

Attraction factors for *Paederus fuscipes*' dispersal, a vector of *Paederus dermatitis* towards human residential premises

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ABSTRACT

Paederus fuscipes, a vector of *Paederus dermatitis* in most tropical and subtropical countries of the world have a high prevalence in human dwellings due to their positively phototaxic behaviour which has caused a tremendous impact on human health. In this paper, *P. fuscipes* dispersal flights were studied for two seasons of the rice cultivation phases in residential premises built close to rice field areas (≈32-60 m and 164 m) in mainland Penang, Malaysia. We examined the effects of different light illuminance, building floor level and their association with rice stages as a focal cause of *P. fuscipes* dispersion from the rice fields towards human dwellings. The present study showed a significant interaction between different light illuminances and rice cultivation phases in attracting *P. fuscipes* to disperse and invade human dwellings. The highest number of *P. fuscipes* was captured near the bright light. *P. fuscipes* flights increased in line with each floor level, and the highest captures took place at higher building floor levels (levels 2 and 3) compared to lower building floor levels (ground floor and level 1) of a three storey apartment in both rice seasons. This finding not only conveys a better understanding on *P. fuscipes* dispersal pattern, but also draws public attention on the occurrence of dermatitis linearis caused by the *Paederus* beetles.

KEYWORDS: Built environment. Phototoxicity. *Paederus*. Rove beetle. Staphylinidae.

INTRODUCTION

About 50,000 staphylinid species are distributed worldwide¹, with at least 650 species of the genus *Paederus*. These beetles are notoriously known to cause human health hazards due to its vesicant toxin hemolymph, pederin. Pederin inhibits mitosis in eukaryotic cells and triggers an offensive skin condition called *Paederus dermatitis*, or dermatitis linearis on affected human skin. This poisonous ant-like beetle is commonly distributed in the tropics and temperate regions², and on all continents except Antarctica³.

In tropical countries, epidemics of dermatitis linearis have been frequently reported in Iran, Iraq, India, Pakistan, Sri Lanka and Southeast Asia. However, *Paederus dermatitis* is an extensively neglected insect-induced skin lesion especially in the tropics. Often neglected and seldomly reported, many go untreated due to unawareness of the skin condition⁴ as they are rather considered a common skin problem by the local residents^{5,6}. Thus, many individuals do not seek treatment and have even ignored the symptoms. Only a small proportion of patients pursues medical care or is self-treated⁷. As a consequence, misdiagnosis can occur as the clinical appearance of *Paederus dermatitis* mimics many other dermatosis including herpes simplex, herpes zoster, phytophotodermatitis, acute allergic or other irritant

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dermatitis caused by some other venomous insects^{7,8,9,10}. Interestingly, rove beetles do not display spontaneous bleeding effect as the *Epicauta* genus and they do not bite or sting. However, when a beetle is crushed on the skin surface, pederin is released causing the dermatitis^{7,11}. They are also known to release the potent pederin when they are threatened, as a defensive response towards potential predators¹².

Paederus is a nocturnal insect very strongly attracted by luminescent, fluorescent and neon lights that certainly and inadvertently bring the, near humans^{8,13}. This is because brightly illuminated lamps from artificial light sources emitted by human residential premises attract *Paederus* beetles. In addition to those lights, long wave UV is found to be a factor that causes the attractiveness of beetles towards the light source¹⁴. This is true to most species of insects that are particularly sensitive to light of shorter wavelengths. Hence, well-lit premises at night in urban and suburban areas could inevitably attract them, resulting in high dermatitis infestation to individuals living nearby. For example, military operations that often involve the construction of bright lighted camps in *Paederus* endemic areas such as *Paederus ilsaе* and *Paederus iliensis* in Iraq¹⁵, *P. fuscipes* in India¹⁶ and Pakistan¹⁷ were affected by the outbreaks of dermatitis linearis. Overall, it can be confirmed that most of the affected individuals worked near to artificial lightings at night.

Intermittent dermatitis cases have been reported in high-rise buildings in mainland Penang¹⁸. For these reasons, we sought to understand each floor level of an apartment building on *Paederus* dispersal flight pattern. Thus, the effect of different floor level has also being taken into account as one of the attraction factors for *Paederus* beetles to infest human dwellings. Generally, insects are known to take advantage of the wind to help them on their migratory flights. According to Drake & Gatehouse¹⁹ and Chapman *et al.*²⁰, the wind factor causes insects to frequently migrate to the higher altitudes of several meters above the ground and utilize fast moving airstreams to travel hundred kilometers in a single flight. Besides, flying at higher altitudes is a good migration approach which subsequently maximizes the insect population displacement, and helps finding suitable habitats to feed, mate and produce the next generation²¹.

Paederus fuscipes Curtis is the predominant *Paederus* species found mainly distributed in moist and damp conditions such as in rice fields of Malaysia²². Consequently, it is also noted that *Paederus* dermatitis cases in the Northern region of Peninsular Malaysia are more common in residential premises situated adjacent to the rice field areas¹⁸. Therefore, the present work aimed to investigate the effects of different light illuminance and the building floor level of a high-rise apartment during different rice

cultivation phases as a focal cause of *P. fuscipes* beetles dispersion from the rice fields towards human dwellings.

MATERIALS AND METHODS

Study Site

Paederus fuscipes sampling started in October 2013 until October 2014 for one year period. Sampling was performed in two rice cultivation phases; Season 1 consisted of a five months sampling period from October 2013 to March 2014 (known as the main season) which coincided with the wet period, and Season 2 consisted of a seven month period from March 2014 to October 2014 (known as the off season) which coincided with the dry period. A complete cycle of rice cultivation phases consisted of (1) the ploughing stage, (2) the seeding stage, (3) the growing stage, and (4) the harvesting stage (Bong *et al.*)¹⁸.

The study site was located at Jalan Sejahtera, Telok Air Tawar, Butterworth, Penang (5° 29' 9.3171" N, 100° 23' 1.3012" E). This sampling site is situated on the Northeastern coast of Peninsular Malaysia and has consistently warm and humid environment throughout the year with an annual rainfall of approximately 2,670 mm. The temperature varies between 29 - 35°C during the day and 26 - 29°C at night. This site was chosen due to the highest infestation of *P. fuscipes* occurrence in mainland Penang which was based on the infestation report provided by the Seberang Perai city council department. In addition, rice fields are adjacent to the residential premises.

A three storey apartment (5° 29' 8.9519" N, 100° 23' 10.6481" E) and three landed houses, tagged as H1 (5° 29' 9.3748" N, 100° 23' 17.33" E), H2 (5° 29' 9.9131" N, 100° 23' 19.493" E), H3 (5° 29' 7.414" N, 100° 23' 19.7633" E) were selected as the study sites. The high-rise apartment building was approximately 164 m from the edge of the closest rice field, whereas the landed houses were between 32 and 60 m north to the boundary edge of the rice fields.

Experimental design

Effects of the light illuminance: Sticky trap size (Jamin, Seng Lee Trading) 18.9 cm (height) x 27.8 cm (length) was placed on each selected light source. These sticky traps were deployed on respectively three different light illuminance; (1) no light (≈ 0 lux); where sticky traps were fixed surrounding fluorescent lamps that switched off their lights throughout the night, (2) low light (≈ 82 lux); where sticky traps were fixed on the ceiling approximately 1.5 m away from the fluorescent lamp and this distance was selected because it is the furthest possible location from

the light source which represents the lowest illuminance, and (3) bright light ($\approx 1,206$ lux); where sticky traps were fixed surrounding the fluorescent lamp around 1 cm from the light source to represent the highest illuminance. The illuminance level was measured using a digital lux meter device (LX1010BS, China).

The first set of experiments was performed to determine the attractiveness of *P. fuscipes* beetles to the three different light illuminances on land residential premises. No light was represented by H1 and H3 of the land houses; low light was represented by the ground floor (level 0) of a three storey apartment, and bright light was represented by H2 of the landed houses including the ground floor (level 0) of the apartment. A different set of premises was used due to the lack of permission from the landlord to use their premises as an experimental site. Therefore, the ground floor (level 0) has the same level of landed houses was also included.

The second set of experiments was performed to determine the attractiveness of *P. fuscipes* beetles towards two different light illuminances based on different floor levels at the three storey apartment. Three sticky traps were placed at each low light and bright light illuminance on each floor level of the apartment building (level 0, level 1, level 2, level 3).

Effects of the building floor level: For this study, the experiment was conducted in a three storey apartment building. Six sticky traps were fixed on each floor of the three storey apartment building (level 0, level 1, level 2 and level 3) surrounding fluorescent lamps. All of the trials were illuminated by ceiling-mounted white fluorescent lamp of MCF Model (240V, 50Hz, 40W). After 24 hours, the first reading was taken and the subsequent readings were taken daily for three consecutive days every fortnight. Sticky traps were replaced at every sampling occasion. All of the trials were run using three replicates for each light illuminance. Samples of *P. fuscipes* at each floor were examined and counted using a blue Sharpie marker pen to avoid mistakes during calculation of the *P. fuscipes*' abundance. Comparisons were then made to estimate the number of beetles trapped on different floor levels of the three storey apartment.

Statistical analysis

All of the data were examined for distribution normality at a 5% significance level by using the Shapiro-Wilk Normality test. A log₁₀ transformation was performed to normalize the data to fulfill the assumption of the two-way analysis of variance ANOVA which was used to examine; (1) the effects of three different light illumination sources

from the same floor level of land houses/ground floor apartments and rice cultivation phases; (2) the effects of two different light intensity sources at a three storey apartment with different floor levels; (3) the effects of three different floor levels of a three storey apartment and rice cultivation phases. Post hoc multiple comparisons were run to determine differences among the means by using the Tukey's honestly significant difference (HSD) test at $\alpha = 0.05$. All the analyses were performed using the SPSS software, version 20.0. Data for rice cultivation phases in the main season and in the off season were analyzed separately as a comparison between two different rice seasons. One-way multivariate analysis of variance (MANOVA) was conducted to compare the number of captured beetles in a three storey apartment during the main season and the off season of the rice cultivation phases.

RESULTS

Effects of different light illuminances and building floor levels and association with rice cultivation phases

During the course of a year sampling period from October 2013 until October 2014, a total of 4,768 specimens of *P. fuscipes* beetle was collected from the residential premises throughout the main and the off rice seasons. A total of 1,279 beetles was captured in the main season (October 2013 - March 2014) of the rice cultivation phase. The highest number of beetles was captured during the harvesting stage totalling 728 individuals.

During the off season (March 2014 - October 2014) the number of captured beetles increased approximately three-fold, by 3,494 compared to the main season. The highest amount of beetles was 2,719 individuals during the rice growing stage. A statistically significant effect of rice cultivation phase on the number of captured *P. fuscipes* in the three storey high-rise apartment for both, the main and the off rice season was found throughout the one year sampling period ($F = 18.250$; $df = 6,14$; $p = 0.000$; MANOVA).

Effects of light illuminance and rice cultivation phases

The attraction of *P. fuscipes* beetle towards the light differed significantly among the three different light illuminances ($F = 123.393$; $df = 2, 48$; $p = 0.000$; Table 1). However, *P. fuscipes* was significantly more attracted towards sticky traps placed near the bright light compared to the low and to no light ($p < 0.05$; Fig. 1). *Paederus fuscipes* dispersion from the rice field towards the bright light found the highest number of trapped beetles with a total mean \pm SE of 20.4 ± 25.92 . Conversely, *P. fuscipes*

Table 1 - Effects of light illumination at the ground/ land floor level and rice cultivation phase on the dispersion of *Paederus fuscipes* beetles using two-way ANOVA.

Source	Type III sum of squares	df	Mean square	F	Sig.
Rice Phase (RP)	2.807	3	0.936	42.938	0.000
Light illumination (LI)	5.378	2	2.689	123.393	0.000
RP X LI	3.680	6	0.613	28.139	0.000

* 'No light data were collected from H1 and H3 land houses. Whereas low light data from H2 and ground floor apartment and bright light data were collected from the ground floor of apartments.

Table 2 - Effects of three different light illumination at the ground/ land floor level and four rice stages on the dispersion of *Paederus fuscipes* beetle.

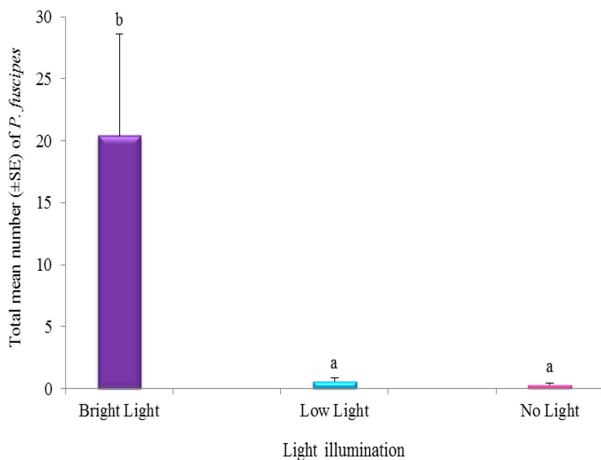
Rice cultivation phase	No light	Low light	Bright light
	Mean \pm SE	Mean \pm SE	Mean \pm SE
Ploughing stage	0.17 \pm 0.17 ^{aA}	0.0 ^{aA}	1.0 \pm 0.52 ^{bA}
Seeding stage	0.0 ^{aA}	0.0 ^{aA}	0.17 \pm 0.17 ^{bA}
Growing stage	0.17 \pm 0.17 ^{aB}	1.33 \pm 0.67 ^{aB}	11.83 \pm 1.38 ^{bB}
Harvesting stage	0.17 \pm 0.17 ^{aB}	0.67 \pm 0.33 ^{aB}	21.0 \pm 2.14 ^{bB}

*Mean value within the same row (different light illumination) with different superscript small letters are significantly different ($p < 0.05$; ANOVA).

*Mean value within the same column (rice cultivation phase) with different superscript capital letter are significantly different ($p < 0.05$; ANOVA).

* No light data were collected from H1 and H3 land houses, whereas low light data from H2 and ground floor apartment and bright light data were collected from ground floor of apartment.

seem to be the least attracted towards the low light and no light as the trapped insect counts on sticky traps placed on the same ground/ land floor level obtained the lowest weekly captures with total mean values \pm SE of 0.6 ± 0.84

**Figure 1** - Attraction of *Paederus fuscipes* beetles towards three different light illuminances at the same ground/land floor level. Data were expressed in mean \pm SE; bright light ($n = 24$), low light ($n = 12$), and no light ($n = 24$). Scale bars with the same letters showed no significant difference (Tukey's HSD; $p > 0.05$). 'No light' data were collected from H1 and H3 land houses. Whereas 'low light' data from H2 and ground floor apartment and 'bright light' data were collected from ground floor of apartment.

and 0.3 ± 0.48 , respectively. No significant differences were found for both, no light and low light illuminance, for all the rice cultivation phases ($p > 0.05$; Table 2).

However, there was a significant interaction found between different light illuminance at the same floor level and rice cultivation phase in attracting adult *P. fuscipes* to disperse from the rice field and invade human residential premises ($F = 28.139$; $df = 6, 48$; $p = 0.000$; Table 1). The number of beetles captured in the low light has slightly increased during the growing and harvesting stages compared to the other rice cultivation phase. However, bright lights have captured significantly higher numbers of *P. fuscipes* beetles for all the rice cultivation phases, particularly during the growing and harvesting stages of the rice crop ($p < 0.05$; Table 2).

Effects of different floor levels and rice cultivation phases

Paederus fuscipes was strongly attracted to the higher level compared to the lower level of the three storey apartment building throughout the main and the off rice seasons ($p < 0.05$; Fig. 2a and Fig. 2b). Overall, significantly more beetles were collected at level 3 during the whole sampling period.

During the main rice season, the number of *P. fuscipes* differed significantly among the different floor levels of the three storey apartment ($F = 41.290$; $df = 3, 32$; $p = 0.000$; **Table 3**). *Paederus fuscipes* flights towards each floor increased linearly from the lowest to the highest floor of the apartment building with a total mean of 11.8 ± 13.08 at level 0; 20.8 ± 24.67 at level 1; 38.9 ± 51.80 at level 2; and 46.9 ± 49.04 at level 3.

Paederus fuscipes dispersal flight towards human

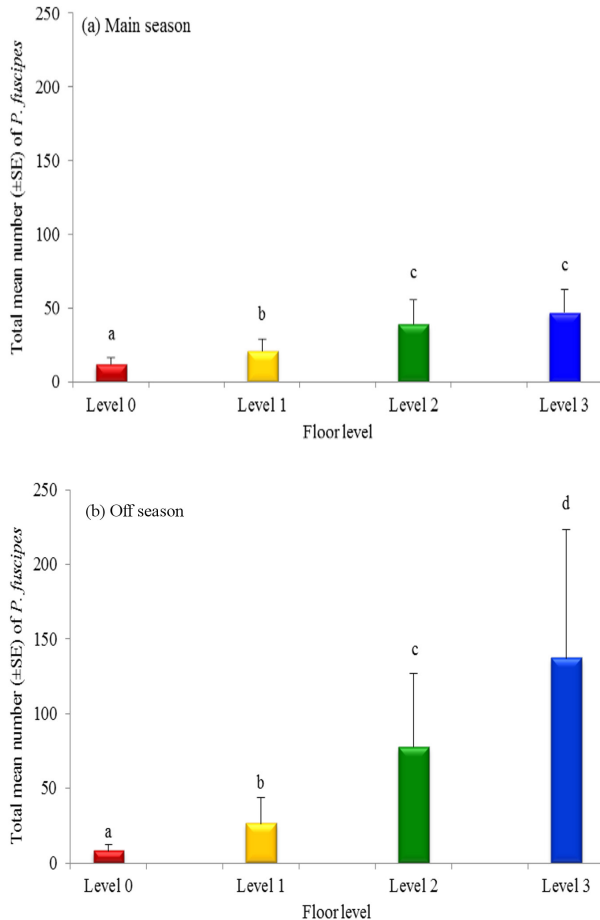


Figure 2 - Attraction of *Paederus fuscipes* beetles towards different floor levels of a three storey apartment during (a) the main season and (b) the off season of the rice cultivation phases. Data were given in mean \pm SE ($n = 12$). Scale bars with the same letters showed no significant difference (Tukey's HSD; $p > 0.05$).

Table 3 - Effects of floor level and rice cultivation phase differences on the dispersion of *Paederus fuscipes* beetles during the rice main season using two-way ANOVA.

Source	Type III sum of squares	df	Mean square	F	Sig.
Rice Phase (RP)	15.546	3	5.182	313.808	0.000
Floor Level (FL)	2.046	3	0.682	41.290	0.000
RP X FL	0.262	9	0.029	1.763	0.115

residential premises was also significantly affected by the rice cultivation phases ($F = 313.808$, $df = 3$, $p = 0.00$; **Table 3**). During the ploughing stage, the highest number of beetles was captured at level 3 with a mean of 14.33 ± 0.58 . However, the present study showed no significant difference between both level 2 and level 3 of the high-rise apartment ($p > 0.05$; **Table 4**). There was also no significant interaction found between the different building floor level of the three storey apartment and the rice cultivation phase of the main rice season ($F = 1.763$, $df = 9, 32$; $p = 0.115$; **Table 3**).

During the off rice season, a significant difference was also found in *P. fuscipes* dispersion between different floor levels of the three storey apartment ($F = 90.500$; $df = 3, 32$; $p = 0.000$; **Table 5**). Most *P. fuscipes* were captured from the top floor at level 3 compared to the other levels. Captured beetles increased gradually from the lowest to the highest floor with a total mean of 8.14 ± 15.85 at level 0; 26.5 ± 64.83 at level 1; 77.64 ± 183.86 at level 2 and 137.29 ± 322.72 at level 3 of the three storey apartment.

The number of beetles in residential premises was affected by the rice cultivation phases ($F = 397.735$, $df = 3$, $p = 0.000$; **Table 5**). More beetles were captured during the ploughing stage due to the prolonged ploughing period. A significant abundance of captured *P. fuscipes* was found throughout the rice growing stages at all levels of the high-rise building ($p > 0.05$; **Table 6**). On this rice season, a significant interaction was found between different floor levels of the three storey apartment and rice cultivation phase ($F = 6.686$; $df = 9, 32$; $p = 0.000$; **Table 5**).

Effects of light illuminance at a three storey apartment

At different levels of the apartment building, bright light has also received the highest quantity of trapped beetles at all floor levels of the three storey apartment with a total mean number of 108.3 ± 124.28 during the main rice season. Unlike the bright light, low light has only captured a smaller amount of beetles with a total mean number of 10.1 ± 12.7 . No light was discarded in this analysis due to very the insufficient number of captured beetles in the previous experiment.

In general, our results indicated that the dispersion of beetles towards the apartment building increased in

Table 4 - Effects of different floor levels and four rice stages on the dispersion of *Paederus fuscipes* beetle during the main rice season.

Rice cultivation phase	Level 0	Level 1	Level 2	Level 3
	Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE
Ploughing stage	2.0 ± 0.58 ^{aA}	3.67 ± 1.76 ^{bA}	5.0 ± 1.0 ^{cA}	14.33 ± 0.33 ^{cA}
Seeding stage	0.33 ± 0.33 ^{aB}	0.67 ± 0.33 ^{bB}	1.67 ± 0.33 ^{cB}	1.67 ± 0.33 ^{cB}
Growing stage	14.67 ± 0.33 ^{aC}	28.33 ± 2.96 ^{bC}	50.0 ± 7.37 ^{cC}	50.33 ± 5.78 ^{cC}
Harvesting stage	22.33 ± 3.33 ^{aD}	36.67 ± 3.18 ^{bD}	73.0 ± 10.02 ^{cD}	89.67 ± 7.31 ^{cD}

*Mean value within the same row (different floor level) with different superscript small letters are significantly different ($p < 0.05$; ANOVA).

*Mean value within the same column (rice cultivation phase) with different superscript capital letters are significantly different ($p < 0.05$; ANOVA).

Table 5 - Effects of floor levels and rice cultivation phase differences on the dispersion of *Paederus fuscipes* beetles during the rice off season using two-way ANOVA.

Source	Type III sum of squares	df	Mean square	F	Sig.
Rice Phase (RP)	24.090	3	8.030	397.735	0.000
Floor Level (FL)	5.481	3	1.827	90.500	0.000
RP X FL	1.215	9	0.135	6.686	0.000

Table 6 - Effects of different floor levels and four rice stages on the dispersion of *Paederus fuscipes* beetle during the rice off season.

Rice cultivation phase	Level 0	Level 1	Level 2	Level 3
	Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE
Seeding stage	0.33 ± 0.33 ^{aA}	0.00 ± 0.00 ^{bA}	0.67 ± 0.33 ^{cA}	1.33 ± 0.67 ^{dA}
Ploughing stage	5.33 ± 0.33 ^{aB}	12.00 ± 2.65 ^{bB}	28.33 ± 3.28 ^{cB}	45.67 ± 4.91 ^{dB}
Harvesting stage	6.33 ± 1.2 ^{aC}	15.00 ± 3.21 ^{bC}	46.00 ± 9.71 ^{cC}	97.33 ± 14.1 ^{dC}
Growing stage	25.67 ± 6.33 ^{aD}	96.67 ± 8.84 ^{bD}	287.33 ± 8.69 ^{cD}	496.33 ± 47.88 ^{dD}

*Mean value within the same row (different floor level) with different superscript small letters are significantly different ($p < 0.05$; ANOVA).

*Mean value within the same column (rice cultivation phase) with different superscript capital letters are significantly different ($p < 0.05$; ANOVA).

line with different floor levels. The maximum number of *P. fuscipes* was found on level 3 of the three storey apartment near the bright light with a mean number of 42.8 ± 45.44 . Conversely, the lowest mean number of *P. fuscipes* was recorded in low light on the ground floor (level 0) of the apartment with a mean of 0.6 ± 0.84 individuals. However, no significant difference was found between the captured beetles on level 2 and level 3 for both bright light and low light illuminances ($p > 0.05$; Fig. 3a). Overall, no significant interaction was found during the main rice season on the number of captured beetles near light illuminances on each different floor level of the high-rise apartment on the dispersion of *P. fuscipes* towards human dwellings ($F = 0.710$; $df = 3, 16$; $p = 0.560$; Table 7).

During the rice off season, the number of captured beetles by sticky traps located on all floor levels near the bright light showed a total mean number of 220.29 ± 525.95 individuals, followed by the low light with a total mean number of 29.29 ± 62.64 . Level 3 had the highest number of captured beetles by sticky traps placed adjacent to the

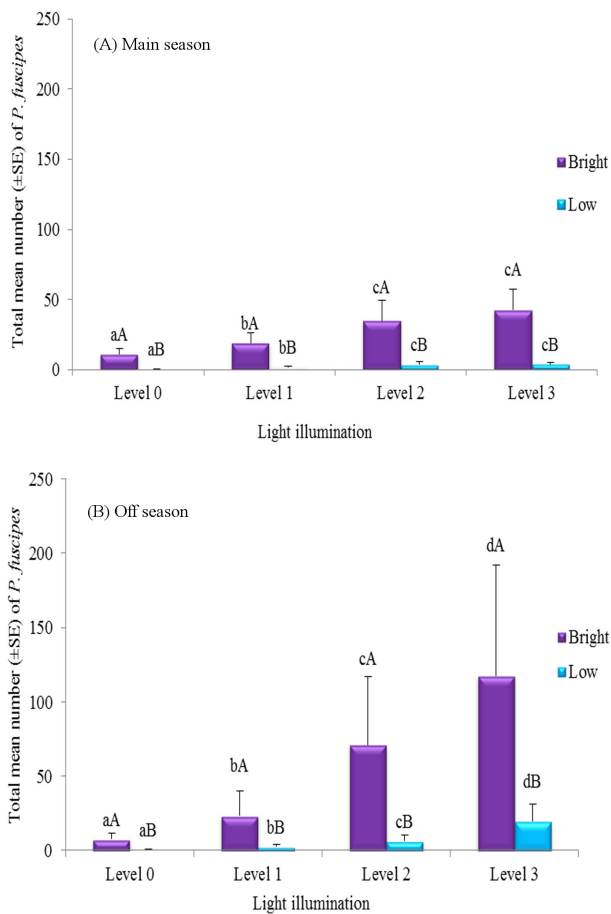
bright light with a mean number of 117.57 ± 279.07 . Conversely, sticky traps placed near the low light at level 0 captured only 0.5 ± 1.40 individuals. Thus, a significant difference was found between the captured beetles on all floor levels of the apartment building for both bright light and low light illuminances ($p < 0.05$; Fig. 3b). Due to greatest difference in the number of beetles captured at this rice season, a significant interaction was found between light illuminance at different floor levels of the high-rise apartment on *P. fuscipes* dispersal towards human dwellings ($F = 3.916$; $df = 3, 16$; $p = 0.029$; Table 7).

DISCUSSION

The primary reason why these insects come out in the evening from their foraging sites in the rice field and invade residential premises during twilight is because they are drawn to the artificial lights produced by the light bulbs. Our results indicate that bright light has a profound impact on *P. fuscipes* dispersal flights towards human dwellings.

Table 7 - Effects of light illumination at different floor levels of a three storey high-rise apartment building on the dispersion of *Paederus fuscipes* beetles using two-way ANOVA.

Rice season	Source	Type III sum of squares	df	Mean square	F	Sig.
Main season	Light Illumination (LI)	6.443	1	6.443	293.006	0.000
	Floor Level (FL)	1.629	3	0.543	24.698	0.000
	LI X FL	0.047	3	0.016	0.710	0.560
Off season	Light Illumination (LI)	6.160	1	6.160	443.042	0.000
	Floor Level (FL)	6.738	3	2.246	161.537	0.000
	LI X FL	0.163	3	0.054	3.913	0.029

**Figure 3** - Attraction of *P. fuscipes* beetles towards two different light illuminances at different floor levels of an apartment building during (a) the main season, and (b) the off season. The lowercase letter refers to the comparison between floor levels, whereas the uppercase letter refers to the comparison between two light illuminances on the dispersion of *P. fuscipes*. Scale bars with the same letters are not significantly different (Tukey's HSD; $p > 0.05$).

Most circumstances that trigger outbreaks are at high-rise apartments particularly during rice growing and harvesting stages. Most recently, Heo *et al.*⁶ stated that *P. fuscipes* are night-flying insects and are extremely attracted by bright illuminances after dusk. *Paederus fuscipes* positive phototaxis behaviour is an advantage as artificial lighting

tend to attract other insect species from the rice field such as the rice pest making them easy preys due to their vulnerability to predation.

Paederus fuscipes rove beetles are the prevalent species and lavishly found in Malaysian rice fields as an aggressive predator of the rice pests²². Therefore, our study was conducted in residential buildings nearby rice fields because *P. fuscipes* epidemics were mostly reported in people living adjacent to rice field areas. *Paederus* flew to residential premises during the nocturnal period due to light attraction, suggesting a higher possibility of infection by *Paederus dermatitis* during the night time. However, dermatitis lesions could also happen during the day time whenever a *Paederus* beetle is still present inside the residential house. In Malaysia, major *P. fuscipes* outbreaks in human dwellings occurred next to rice fields as reported in Kelantan²³ and Terengganu²⁴.

Besides Malaysia, other countries all over the world have also similar problems regarding *Paederus* sp. invasions particularly for people living nearby moisty and condensed vegetated areas such as rice agricultural farms²⁵. Approximately 62% of hostel pupils residing near rice fields were affected by dermatitis linearis in a suburban teaching hospital in Kanchipuram, India²⁶. Other similar reported cases of *P. fuscipes* attacks in India were further supported by data from the study of Gnanaraj *et al.*²⁷ and Gopal²⁸.

Our study has also found that the light factor plays an important role in attracting *P. fuscipes* beetles to disperse towards human dwellings. This statement can be further supported by an infestation of beetles in a well illuminated hospital in Sri Lanka²⁶ and in a toy building factory in central China, all due to good lighting conditions at night²⁹. In South Sudan, Iserson *et al.*³⁰ reported that due to the use of bright lights in a house compound area, an individual developed a skin lesion known as the "Nairobi fly rash" (also known as *Paederus dermatitis*) caused by the *Paederus* beetles. Our study has proved that *P. fuscipes* adults flight can even be stimulated by the light illumination from the residential areas located many miles away from their natural habitats. In this current study, the residential premises were about 32-60 m and 164 m distant from the nearest rice field,

but they could still attract the flight dispersal of *P. fuscipes* towards the land houses and the high-rise apartments. Warrant and McIntyre³¹ indicated that insects living in low light environment surroundings have compound eyes that confer a superior sensitivity to a wide range of light sources, a similar situation experienced by *P. fuscipes* populations living in low light conditions of rice fields.

Nocturnal insects are known to have enhanced sensitivity towards light sources³². Thus, *P. fuscipes* were found to be attracted to both bright and low illuminances throughout this study. However, the highest number of beetles was captured near the bright light compared to the low light due to the brightness (luminous intensity) and illuminance (luminous flux density) that *P. fuscipes* senses in space. Consequently, to minimize the contact with *Paederus* beetle, it is advised to use low intensity lighting during the night time, especially in human dwellings situated near rice field areas, as the current study showed that light illuminance has caused an attraction of *P. fuscipes* and they flew towards human residential premises.

Attraction of *P. fuscipes* towards human residential premises has also been influenced by the type of lighting used for illuminance as revealed by Lima *et al.*³³. According to Briscoe and Chittka³⁴, the insect vision perceives three specific colors of the ultraviolet, blue or green, while red or infrared lights emitted by the tungsten incandescent light bulb are invisible to certain insect species. *Paederus fuscipes* are mostly found attracted to fluorescent lightings instead of tungsten filament incandescent light bulbs³⁵. During our experiment on the dispersal of beetles towards human dwellings, fluorescent lamps were predominantly used for lighting in all landed houses and high-rise apartment building. Hence, this could be another factor that attracts beetles to invade housing areas as fluorescent lamps contain low pressure mercury-vapor gas that produces a small amount of short wave ultraviolet lights³³ or sometimes has a tinge of blue or green in color that is perceived by most insects.

According to Huang *et al.*²⁹ the victims of dermatitis linearis were mainly those living in apartments at the top and middle levels compared to the bottom level. The results of our study on *P. fuscipes* dispersal pattern at different floor levels are in line with previous reports in the literature. The present study found that higher floor level have significantly more beetle infestation compared to the lower floor levels of the three storey high-rise apartment. Besides, a reported dermatitis epidemic occurred at a higher floor level apartment buildings in Penang in the year of 2002 where thousands of high-rise apartment residents were affected by the invasion of *P. fuscipes* beetles²⁴. Subsequently, living in high-rise building is associated with a greater risk of acquiring dermatitis linearis from *Paederus* beetles

as found in our study. Henceforth, an approach to reduce the chances of becoming *Paederus* dermatitis victims, residents of upper floor levels are particularly advised to take appropriate precaution measures, such as reducing light utilization and the intensity at night, to lower the risk of *Paederus* dermatitis.

Pedgley³⁶ stated that dispersion of insects at long distances by the large-scale of wind system is a common initial factor of agricultural pests or insect-borne infections outbreaks. Thus, most insects, particularly those that are passive fliers are benefited by the wind factor to fly at heights of more than a few hundred meters above the ground level, involving them in high-altitude flights^{19,37}. The findings of this study showed that the preference of *P. fuscipes* to fly at the higher floor levels of the high-rise apartments may be entirely due to the wind-assisting migration from the rice fields. According to Drake³⁸, the number of infestation at a given altitude level also depends on the atmospheric stability in nature favoring flight activities.

P. fuscipes dispersal flight from the rice field towards human residential areas was also prompted by the rice cultivation phases. Throughout this experimental study, the number of captured beetles was the highest during the growing and harvesting stages in both rice seasons. On the contrary, an extremely low number of beetles was found to disperse towards the residential buildings during the rice seeding stage. According to Bong *et al.*¹⁸, *P. fuscipes* flight dispersal was primarily initiated once their habitats in the rice field were severely destroyed by farmers, particularly during the harvesting stage when the rice stalks and straws were cut and eventually burned.

Consequently, adult beetles might migrate and seek refuge when their breeding habitat is disturbed, which is unsuitable for beetle's harborage. Some of them will even disperse towards nearby rice crops at other rice plots that have not yet been harvested or towards other immediate places. Hossain *et al.*³⁹ claimed that the adult pests of *Helicoverpa* spp. including the natural enemies dispersed from harvested towards unharvested alfalfa to seek refuge as an immediate response to harvesting. This showed that habitat manipulation has indeed increased as a natural enemy as well as native pest abundance and movement. Moreover, in the absence of beetle favorable dense vegetation environment in the rice field for their breeding grounds, *P. fuscipes* are easily drawn towards luminescent and fluorescent light sources at human residential premises during night time especially when rice crop has been harvested⁴⁰.

Dispersal of *P. fuscipes* from the rice field was also due to host/ prey shortages following the rigorous disturbance and decimation of rice fields caused by human activities. According to Van Driesche and Bellows⁴¹, agronomic

practices also affect predator-prey interaction in crop fields. *Paederus fuscipes* is an important predator on many rice pest species in the rice field area⁴². Small phytophagous insects are generally consumed by the *P. fuscipes* beetles²². Hence, as the population of pests has massively decreased as a consequence of the destruction of crop vegetation at harvest, these polyphagous predators will move to other suitable places. The searching for food supply in other close areas to support their population needs to survive, has inadvertently brought *P. fuscipes* in contact with human beings due to light attraction at night, thus triggering dermatitis linearis outbreaks. Dermatitis linearis may occur when the adult beetle lands on human skin, and by trying to remove it physically, humans provoke the release of the toxic fluid known as pederin⁴³. According to Veraldi *et al.*⁴⁴, the exposed skin area has neutrophils and necrotic vesicles which are normally observed during the progress of the dermatitis.

Once rice seeds were sowed during the rice seeding stage, both populations of rice pests and predators will massively migrate back to the rice fields. The population of both predator and pest increased more abundantly during the rice vegetative stage, and later dispersed to human residential premises towards lights during the night time¹⁵. As a result, the number of captured beetles at residential houses also rises significantly throughout the rice growing stage apart from regular high capture rates during the harvesting phase.

Paederus fuscipes flight dispersal from the rice field towards human dwelling was primarily stimulated during the growing and harvesting stages of the rice crop. Most beetle infestation occurred when artificial lights of greater light illuminances were used, and people were at home after nightfall. Overall, significantly more beetles were captured at the highest floor level of the high-rise apartments as *P. fuscipes* flight took place at higher altitude levels while flying to avoid impending obstacles in the environment. Consequently, standard precautions need to be taken particularly during both, growing and harvesting rice stages, to reduce the risk of *Paederus dermatitis* outbreaks. The fact that the least illuminated residence had the lowest captured number of beetles suggests that lower light intensity bulbs should be used to reduce the probability of *Paederus* infestations. Hence, the most efficient light source that could be introduced for lighting purposes is the LED lamp that uses less energy to function, thus the luminous flux is lower compared to those of fluorescent lights.

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CONFLICT OF INTEREST

The authors declare that there are no conflicts of interest.

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