phormia terronovae*) in Onion (*Allium cepa* L.) Seed Setting. **J. Agric. Res.** 49 (1): 49-56.

Negussie, A., M.J. Wouter Achten, A.F. Hans Verboven, M. Hermy and B. Muys. 2013. Potential Pollinators and Floral Visitors of Introduced tropical Biofuel Tree Species *Jatropha curcas* L. (Euphorbiaceae), In Southern Africa. **African Crop Science Journal** 21 (2): 133-141.

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

Rianti, P., B. Suryobroto and T. Atmowidi. 2010. Diversity and effectiveness of insect pollinators of *Jatropha curcas* L. (Euphorbiaceae). **HAYATI J. Biosci.** 19 (1): 38-42.

Sajjad, A and J. Y. Kown. 2008. Fidelity of hymenoptera and Diptera pollinators in onion (*Allium cepa* L.) **Pollination Entomol. Res.** 38 (4): 276-280.

Statistical Package of Social Sciences. 2009. **SPSS for Windows. User's guide: Statistics version 21.** SPSS Inc. Chicago, IL, USA.

Tasen, W. and W. Sittichaya. 2014. Relationships Among Insect Pollinators, Micro-environmental Factors and Fruit Settings of Teak (*Tectona grandis* L.F.) in Seed Orchards in Thailand. **Thai J. For.** 33 (3): 96-108.

UThong Meteorological Station. 2014. **Annual Weather Summary.** Available Source: http://www.tmd.go.th/en/downloads.php, July 16, 2015.

Wolda, H. 1988. Insect seasonality why. **Annual Review of Ecology and Systematics.** 19: 1-18.