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Relationship of leaf miner populations with biotic and abiotic factors in tomato farms in Cameron Highlands

(Hubung kait populasi pelombong daun dengan faktor biotik dan abiotik di ladang tomato di Cameron Highlands)

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Abstract

Leaf miners have high economic value on vegetables industry in many parts of the world. A monitoring study was conducted to record current population trend of the leaf miners with its natural enemies. The study was carried out in local vegetable farms of Cameron Highlands by sampling the infested tomato leaves from three zones categorised according to elevations monthly. Results showed that the populations of two leaf miner species were not significantly different between months (P = 0.67) and the three zones (P = 0.74). On contrary, different zones and months affected the population of its natural enemies significantly (P = 0.0002 and P = 0.0023 respectively). Results showed highest parasitism rate by *Hemiptarsenus varicornis* (23.25%) as compared to the *Macrolophus* sp. (18.3), *Opius pallipes* (11.06%) and *Chrysocharis pentheus* (2.13%). This study suggested that weather conditions did not affect the population dynamics of both the leaf miners and its natural enemies. However, it is suggested to carry out the study for a longer time scale to understand further the relationship and interactions.

Keywords: *Liriomyza huidobrensis*, population dynamics, natural enemies, leaf miner parasitoids, predators, *Solanum lycopersicum*

Introduction

Tomato has been categorised as a high-value crop under the Entry Point Project (EPP) 7 of agriculture NKEA in Malaysia's Economic Transformation Programme (ETP). According to Department of Agriculture Malaysia (2012), Pahang is the biggest producer of tomato (106,389.93 mt) which is mainly dominated by the Cameron Highlands district. In 2011, tomato production was recorded as the second highest vegetable produced in Malaysia with 137,128.4 mt (Department of Agriculture Malaysia 2012). Even though tomato has achieved the Self-Sufficiency Level (SSL) (129.6% in 2011) (FAMA 2014) but increase in productivity of better quality has not been achieved to enable access to premium markets in the Middle East and Europe.

The government's encouragement to improve productivity for tomato has created a good opportunity for farmers to expand their planting areas and generate more income. However, the increasing trend of these planting areas will cause

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further problems of insect pest infestations especially by leaf miner, one of the major pests of tomato.

The leaf miner is a polyphagous insect pest that attacks the leaves of a wide range of host plants. The pest which is originated from America was believed to be transferred to Malaysia via transportation of temperate cut flowers (Myint 1997). Three species of leaf miners (*Liriomyza sativae*, *L. huidobrensis* and *Chromatomyia horticola*) have been found on several crops including tomato, sugarpea, chrysanthemum and crucifers. A survey conducted in 2012 recorded that the leaf miner was the highest pest infesting tomato with 56% infestation (Nur Liyana et al. 2012). Yield losses up to 30% caused by leaf miner have also been reported. Due to the susceptibility of a wide range of host plants, it can result in serious outbreaks whenever the environment is favourable.

Chemical pesticides will always become the farmer's primary choice of controlling pests. However, the negative effects related to environmental pollution and health risk will eventually outweigh the benefits. Therefore, it is crucial to look for other alternatives for pest control such as biological control methods. Application of biological control agents (BCAs) is proven to be effective in controlling many other incidence of pest infestations (Heikal and Ebrahim 2013; Sohati 2012).

Several studies have been done on the leaf miners (Nur Liyana et al. 2012; Sivapragasam and Syed 1999; Myint 1997; Sivapragasam et al. 1992; Sivapragasam et al. 1995a and 1995b; Sivapragasam et al. 1999a and 1999b). Following these studies, there is no record of current status of leaf miner populations and its natural enemies on tomato in Cameron Highlands. Thus, this paper reports population abundance of leaf miners and relationships with its natural enemies as well as weather parameters.

Materials and methods

Sampling

Twelve tomato farms which regularly applied chemical pesticides were chosen from three zones of Cameron Highlands (Northern zone - Blue Valley, Kuala Terla and Kg. Raja, Central zone - Mensum Valley, Tanah Rata and Kea Farm and Southern zone - Ulu Ringlet and Ringlet). Due to different size of each farm, only one acre of tomato planting area was selected for sampling from each farm. In each farm, between 30 – 40 tomato plants were selected randomly and tomato leaves with symptoms of leaf miner infestations were collected before being placed in labelled sampling bags. Leave samples were brought back to the laboratory and observed for presence of leaf miner larvae under light before being placed individually in labelled petri dishes. Infested leaf miner samples were collected monthly from February until September 2015.

Sorting and identification

All of the petri dishes were observed daily for emergence of adult leaf miners or natural enemies. The newly emerged insects and others were collected using an aspirator or brush and transferred into labelled glass vials for sorting and identifications. The identifications were carried out according to Myint (1997).

Number of leaf miners and natural enemies were recorded for each sample collection. The parasitism rate or percentage of predators emerged were calculated according to Cai and Saito (2011) following the formula as below:

$$\text{Parasitism rate or predators (\%)} = \frac{\text{Number of parasitoids or predators emerged}}{\text{(Total parasitoids or predators emerged + Total leaf miners collected)}}$$

Data analysis

Temperature and humidity were recorded on every sampling day using a pocket anemometer (model Extech 45160). Additional data on pesticides usage were also recorded through a simple questionnaire given to the farmers on the first day of sampling. All recorded data were analysed using Regression and Pearson Correlation Analysis for population trend as well as relationship between organisms. Two factorials analysis of variance (2-factorials ANOVA) followed by LSD were done at 95% confidence level to compare the populations.

Results and discussion

Species of leaf miners and its natural enemies

Based on the study, there are two species of leaf miners infesting the tomato leaves (*Liriomyza huidobrensis* and *Chromatomyia horticola*), three solitary parasitoids species parasitising the leaf miners (*Hemiptarsenus varicornis*, *Opius pallipes* and *Chrysocharis pentheus*) and one predator (*Macrolophus* sp.) (*Figure 1*). The leaf miners and parasitoids species collected were the same as those identified by Myint (1997) on sweetpeas and Sivapragasam et al. (1995b) on chrysanthemum.

Meanwhile, *Macrolophus* sp. has been recorded as predator of whitefly in Cameron Highlands (Mohd Rasdi 2005). However, based on its discovery in this study, the predator could also be responsible in regulating the population of leaf miners. A study conducted by Arno et al. (1987) explained the use of *Macrolophus caliginosus* alone and in combination with the parasitoid *Diglyphus isaea* to control leaf miners. This was also supported by Nedstam and Johansson-Kron (1999) in which they applied the parasitoid *D. isaea* combined with *M. caliginosus* to manage infestation of *Liriomyza bryoniae* on commercial tomato production under greenhouse condition. According to Mohd Rasdi (2009), *Macrolophus caliginosus* was first discovered by Syed in 2000. Since then, some work has been done to develop rearing technique of this predator focusing on whitefly management. Due to its characteristic of being a generalist, it could be the reason why *Macrolophus* sp. has been found in tomato plants infested by leaf miners. Further clarification is required to confirm the species of the mirid bug due to several changes on the nomenclature of the species and confusion of its identification with *M. pygmaeus* as reported recently (Castane et al. 2013).

Figure 1. (A) Chromatomyia horticola; (B) Liriomyza huidobrensis; (C) Hemiptarsenus varicornis (male); (D) Opius pallipes (male); (E) Chrysocharis pentheus and (F) Macrolophus sp.

Population of leaf miners

The results (*Figure 2*) showed that Central zone (220 leaf miners) had the highest number of total individual leaf miners followed by Northern (214 leaf miners) and Southern zones (192 leaf miners) with *L. huidobrensis* dominating the infestation of all three zones. However, they do not differ statistically (P = 0.74) and are not correlated with natural enemies (p >0.05). Therefore, other factors could be responsible for the fluctuation of leaf miners populations in the three zones. One of the factors would be injudicious use of chemical pesticides.

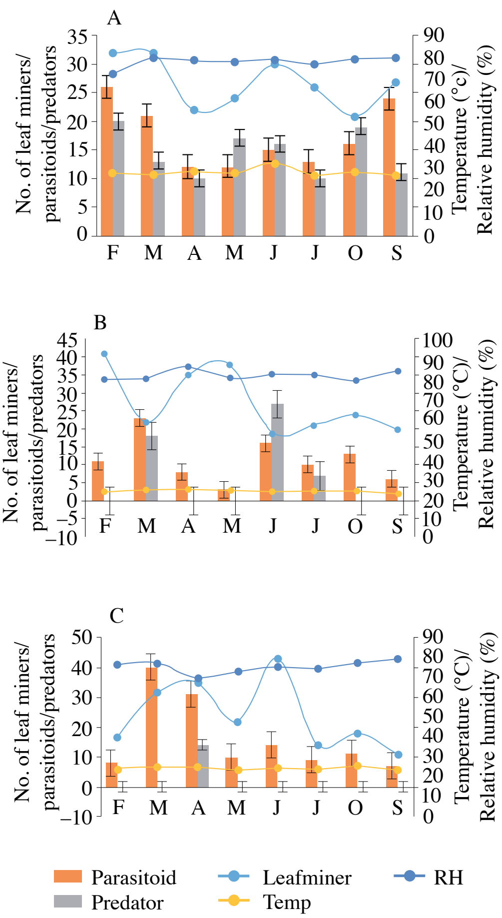

Figure 2. Population fluctuation of leaf miners and natural enemies on tomato in (A) Northern zone, (B) Central zone and (C) Southern zone of Cameron Highlands

From a survey conducted, a total of 16 types of pesticides were used to control leaf miners infestation on tomato. Some of the respondents (5%) reported failure to control the pest when using abamectin while the rest did not. Even though there is a record on moderate resistance of leaf miners to this chemical (Ferguson 2004), further studies have to be conducted to confirm this. Besides that, the tomato varieties or farmer's cultural practices should also be looked into in detail.

Population of natural enemies

Based on the data in *Table 1*, *H. varicornis* dominates the population of natural enemies with 23.25% parasitism rate while the least number of natural enemy species is *C. pentheus* (2.13%).

Sulaeha and Maryana (2009) reported that the generation time of *H. varicornis* is 13.9 days and this could be the reason for high population of the parasitoid as compared to the other two parasitoid species that requires longer time to double their generations (Awadalla et. al. 2009; Mafi and Ohbayashi 2010). The proportion of the natural enemies recorded in Northern Zone is the highest compared to Central and Southern zones (*Table 2*). This is also supported by data from ANOVA that showed significant difference in natural enemies between zones (*Table 3*). It is probably due to the fact that the Northern part of Cameron Highlands is occupied by numerous commercial and smallholders farms with a wide range of crops including flowers. Presence of various types of plants could have probably provided alternative hosts for the parasitoids to survive whenever leaf miner populations dropped.

Table 1. Parasitism/predation rate of natural enemies on leaf miners

Natural enemies	*H. varicornis*	*O. pallipes*	*C. pentheus*	*Macrolophus* sp.
Parasitism/ predation (%)	23.25	11.06	2.13	18.3

Table 2. Mean comparison of natural enemy populations between months and zones

Months		Zones	
Months	Means*	Zones	Means
March	12.78[a]	North	10.63[a]
June	9.78[ab]	South	6.00[b]
April	8.34[bc]	Central	5.92[b]
February	7.22[bc]		
August	6.56[bc]		
July	5.44[c]		
September	5.33[c]		
May	4.67[c]		

*Different letters indicate significant differences in mean values (p <0.05)

Many studies related to insects' ecology have proven the effects of temperature on the insects' abundance and population dynamics (Tingle and Copland 1988; Kollberg 2013). However, the difference of temperature and relative humidity between elevations (zones) does not seem to give effect on the populations of natural enemies in this study.

Therefore, other possible factors contributing to the regulation of natural enemies could be the type of pesticides used by the farmers. The additional data on pesticide usage (*Table 4*) to control leaf miner infestations recorded the use of abamectin in Central and Southern zones, meanwhile cyromazine is familiar among tomato farmers in Northern and Central zones. According to a study conducted by Bjorksten and Robinson (2005), cyromazine is compatible with parasitoids and suitable for IPM of leaf miners. However, they advised to use abamectin with caution when integrated with biological control because of high mortality of parasitoids.

Relationship with weather

Correlations of both leaf miners and natural enemies are not significant with any weather parameters recorded (*Table 5*). A possible reason for this could be the death of leaf miners caused by other natural enemies such as beneficial microbes through infection. Tagami et. al. (2006) reported the occurrence of endosymbiotic bacteria known as *Wolbachia* in leaf miners and studied its potential to be developed as a biological control agent. However, further observation on pathogens associated with leaf miners was not done in this study to confirm that. Aside from that, the use of a fully netted rain shelter by some farmers also inhibited movement of the insects to other areas especially when the area has been infested previously. Based on visual observations, leaf miners dispersions were restricted by the netted wall of the rain shelter and did not occur in the neighbouring tomato farm. According to Yoshimoto and Gressitt (1964), agromyzid flies are considered as moderate fliers. They remain close to targeted crops and moving very short distances between plants (Zehnder and Trumble 1984). Apart from that, polyphagous nature of leaf miners could also contribute to continuous infestations since most of the farmers planted several types of vegetables within an area which later served as an alternative source of food for the pest.

Table 3. ANOVA of leaf miners and natural enemies populations

Source	df	Leaf miners		Natural enemies	
		F value	Pr > F	F value	Pr > F
Months	7	0.73	0.67^{ns}	3.84	0.0023^{*}
Zones	2	0.31	0.74^{ns}	10.07	0.0002^{*}
Months*Zones	14	0.94	0.53^{ns}	3.24	0.0013^{*}

ns = not significant; * significantly different ($p < 0.05$)

Table 4. Types of pesticides used by farmers to control leaf miners

Zones	Pesticides	% of usage
Northern	Emamectin	24.0
	Profenofos	16.7
	Cyromazine	9.3
	Diafenthiuron	8.3
	Lambda-cyahalothrin	8.3
	Imidacloprid	8.3
	Cypermethrin	8.3
	Dimethoate	8.3
	Methomyl	8.3
Central	Emamectin	15.4
	Abamectin	23.0
	Cyromazine	15.4
	Thiocyclam-hydrogen oxalate	15.4
	Spinosad	7.7
	Imidacloprid	7.7
	Fenobucarp	7.7
	Pyriproxyfen	7.7
Southern	Abamectin	34.0
	Lufenuron	16.0
	Malathion	16.0
	Spinosad	34.0

Table 5. Correlation of leaf miners and natural enemies with weather parameters

Organism	Temperature (°C)	Relative humidity (%)
Leaf miners	0.44 (0.30)	0.63 (–0.22)
Natural enemies	0.51 (0.22)	0.33 (0.16)

Number in brackets: Correlation coefficient value (r)

Conclusion

This study suggests that incidence of leaf miners and parasitism or predation activities by natural enemies are not affected by the weather conditions. They could be attributed by other factors such as types of pesticides used to control the leaf miner. Meanwhile, population stability of the beneficial insects may be also be affected by interactions with other external factors such as presence of beneficial plants. It is suggested that this study should be conducted for a longer time scale while considering sampling locations with minimum application of pesticides to understand the relationship and interaction between the organisms. Investigation on parasitism/predation efficiency of the potential natural enemy species should be considered to ensure establishment of these natural enemies as biological control agents of leaf miners.

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References
Arno, J., Alonso, E. and Gabarra, R. (1987). Role of the parasitoid *Diglyphus isaea* (Walker) and the predator *Macrolophus caliginosus* Wagner in the control of leaf miners. *Bulletin of International Organization of Biological Control* 10(10): 79 – 84

Awadalla, S.S, Shahab, L.M., Abd El-Kareim, A.L, El-Nagar, M.E. and El-Khouly, E.R. (2009). Biological studies on larval pupal endoparasitoid *Opius pallipes* Wesmael (Hymenoptera: Braconidae). *Journal of Agricultural Sciences* 34(1): 511 – 514

Bjorksten, T.A and Robinson, M. (2005). Juvenile and sublethal effects of selected pesticides on the leaf miner parasitoids *Hemiptarsenus varicornis* and *Diglyphus isaea* (Hymenoptera: Eulophidae) from Australia. *Journal of Economy Entomology* 98(6): 1831 – 1838

Cai, D. and Saito, T. (2011). Current status of exotic *Liriomyza* leaf miners and their associated parasitoids in Shizuoka Prefecture. *Annual Report of the Kansai Plant Protection Society* 53: 43 – 47

Castañé, C., Agustí, N., Arnó, J., Gabarra, R., Riudavets, J., Comas, J. and Alomar, Ó. (2013). Taxonomic identification of *Macrolophus pygmaeus* and *Macrolophus melanotoma* based on morphometry and molecular markers. *Bulletin of Entomological Research* 103(2): 204 – 215

Department of Agriculture Malaysia (2012). Vegetables and cash crops statistics

FAMA (2014). Statistik utama pemasaran FAMA 2014

Ferguson, J.S. (2004). Development and stability of insecticide resistance in the leaf miner *Liriomyza trifolii* (Diptera: Agromyzidae) to cyromazine, abamectin and spinosad. *Journal of Economy Entomology* 97(1): 112 – 119

Heikal, I.H. and Ebrahim, A.A. (2013). Biological control of *Tetranychus urticae* Koch on sweet pepper plantations in a comercial farm by the predatory mite, *Phytoseiulus macropilis* (Banks). *Egypt Journal Agriculture* 91(3): 1161 – 1173

Kollberg, I. (2013). Implications for the population dynamics of a forest insect pest in a warmer climate. In: *The effect of temperature on trophic interactions*. Ph.D. Thesis. Swedish University of Agricultural Sciences, Uppsala, Sweden

Mafi, S.H. and Ohbayashi, N. (2010). Biology of *Chrysocharis pentheus*, an endoparasitoid wasp of the citrus leaf miner *Phyllocnistis citrella* Stainton. *Journal of Agricultural Science and Technology* 12: 145 – 154

Mohd Rasdi, Z. (2005). Biology, distribution and effect of selected insecticides against whitefly (*Trialuerodes vaporariorum* Westwood and *Bemisia tabaci* Gennadius) on brinjal (*Solanum melongena* L.). Ph.D. Thesis, Universiti Teknologi MARA, Shah Alam, Selangor, Malaysia

Mohd Rasdi, Z., Fauziah, I. and Wan Mohamad, W.A.K. (2009). Biology of *Macrolophus caliginosus* (Heteroptera: Miridae) predator of *Trialeuroides vaporariorum* (Homoptera: Aleyroridae). *International Journal of Biology* 1(2): 63 – 70

Myint, T. (1997). Ecology and control of leaf miners (Diptera: Agromyzidae) on sugarpea in Cameron Highlands. Ph.D. Thesis, Universiti Kebangsaan Malaysia, Bangi, Selangor, Malaysia

Nedstam, B. and Johansson-Kron, M. (1999). *Diglyphus isaea* (Walker) and *Macrolophus caliginosus* Wagner for biological control of *Liriomyza bryoniae* (Kaltenbach) in tomato. *Bulletin of International Organization for biological control of noxious animals and plants* 22(1): 261 – 263

Nur Liyana, I., Abu Zarim, U., Mohamad Roff, M.N. and Saiful Zami, J. (2012). Survey on pests and diseases of tomato and its management in Cameron Highlands. *Proceedings of 5th International Integrated Pest and Disease Management (IPM) Conference*, 18 – 20 December 2012, Kota Kinabalu, Malaysia, p. 124 – 126

Sivapragasam, A. and Syed, A.R. (1999). The problem and management of leaf miners on vegetables in Malaysia. Paper presented in CABI-FAO Workshop on leafminers of vegetables in South East Asia, 2 – 5 February, 1999

Sivapragasam, A., Syed, A.R. and Loke, W.H. (1992). The leaf miner, *Chromatomyia horticola* (Goureau) and its increasing menace to farmers in Cameron Highlands. *MAPPS Newsletter* 16(3): 19 – 20

Sivapragasam, A., Loke, W.H., Syed, A.R. and Ruwaidah, M. (1995a). Dipteran leaf miners on highland crops of Malaysia and an integrated approach towards their management. In: *European Journal of Plant Pathology, XIII International Plant Protection Congress*, 2 – 7 July, 1995. The Hague, Netherlands. Kluwer Academic Publishers

Sivapragasam, A., Loke, W.H., Syed, A.R. and Ruwaidah, M. (1995b). Agromyzid leaf miners and their parasitoids on some ornamentals in Cameron Highlands. *Proceedings of National Seminar and Exhibition on integrated production of temperate cut flowers*, 27 – 30 June 1995, Cameron Highlands, Malaysia (Zaharah, H. et al., eds.)

Sivapragasam, A., Syed, A.R., La Salle, J. and Ruwaida, M. (1999a). Parasitoids of invasive agromyzid leaf miners on vegetables in Peninsular Malaysia. *Proceedings of the symposium on biological control in the tropics*. CAB International South East Asia Regional Centre, Malaysia (Loke, W.H. et al., eds.)

Sivapragasam, A., Loke, W.H. and Ruwaida, M. (1999b). A strategy towards managing the agromyzid leaf miner *Chromatomyia horticola* (Goureau) on chrysanthemums through the selective use of insecticides. *Proceedings of the 5th International Conference on plant protection in the tropics*, 15 – 18 March 1999, Kuala Lumpur, Malaysia (Sivapragasam, A. et al., eds.) p. 93 – 95

Sohati, P.H. (2012). Establishment of *Cotesia vestalis* (Haliday) and *Diadromus collaris* (Grav.) parasitoids of the diamondback moth, *Plutella xylostella* (L.), and assessment of the effectiveness of C. *vestalis* as a biological control agent in Zambia. M. Sc. Thesis. University of Zambia

Sulaeha, R.A. and Maryana, N. (2009). Parameter demografi parasitoid *Hemiptarsenus varicornis* Gerault (Hymenoptera: Eulophidae) pada lalat pengorok daun *Liriomyza huidobrensis* (Diptera: Agromyzidae). *Jurnal Hama dan Penyakit Tumbuhan Tropika* 9(1)

Syed, A.R., Sivapragasam, A., Loke, W.H. and Mohd. Roff, M.N. (2000). Whiteflies infesting vegetables in Malaysia. *Proceedings of Plant Resource Management Conference*, 23 – 24 November 2000, Kuching, Sarawak, p. 38 – 43

Tagami, Y., Doi, M., Sugiyama, K., Tatara, A. and Saito, T. (2006). Wolbachia-induced cytoplasmic incompatibility in *Liriomyza trifolii* and its possible use as a tool in insect pest control. *Biological Control* 38(2): 205 – 209

Tingle, C.C.D. and Copland, M.J.W. (1988). Effect of temperature and host-plant on regulation of glasshouse mealybug (Hemiptera: Pseudococcidae) populations by introduced parasitoid (Hymenoptera: Encyrtidae). *Bulletin of Entomological Research* 78(1): 135 – 142

Yoshimoto, C.M. and Gressitt, J.L. (1964). Dispersal studies on Aphididae, Agromyzidae and Cynipoidea. *Pacific Insects* 6: 525 – 531

Zehnder, G.W. and Trumble, J.T. (1984). Intercrop movement of leaf miners. *California Agriculture* 38: 7 – 8

Abstrak

Pelombong daun merupakan perosak yang memberikan impak terhadap ekonomi industri sayur-sayuran di kebanyakan tempat di seluruh dunia. Satu kajian pemantauan telah dijalankan untuk merekod tren populasi terkini pelombong daun dan musuh semulajadinya. Kajian tersebut telah dilaksanakan di ladang sayur-sayuran tempatan di Cameron Highlands melalui persampelan daun tanaman tomato yang diserang oleh pelombong daun pada setiap bulan dari tiga zon kawasan yang dikategorikan mengikut ketinggian. Keputusan mendapati bahawa populasi bagi dua spesies pelombong daun adalah sama pada setiap bulan (P = 0.67) dan zon (P = 0.74). Walaubagaimanapun, bulan serta zon yang berbeza memberikan kesan yang signifikan terhadap populasi musuh semulajadinya (P = 0.0002 dan P = 0.0023 setiap satu). Keputusan menunjukkan kadar memparasit tertinggi adalah didominasi oleh *Hemiptarsenus varicornis* (23.25%) berbanding dengan *Opius pallipes* (11.06%) dan *Chrysocharis pentheus* (2.13%). Kajian ini mencadangkan bahawa keadaan cuaca tidak mempengaruhi populasi kedua-dua pelombong daun dan musuh semulajadinya. Namun, kajian ini dicadangkan supaya dilakukan dalam tempoh masa yang lebih lama bagi memahami hubungan interaksi antara kedua-dua jenis serangga serta keadaan cuaca.