Trends in Entomology
Vol. 8, 2012

Original Communication

Composition of insect visitors in apple crop in Malang and Batu, East Java, Indonesia

Amin Setyo Leksono[1,2,*], Bagyo Yanuwiadi[1,2], M. Asmuni Hasyim[1], Budi Purwantiningsih[2] and Frank Leonardo Apituley[2]

[1]Department of Biology, Faculty of Mathematic and Natural Sciences, [2]Graduate Program, University of Brawijaya, Jl. Veteran Malang, 65145, Indonesia

ABSTRACT

The objective of this study is to analyze composition of insect visitors in canopy of apple trees in correlation with environmental factors in Poncokusomo (Malang) and in Bumiaji (Batu), East Java. This research was conducted on July to October 2011. The insects were observed by visual observation conducted on 5 apple trees. Those observation efforts were repeated four times in flowering season and fruiting season of the apple respectively. Overall, 2258 individuals were observed visually in Malang and 485 individuals were found in Batu. Pompilidae, Dolichopodidae, and Culicidae were dominant in the samples from Poncokusumo, Malang composing about 44% individual in flowering season, and 55% in fruiting season. Whereas, Drosophilidae, Ichneumonidae and Syrphidae were dominant in Bumiaji samples composing about 63% individual in flowering season and 88% in fruiting season. This study indicates the abundance and diversity of insect visitors to apple canopy in Malang were higher than those in Batu. The composition of insect visitors in apple crop is affected by study site and seasonal flowering phenology. The abundance and diversity of insect visitors were greater in flowering season in both locations. The peak of insect visitor abundance occurred in the morning, mostly during second period (09.00-10.15).

KEYWORDS: apple tree, insect visitor composition, pollinator, temporal variation, visual observation

INTRODUCTION

Studies about pollination system have increased recently because global pollinator decline [1, 2, 3, 4]. In most of those studies, pollinator assemblages were studied in relation with flower trait and flower phenology especially in savannas and herbaceous plant [4, 5] as well as woody species in natural ecosystem [6]. Other studies have concerned to the advantages of the provision of pollination services by a suite of unmanaged pollinators [7, 8, 9].

Recent studies have demonstrated that most of the plant species are pollinated by diverse pollinators [10, 11, 12, 13]. Several researches showed that many agricultural crops and natural plant populations are dependent on the services provided by wild, unmanaged, pollinator communities [14, 15]. However, study of pollinators in cultivation trees especially in apple crop is few [16, 17].

Apple is the major fruit of the region in Malang and Batu, accounting for 92% of total fruit production. However, during the last four years, the production of apple fruits per tree stand has decreased 2% per year in spite of increased effort

*Corresponding author: Dr. Amin Setyo Leksono, Jurusan Biologi, FMIPA, Universitas Brawijaya, Jl. Veteran, Malang, Jawa Timur, 65145, Indonesia.
amin28@ub.ac.id

to apple cultivation [18]. Recently, efforts to search other possible strategy for increasing apple production in this region have become concerted, and data of insect visitor compositions, including pollinators, are substantial for management plan. However, local-scale data of canopy insects in these areas is insufficient. The objective of this study is to analyze composition of insect visitors in canopy of apple trees in correlation with environmental factors in Poncokusomo (Malang) and in Bumiaji (Batu), East Java.

MATERIALS AND METHODS

The study was carried out in two study sites, located in Poncokusumo, Malang (7°87'S and 112°52'E, 800 m in altitude) and Batu, East Java (8°05'S, 112°80'E, 950 m in altitude) on July - October 2011. Apple (*Malus sylverstris*) is the most important crop in these areas. In each study site, samplings were established based on visual observation. To calculate insect visitor abundance per number of open flowers, five observations were established per field, four at the corners and one in the center of the field. Observations of floral visitors were made by walking around the trees and recording all insect families and abundances during a 15-min period. When species identity was not determined at the time of observation, specimens were collected and taken back to the laboratory for identification. The insect collections from each sampling unit were sorted and identified into families based on standard identification [19]. It took approximately 1 hour and 15 minutes to complete observations in all five trees within one period. All five trees in each field were observed for four observation periods throughout the day, (07.00-08.15; 09.00-10.15; 12.00-13.15; and 15.00-16.15). The sampling efforts were repeated four times in each seasonal flowering phenology. The differences in the abundance and diversity were analyzed by using general linear model analysis of variance (ANOVA) with sites (Malang and Batu), seasonal flowering phenology (flowering season and fruiting season) and time (observation periods) as between-subject factors and sampling dates as a within-subject factor. The number of individuals was considered normal because number of observations was large. The tests were performed using SPSS® version 13 (SPSS Inc. Chicago, IL, USA), and the F-statistic test was considered significant. The flower visitor compositions in all locations were compared by using the Bray-Curtis percent similarity those calculated for all captured, followed by un-weighted pair-group method using arithmetic average (UPGMA) cluster analysis. Canonical correspondence analysis (CCA) was applied to analyze the relationship between the abundance of family and environmental variables (location, number of flower or fruit (resource abundance), phenology, period, temperature, humidity, and light intensity) using the CANOCO version 4.5 (Biometris, Wageningen University and Research Centre, Wageningen, The Netherlands). All factors were coded as categorical variables. Rare families (less than 10 individuals) were excluded from analysis. The families and environmental factors were clustered by k-means clustering [20].

RESULTS

There were 2258 individuals observed visually in Malang and 485 individuals were found in Batu. Overall the samples showed that apple flowers were visited by 39 families of insects belonging to 7 orders, while apple fruits were visited by 24 families belonging to 7 orders. The abundance and diversity of insect visitors varied between location, seasonal phenology of flowering and observation time. This study showed that the abundance of insect visitors of canopy apple was highest in blossom season in Poncokusumo, Malang (17.20 ± 1.13), while the lowest was observed in fruiting season in Bumiaji, Batu (1.51 ± 0.12). The diversity was also higher found in Malang (2.67 ± 0.07) than that in Batu (0.87 ± 0.06). Overall, Pompilidae, Dolichopodidae, and Culicidae were dominant in the samples from Poncokusumo composing about 44% individual in flowering season, and 55% in fruiting season. (Table 1). Whereas, Drosophilidae, Ichneumonidae and Syrphidae (e.g. *Episyrphus* sp., *Syrphus* sp., and *Ischidion* sp.) were dominant in Bumiaji samples composing about 63% individual in flowering season and 88% in fruiting season. Bee species (*Apis mellifera*) was found restricted in blossom season in both locations. It was at low abundance composing about 3% in Malang and 18% in Batu (Table 1).

Table 1. Mean of dominant groups of insect visitors (abundances ± SE) (%) in Malang and Batu observed in blossom season and fruiting season.

No	Groups	Locations			
		Malang		Batu	
		Blossom season	Fruiting season	Blossom season	Fruiting season
1	Culicidae	2.28 ± 0.18 (13)	1.30 ± 0.10 (12)	0 (0)	0 (0)
2	Pompilidae	2.14 ± 0.22 (12)	1.74 ± 0.14 (16)	0 (0)	0 (0)
3	Dolichopodidae	1.90 ± 0.21 (11)	1.74 ± 0.14 (16)	0 (0)	0 (0)
4	Chloropidae	1.29 ± 0.13 (7)	1.16 ± 0.11 (11)	0 (0)	0 (0)
5	Simuliidae	1.20 ± 0.17 (7)	1.03 ± 0.11 (9)	0.05 ± 0.03 (1)	0.06 ± 0.03 (4)
6	Drosophilidae	1.06 ± 0.11 (6)	0 (0)	0.55 ± 0.08 (12)	0.36 ± 0.08 (24)
7	Syrphidae (*Episyrphus* sp., *Syrphus* sp., and *Ischidion* sp.).	0.30 ± 0.06 (1)	0 (0)	1.26 ± 0.11 (28)	0.36 ± 0.07 (24)
8	Cicadellidae	0.76 ± 0.10 (4)	0.50 ± 0.09 (4)	0 (0)	0 (0)
9	Formicidae	0.74 ± 0.12 (4)	0.73 ± 0.09 (5)	0 (0)	0 (0)
10	Ichneumonidae	0.66 ± 0.09 (3)	0.81 ± 0.09 (5)	0.79 ± 0.10 (17)	0.60 ± 0.09 (40)
11	Vespidae	0.61 ± 0.10 (3)	0.49 ± 0.07 (4)	0.09 ± 0.03 (2)	0.03 ± 0.02 (1)
12	Coccinellidae	0.58 ± 0.09 (3)	0.60 ± 0.10 (5)	0 (0)	0 (0)
13	*Apis mellifera*	0.48 ± 0.08 (3)	0 (0)	0.81 ± 0.12 (18)	0 (0)
14	Danaidae	0.19 ± 0.05 (1)	0 (0)	0 (0)	0 (0)
15	Papillionidae	0.08 ± 0.05 (0.5)	0 (0)	0 (0)	0 (0)
16	Miscellenies	2.95 ± 0.32 (20)	0.94 ± 0.14 (25)	1.01 ± 0.10 (2)	0.10 ± 0.03 (7)
	Total	17.20 ± 1.13	11.03 ± 0.65	4.51 ± 0.20	1.51 ± 0.12

Statistical analysis of variance showed that the abundance (F = 767.38; P<0.001) and diversity (F = 17.6; P<0.001) of apple visiting insect were significantly higher in Poncokusumo, Malang. Sampling time had a significant effect to many groups. The abundances of most taxa were also significantly higher in Poncokusumo, Malang. These included several dominant groups such as Pompilidae, Dolichopodidae, Culicidae and Chloropidae. Interestingly, the abundance of some families such as Drossophilidae, Apidae, Ichneumonidae and Papilionidae was not significantly different between locations (Table 2).

In Figure 1, the insect visitors were grouped according to their sites. Family similarity was greater between the insect visitor compositions in blossom season and fruiting season in Malang. Branching of four insect visitor compositions in apple crop from Poncokusumo, Malang occurred at 75.8%, while those from Bumiaji, Batu occurred at 48.5%. Both compositions from two locations had 18.5% similarity (Figure 1).

Canonical Correspondence Analysis revealed that the environmental variables were significant to explain the variance in family abundance pattern.

Table 2. Summary of F values followed by degree of significance using General Linear Model repeated-measure analysis of variance (ANOVA) of the abundance and diversity of several insect visitor orders/ families.

Group	Location (L)	Season (S)	Time period (T)	L*S	L*T	S*T	L*S*T
Abundance	767.4^{***}	93.6^{***}	131.1^{***}	81.6^{***}	15.7^{***}	9.3^{***}	6.41^{***}
Diversity	17.6^{***}	1.1^{ns}	1^{ns}	0.5^{ns}	0.1^{ns}	0.1^{ns}	0.13^{ns}
Coleoptera	19.8^{***}	0^{ns}	3.2^{*}	0^{ns}	3.2^{*}	0.1^{ns}	0.06^{ns}
Coccinellidae	15.7^{***}	0^{ns}	2.3^{ns}	0^{ns}	2.3^{ns}	0.06^{ns}	0.06^{ns}
Diptera	527.8^{***}	86.7^{***}	66.9^{***}	30.5^{***}	73.9^{***}	5.21^{**}	5.94^{***}
Chloropidae	64.4^{***}	0.2^{ns}	4.3^{**}	0.2^{ns}	4.3^{**}	0.06^{ns}	0.06^{ns}
Culicidae	145.2^{***}	11.2^{***}	10.8^{**}	11.3^{***}	10.8^{**}	0.82^{ns}	0.82^{ns}
Dolichopodidae	138.1^{***}	0.3^{ns}	12.1^{***}	0.3^{ns}	12.1^{***}	0.17^{ns}	0.17^{ns}
Drosophilidae	0.2^{ns}	16.6^{***}	0.3^{ns}	8.1^{**}	2.1^{ns}	0.72^{ns}	1.07^{ns}
Simuliidae	55.1^{***}	0.2^{ns}	5.9^{***}	0.7^{ns}	6.1^{ns}	0.14^{ns}	0.19^{ns}
Syrphidae	18.8^{***}	15.4^{***}	0.3^{ns}	3.9^{ns}	0.2^{ns}	0.39^{ns}	0.33^{ns}
Hemiptera	11.4^{***}	1.1^{ns}	2.2^{ns}	1.1^{ns}	2.2^{ns}	0.71^{ns}	0.71^{ns}
Homoptera	20.9^{***}	0.7^{ns}	2.8^{*}	1.7^{ns}	3.2^{*}	2.74^{*}	2.73^{*}
Cicadellidae	20.6^{***}	0.9^{ns}	2.7^{*}	0.9^{ns}	2.7^{*}	2.08^{ns}	2.08^{ns}
Hymenoptera	191.7^{***}	19.6^{***}	37.7^{***}	0.2^{ns}	29.4^{***}	0.87^{ns}	0.23^{ns}
Apis sp.	1.9^{ns}	27^{***}	2.4^{ns}	1.9^{ns}	0.6^{ns}	2.44^{ns}	0.59^{ns}
Ichneumonidae	0.1^{ns}	0^{ns}	1.6^{ns}	1.1^{ns}	2.7^{*}	0.69^{ns}	0.34^{ns}
Pompilidae	142.3^{***}	1.5^{ns}	10.7^{***}	1.5^{ns}	10.7^{***}	0.11^{ns}	0.11^{ns}
Vespidae	12^{***}	0.4^{ns}	2.6^{ns}	0^{ns}	1.4^{ns}	0.15^{ns}	0.14^{ns}
Lepidoptera	5.2^{*}	21.22^{***}	3.2^{*}	2.5^{ns}	0.6^{ns}	1.37^{ns}	1.13^{ns}
Papilionidae	0.1^{ns}	0.1^{ns}	0^{ns}	0.1^{ns}	0^{ns}	0.03^{ns}	0.03^{ns}

Note: * = P<0.05, ** = P<0.01, *** = P<0.001, ns = not significant.

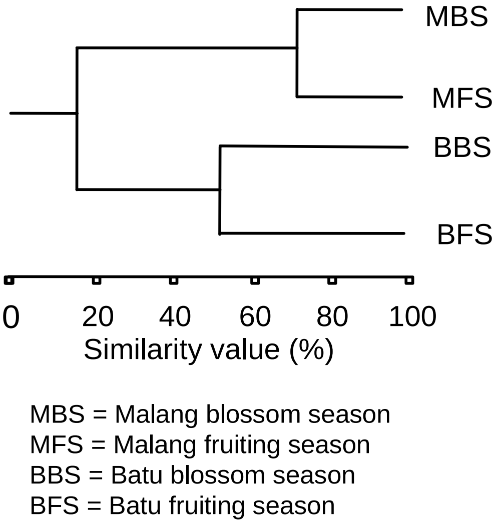

Figure 1. Dendogram showing similarity among compositions of insect visitor in Poncokusumo, Malang and Bumiaji, Batu.

The sum of the first two canonical eigenvalues was 0.69. The first axis, with a correlation of 0.99 between family and environmental factor, explained 68.6% of the family-environment relations and 35.8% of family variation. The second axis showed a 0.82 family-environment correlation, and cumulative with the first axis explained 80.6% of the family-environment relations and 42.1% of family variation. The site (λ = 0.58, F = 33.75, P<0.01), period (λ = 0.09, F = 6.19, P<0.01), and flower phenology (λ = 0.09, F = 5.92, P<0.01) explained significantly to the variation in family composition while layer and season were not significant. Variation in the abundance between study sites seemed to associate with sampling time, phenology or light intensity. Furthermore, association between period and resource abundance and temperature was recorded.

The score of the CCA are plotted for families in Figure 2. This figure showed the classification of the families into four groups. Group I was more abundant in Malang and include Syrphidae and Ichneumonidae. Group II was highly abundant in flowering season and includes Apidae and Drossophilidae. Group III was comprised of dominant families found specifically in Malang and includes several flies belonging to Chloropidae, Culicidae, Dolichopodidae, Pompilidae and Simuliidae. Group IV included many of less abundant families which were mostly found in Malang, and more abundant in flowering season. This group includes Cicadellidae, Nymphalidae, Asilidae, Coccinellidae, Danaidae, Formicidae, Papillionidae, Vespidae, Muscidae, Pentatomidae and Sarcophagidae.

The number of individual of Diptera, Hymenoptera and Lepidoptera showed seasonal variation between blossoming season and fruiting season. In the first group, the effect of flowering season was significant for mosquitoes and flies belonging to Culicidae (F = 11.26, P<0.001), Drosophilidae (F = 16.58, P<0.001) and Syrphidae (F = 15.45, P<0.001) (Table 2). Among the hymenopteran groups, Apidae were appeared restrict in flowering season. Similar situation was observed on the temporal variation of Diptera and Hymenoptera. The abundance of several dipteran groups, such as Chloropidae, Culicidae, Dolichopodidae and Simuliidae were significantly different among observation time. All of these families were peaked in second period (09.00 - 10.15) resulting the highest abundance in this period (Figure 3).

The abundance of all samples and dipteran group varied between locations associated with season and observation time. Association effect between location and observation time was found in Homoptera and Hymenoptera (Table 2).

The mean abundance of insect visitor in Malang increased from 07.00 to 10.15, and then decreased in the afternoon. In this location, the highest mean of the insect abundance occurred in the second period (09.00-10.15). This situation was consistently in flowering season (143 ± 4.7) and fruiting season (84.5 ± 3.07). The mean of abundance of insect visitor in Batu decreased from the first to the last period. This situation was not consistent with that observed in fruiting season. In the latter season, the abundance of the insects fluctuated from first period to the last period. That slightly increased from 07.00-08.15 (7.75 ± 1.46) to 09.00-10.15 (9.25 ± 2.10) than decreased substantially in the 12.00-13.15 (4.25 ± 1.13) and increased again in the last period (9.00 ± 1.23) (Figure 3).

In Malang the diversity of insect visitor tended to increase from 07.00-08.15 and peaked in 09.00-10.15, then decrease in afternoon. This situation

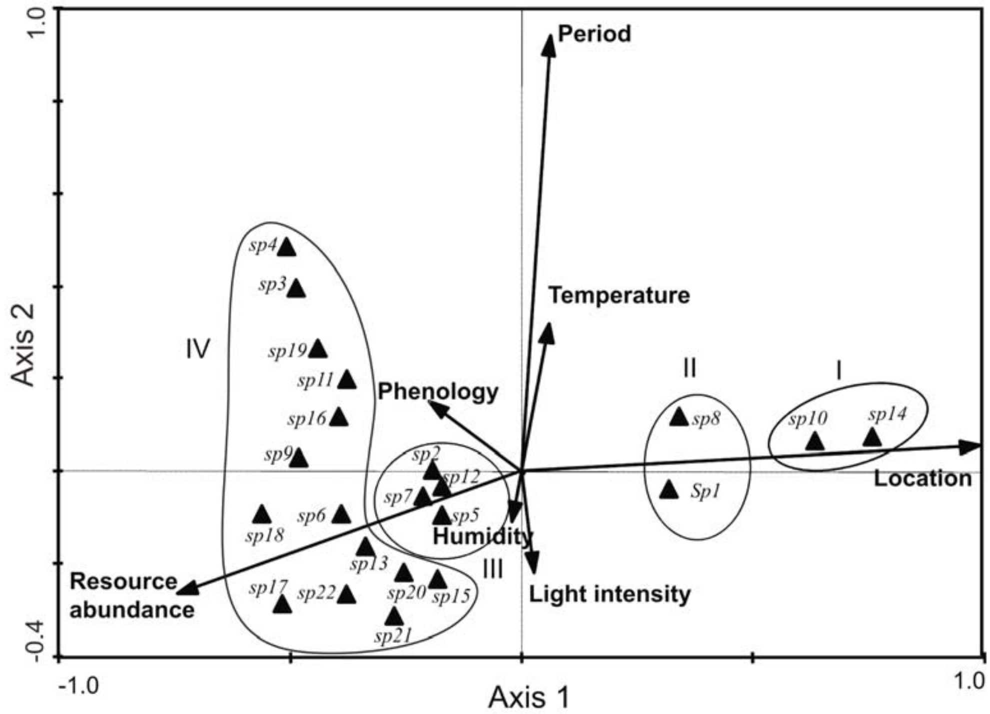

Figure 2. Ordination of family compositions responding to environment factors: arrows represent degree of environmental variable. The numbers of families enclosed were grouped by k-means clustering. Numbers in family score are as follows: sp1. Apidae, sp2. Chloropidae, sp3. Cicadellidae, sp4. Coccinellidae, sp5. Culicidae, sp6. Danaidae, sp7. Dolichopodidae, sp8. Drosophillidae, sp9. Formicidae, sp10. Ichneumonidae, sp11. Papillionidae, sp12. Pompilidae, sp13. Simuliidae, sp14. Syrphidae, sp15. Vespidae, sp16. Amatidae, sp17. Asilidae, sp18. Muscidae, sp19. Pentatomidae, sp20. Sarcophagidae, sp21. Tabanidae and sp22. Tephritidae.

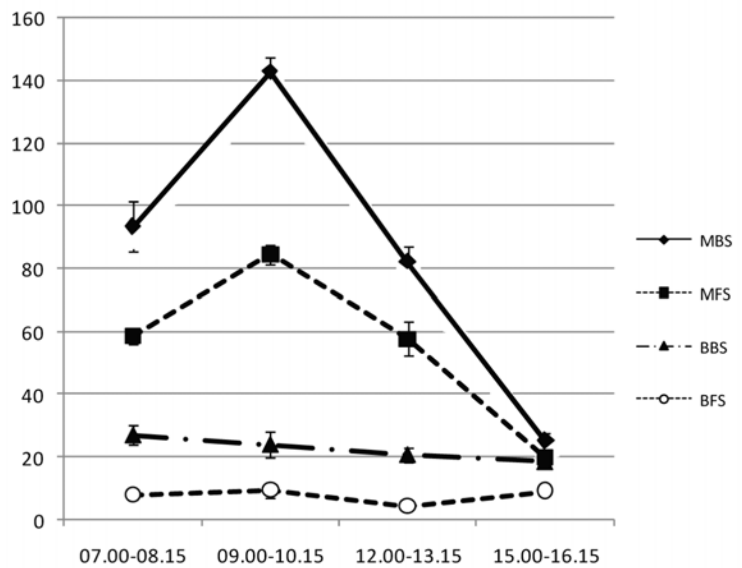

Figure 3. The mean of abundance (± SE) of insect visitors in canopy of apple in Poncokusumo, Malang and Bumiaji, Batu. MBS (Malang blossom season), MFS (Malang fruiting season), BBS (Batu blossom season), and BFS (Batu fruiting season).

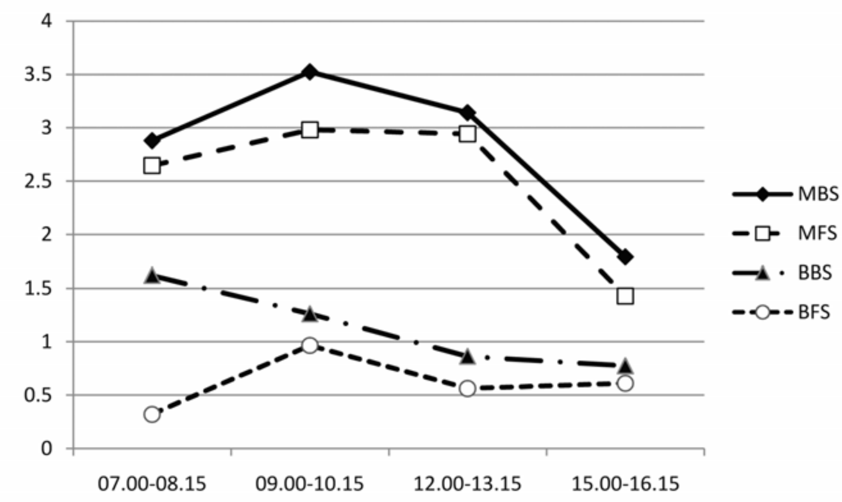

Figure 4. The diversity of insect visitors in canopy of apple in Poncokusumo, Malang and Bumiaji, Batu. MBS (Malang blossom season), MFS (Malang fruiting season), BBS (Batu blossom season), and BFS (Batu fruiting season).

was consistent in flowering season (3.52) and fruiting season (2.98). In Batu, insect diversity observed in flowering season decreased from the 07.00-08.15 (1.62) to the 15.00-16.15 (0.77). This situation was not consistent with that observed in fruiting season. In the latter season, the abundance of the insects fluctuated from first period to the last period. This fluctuation peaked in 09.00-10.15 (0.97) (Figure 4).

DISCUSSION

In all study sites, pollinators such as Pompilidae, Dolichopodidae, Culicidae, Drosophilidae, Ichneumonidae and Syrphidae were dominant. Other study reported that Apidae, Vespidae, Halictidae, Andrenidae, Formicidae, Pteromalidae Syrphidae, Cordiluridae, Calliphoridae and Dolichopodidae were common pollinators of apple crop. Among those groups, Syrphidae and Apidae are the most effective pollinators [17]. The flies belonging to Diptera were reported to have a role as important pollinators in some other entomophilous plants in the tropical forests [7]. High number of insect visitor families indicated a better process of pollination in apple tree in the study sites.

This study showed that the effect of apple cultivation to the abundance and diversity of insect visitors was consistent. The abundance and diversity were high in Poncokusumo, Malang than those in Bumiaji, Batu. The high abundance of insect visitors on apple crop in our research is associated with seasonal phenology and sampling time. This tended to increase in flowering season and in second period. Besides these variables, other factors may affect the abundance of insect visitors. It is reported that occurrence of insect visitors was influenced by food, shelter, absence of natural enemies and environmental factors [3]. It implies that the effect of apple cultivation system to insect visitor diversity was substantial in Batu. In our previous study, there was high intensification of apple farming in Batu which alter the soil quality and soil arthropod composition [18]. It was clear that intensification associated with modern agriculture created poorer habitat in the farms for number of pollinators, and many agricultural practices affected directly or indirectly to pollinator populations [21]. Honey bees are considered the susceptible groups to intensification practice of apple farming such as application of pesticides. This study found that the abundance of the bees between study sites was very low compare to other studies [9, 17]. In our study, percentage of bees was 2.7% in Malang and 18% in Batu. *Apis* sp. is among the most important pollinator species. Bees and other insect pollinators are necessary for the successful reproduction of most species of flowering plants, including agricultural crops [9, 22]. Low number of bees may affect the reproduction success to the crop. In other cases, however, the role of unmanaged pollinators was important to act as crop pollinators [8, 23, 24]. Several studies showed the potential for this role is substantially required when the abundance of bees declining.

There is a tendency that the abundance and diversity of the insect visitor decreased in fruiting season. This indicates that the abundance and diversity of canopy insect in the flowering season associate with blooming of the apple flower. A study stated that differences in abundance of insect such as beetles between the wet and dry seasons may be explained by seasonal variation of food availability [25]. Several groups such as *Apis mellifera*, Sarcophagidae and many Lepidopteran groups appeared specifically in flowering season. Variation in abundance is common in relation to seasonal fluctuation. Apidae such as honey bees were reported to peak in April, wild bees from April to July, beetles from May to July, and ants from May to September [26].

There is a temporal variation in the abundance and diversity of insect visits on the blossom. More number of insects visited the flower during late morning hours (09.00-10.15) followed by a sharp decline in the afternoon. In this study, variation in the abundance and diversity associated with resource abundance and temperature. Several insects showed to have seasonal pattern in the abundance such as *Apis mellifera*, mosquitoes, *Drosophila* sp., *Episyrphus* sp., *Syrphus* sp., and *Ischidion* sp. The peak of foraging activities of *A. mellifera* was between 11.00 h and 13.20 h with a temperature range from 21 to 25ºC, and that of *A. cerana* was between 09.00 h and 13.00 h with a temperature range of 15.5 to 21ºC [27]. Similar visitation was shown by two species of pollinators *Trigona carbonari* and *Leioproctus speculiferus* visited on *Persoonia virgata* (Proteaceae) occurred before 12.00 h [28]. Other study also showed the most favorable range of temperature has been 25ºC to 35ºC for the visits of pollinators on the blossom of *Z. mauritiana* [29]. The high abundance and diversity of insect visitors may associate with peak of nectar production in the morning and other environmental factors. Temperature can have considerable influence on pollinator systems, both by affecting the activity of insects or by altering the nectar production [22]. This study implies that insect activity initiation is limited by temperature, and activity termination is determined either by a decline in light intensity or possibly, by a decline in resource availability such as pollen-nectar.

CONCLUSION

This study indicates that the abundance and diversity of insect visitors in Malang were higher than those in Batu. Composition of insect visitors in apple crop is affected by study site and seasonal flowering phenology. The insect visitor abundance and diversity were greater in flowering season in both locations. The insect visitor abundance and diversity were peaked in late morning (09.00-10.15). To optimize pollination services, we recommend farm management practices that consider the needs of both managed and unmanaged pollinator taxa such as using ground-cover plant as pollinator alternative habitat.

ACKNOWLEDGEMENT

The author would like to thank Head of Research and Public Service Institute, University of Brawijaya. We are grateful to Dean of Faculty of Mathematic and Natural Sciences, Head of Department of Biology, and local farmers in both study sites. This project was supported by the Fundamental Research Grant, Directorate of Research and Public Service, Directorate General of Higher Education, Ministry of National Education.

REFERENCES

1. Aizen, M. A., Garibaldi, L. A., Cunningham, S. A. and Klein, A. M. 2008, Cur. Biol., 18, 1572-1575.
2. Allen-Wardell, G., Bernhardt, P., Bitner, R., Burquez, A., Buchmann, S., Cane, J., Cox, P. A., Dalton, V., Feinsinger, P., Ingram, M., Inouye, D., Jones, C. E., Kennedy, K., Kevan, P., Koopowitz, H., Medellin, R., Medellin-Morales, S., Nabhan, G. P., Pavlik, B., Tepedino, V., Torchio, P. and Walker, S. 1998, Cons. Biol., 12, 8-17.

3. Kevan, P. G. and Baker, H. G. 1983, Annu. Rev. Entomol., 28, 407-453.
4. Martins, F. Q. and Batalha, M. A. 2006, Braz. J. Biol., 66, 2.
5. Bosch, J., Retana, J. and Cerdá, X. 1997, Oecologia, 109, 4.
6. Oliveira, P. E., Gibbs, P. E. and Barbosa, A. A. 2004, Plant Syst. Evol., 245, 41-54.
7. Bawa, K. S. 1990, Ann. Rev. Ecol. Syst., 21, 399-422.
8. Rader, R., Howlett, B. G., Cunningham, S. A., Westcott, D. A., Newstrom-Lloyd, L., Walker, M., Teulon, D. and Edwards, W. 2009, J. of Appl. Ecol., 46, 1080-1087.
9. Rader, R., Howlett, B. G., Cunningham, S. A., Westcott, D. A. and Edwards, W. 2012, J. of Appl. Ecol., 49, 126-134.
10. Bawa, K. S. 1994, Am. J. of Bot., 81, 456-460.
11. Waser, N. M., Chitaka, L., Price, M. V., Williams N. M. and Ollerton, J. 1996, Ecology, 77, 1043-1060.
12. Wilson, P. and Thompson, J. D. 1991, Ecology, 72, 1503-1507.
13. Thompson, J. D. 2001, Oecologia, 126, 386-394.
14. Free, J. B. 1993, Insect Pollination of Crops, 2nd Edn. Academic Press, Harcourt Brace Jovanovich, Publishers, London, UK.
15. Kluser S. and Peduzzi, P. 2007, Global Pollinator Decline: A Literature Review, UNEP/GRID Europe, UNEP.
16. Hong, K. J., Lee, S. H. and Choi, K. M., 1989, Korean. J. Apic., 4, 16-24.
17. Raj, H., Mattu V. K. and Thakur M. L. 2012, India I. J. S. N., 3(3), 507-513.
18. Leksono, A. S. and Penatagama, Z. P. 2010, Recommendation of Soil Arthropod Composition Research to Support the Conservation of Apple Farming Ecosystem in Batu City. Proceeding of Basic Science Seminar. Faculty of Mathematic and Natual Sciences. University of Brawijaya.
19. Borror, D., Triplehorn, C. and Johnson, N. 1989, An Introduction to the Study of Insects, Harcourt College.
20. Leksono, A. S., Nakagoshi, N. and Isagi, Y. 2005, Tropics, 14, 335-343.
21. Kremen, C., Williams, N. M. and Thorp, R. W. 2002, Proc. of Nation. Acad. of Sci. USA, 99, 16812-16816.
22. Luo, C. W., Huang, Z. Y., Chen, X. M., Li, K., Chen, Y. and Sun, Y. Y. 2011, Econ. Entomol., 104, 1, 149-154.
23. Klein, A. M., Vaissiere, B. E., Cane, J. H., Steffan-Dewenter, I., Cunningham, S. A., Kremen, C. and Tscharntke, T. 2007, Proc. Royal Soc. B, 274, 303-313.
24. Winfree, R., Williams, N. M., Dushoff, J. and Kremen, C. 2007, Ecol. Let., 10, 1105-1113.
25. Wagner, T. 2003, Seasonality of canopy beetles in Uganda. In Basset, Y., Novotny, V., Miller, S. E. and Kitching, R. L. (Eds.) Cambridge University Press, Cambridge.
26. Bosch, J., Retana, J. and Cerdá, X. 1997, Oecologia, 109, 4.
27. Verma, L. R. 1995, Apis cerana: Biometric, genetic and behavioural aspects, P. G. Kevan, (Ed.), Ontario: Enviroquest Ltd, 41-53.
28. Wallace, H. M., Maynard, G. V. and Trueman, S. J. 2002, Aus. J. of Entomol., 41, 55-59.
29. Mishra, R. M., Gupta, P. and Yadav, G. P. 2004, Trop. Ecol., 45(2), 263-270.