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Abundance, distribution and dispersal time of *Paederus fuscipes* (Coleoptera: Staphylinidae) and its association to human settings

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Abstract. Rove beetle (*Paederus* spp.) is of medical interest because it causes nasty skin lesion in humans known as *Paederus* dermatitis. In addition, *Paederus* is gaining notoriety as urban pests in human-populated areas. This study aimed to determine some factors and conditions controlling the beetle's abundance, distribution and dispersal time along with the rice field towards human setting. Flight dispersion of *P. fuscipes* towards a light trap was studied for two cycles of the rice cultivation phase; main rice season (October 2013 – March 2014) and off rice season (March 2014 – October 2014) at an infestation-prone area in Mainland Penang, Malaysia. The effects of rice cultivation phases and variable environmental conditions were considered to further understand the abundance, distribution and dispersal time of *P. fuscipes*. As shown in the present work, the number of beetles was higher in warmer and humid months, especially during the off season of the rice cultivation phase. The greatest abundance of the beetle towards residential premises was primarily seen during the rice harvesting stage. Peak time of *P. fuscipes* flight was observed starting at 20:45 hours, with threshold temperature 25–27°C and relative humidity 84–94% RH. *P. fuscipes* were capable of flying under marginally windy conditions. However, windless night favour most *P. f*uscipes flights.

INTRODUCTION

The incidence of vesicular dermatitis due to contact with the toxin containing arthropod is common worldwide (Alexander, 1984). The best known dermatitis causing beetle endemic to most tropical and subtropical regions with its only absence in Antarctica (Frank, 1988) is a member of the Staphylinidae family, *Paederus*. Their irritant fluid cause vesicating action that inhibits mitosis in eukaryotic cells (Kellner & Dettner, 1996; Haddad *et al*., 2012). Of the 50,000 staphylinid beetles distributed worldwide (Grebennikov & Newton, 2009), only 650 species of the genus *Paederus* containing the notorious pederin toxin (Willers, 2003; Ghoneim, 2013).

In Malaysia, the endemic species of *Paederus* are *Paederus fuscipes* Curtis which is commonly distributed in the rice fields (Frank & Kanamitsu, 1987; Mokhtar *et al*., 1993; Rahmah & Norjaiza, 2008). It has been given many vernacular names such as "semut semai", "semut kayap" and more commonly as "charlie" (Raju, 2002). Not all rice fields have been infested with *Paederus* population, however, should an outbreak of *P. fuscipes* occurred, the effects are quite devastating to the community, as in the case of the Aborigine community evacuation in North Australia (Todd *et al*., 1996). Besides, those living in close proximity to an infested rice fields have higher risk of receiving serious dermatitis skin lesions (Zargari *et al*., 2003; Assaf *et al*., 2010; Ali *et al*., 2013).

Paederus fuscipes is an aggressive leafhopper feeder in the rice field of West Malaysia (Manley, 1977) and mainly active during the daytime hunting for its prey. At night, this beetle has been attracted to light sources and often fly to human-populated areas causing dermatitis linearis or *Paederus* dermatitis (Morsy *et al.*, 1996; Sendur *et al.*, 1999; Nasir *et al.*, 2011). Thus, *P. fuscipes* has been regarded as a major pest in human settings (Bong *et al.*, 2015).

Under favourable environmental conditions, these beetles populations can reach a spectacular size (Bong *et al.*, 2013a). Studies have indicated that *P. fuscipes* dispersal is mostly affected by the seasonal rice crop cycle and environmental variables. According to Ghoneim (2013), Staphylinidae breeding season in the tropics appears to be dependent on the rainfall seasonality. The seasonal epidemic of dermatitis linearis incidence has been reported in the Permatang Pauh area (Ahmad *et al.*, 2010; Ghoneim, 2013). Intermittent epidemics of *P. fuscipes* beetles were observed during the drastic habitat change of the rice field throughout the harvesting stage of the rice crop and subsequent burning of the field, which triggers massive numbers of *Paederus* plaque into human settings (Bong *et al.*, 2013b). A range of abiotic factors (e.g., temperature, relative humidity, wind and rainfall) are also most likely the key variables for the outbreak of dermatitis. Since most cases of vesicular dermatitis were reported in hot, humid summer of the tropical regions (Sendur *et al.*, 1999; Al-Dhalimi, 2008) and during the rainy seasons (Kamaladasa *et al.*, 1997; Claborn *et al.*, 1999; Verma & Gupta 2012).

Data provided by Seberang Perai Municipal Council, Penang, substantial dermatitis cases were frequently reported in Mainland, Penang starting from 2004 between the month of August and October (Bong *et al.*, 2013b) and the highest reported case in 2015 was with 72 cases. Residential premises situated close to the rice field was mainly pest-ridden with *P. fuscipes* rove beetles such as in the region of Kepala Batas, Penaga, Butterworth, Permatang Pauh, Perai, Bukit Mertajam, Simpang Ampat and Nibong Tebal. Most of the *Paederus* dermatitis cases were often neglected and seldom reported due to (1) misdiagnosis with other skin problem, and some (2) being self-mediated unless they are sure the cause is by the rove beetles.

To date, knowledge of the ecology of *P. fuscipes* in causing *Paederus* plague in human setting has been very limited. Previous study by Bong *et al.* (2013b) has focused mainly on *P. fuscipes*' dispersal pattern in the residential areas using sticky trap and relate it with the environmental factors. However, as artificial lighting affects *P. fuscipes* dispersal flight during night time, it is fundamental to consider on using the light traps to estimate the abundance, distribution and dispersal time from their source natural habitat in the rice field areas towards the direction of the residential areas with the consideration of regular lighting used by the resident. Therefore, in this study, we aimed to investigate the factors associated with the abundance and distribution, also to determine the dispersal time of *P. fuscipes* individuals in one year period which coincides with a complete rice cultivation cycle. The chosen site is considered as the main outbreak area for *P. fuscipes* beetle for many years based on local reports and information from the city council department.

MATERIALS AND METHODS

Sampling site

In the Mainland region of Penang state (Northern Peninsular Malaysia), the study area lies within the rice field closed to the human residential areas (≈30 m) which is situated at Jalan Sejahtera (5° 29' 9.3171" N 100° 23' 1.3012" E), Teluk Air Tawar. Penang has a consistently warm and humid environment. The relative humidity (RH) ranges from 60 to 98% at night time, whereas the temperature ranges from 29 to 35°C at day but from 25 to 29°C at night. Although, September to November is considered to be the wettest period of the year, the average annual rainfall throughout the year is of ≈2,670 mm. The dry season with primarily minimum rainfall is between January to February (Malaysian Meteorological Department 2015).

The study of the rove beetle, *Paederus fuscipes*, was carried out in October 2013 until October 2014, for a year period during the rice crop cycle based on two seasons; (i) main rice season from October 2013 to March 2014 which consisted of five months sampling and (ii) off rice season from March 2014 to October 2014 which consisted of seven months sampling. During the main season, water requirement is met by rainfall, however, farmers are fully depended on irrigation water supplied by the Department of Irrigation and Drainage (DID) Malaysia during the off season due to dry weather conditions (Najim *et al.*, 2010). A study was done for both main and off rice seasons to assess the effect of environmental factors and rice cultivation activities on the collection of beetles.

Two experimental rice field, both covering ≈12100 m^2 was selected for the present study because of their strategic locations for sampling. Those study sites were known to have a high infestation of *P. fuscipes* in the residential premises.

Experimental design

Adult *P. fuscipes* beetles were collected using four ultraviolet (UV) suction light traps, CDC Fay-Prince Blacklight Trap (John W. Hock Co., Florida, USA). (Fig. 1). Each light traps were hung ≈1 m above ground level on an aluminium pole that was inserted in a metal base. The attracted beetles that flew onto the surface of the white panels were aspirated by a Fulton portable mechanical aspirator. The collected beetles were then transferred into 5 cm x 2.7 cm plastic vials.

The beetles trapped in the collection jar were brought back to the Laboratory of Medical Entomology, Vector Control Research Unit for identification and counting. *Paederus fuscipes* was identified on the features described by Lott and Anderson (2011).

The rice field is located at a distance of 30 m South from the housing areas. All traps were placed individually and simultaneously at four collecting points with the first trap set at the 30 m away from the housing area, followed by 55 m, 80 m and 105 m (Fig. 2).

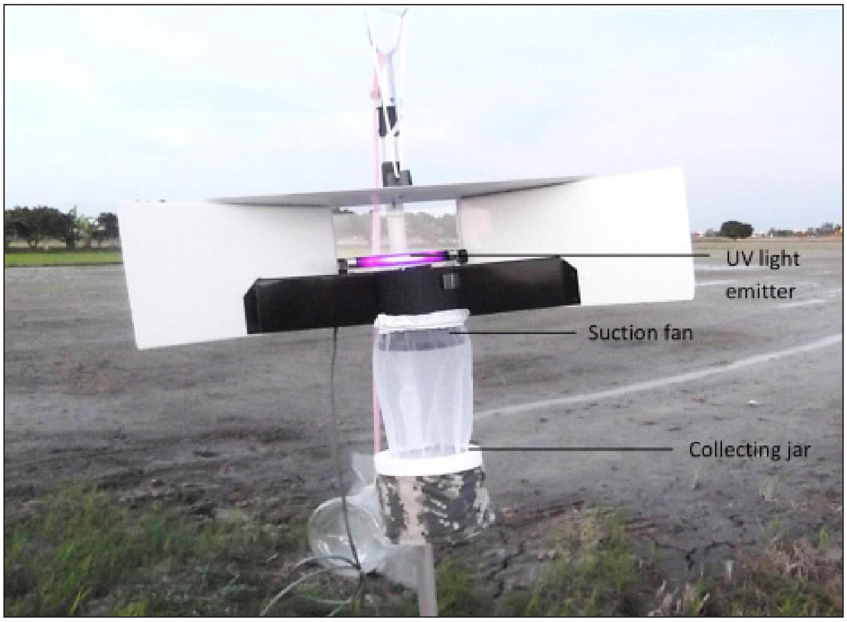

Figure 1. A close up of an ultraviolet (UV) suction blacklight trap placed in the rice field.

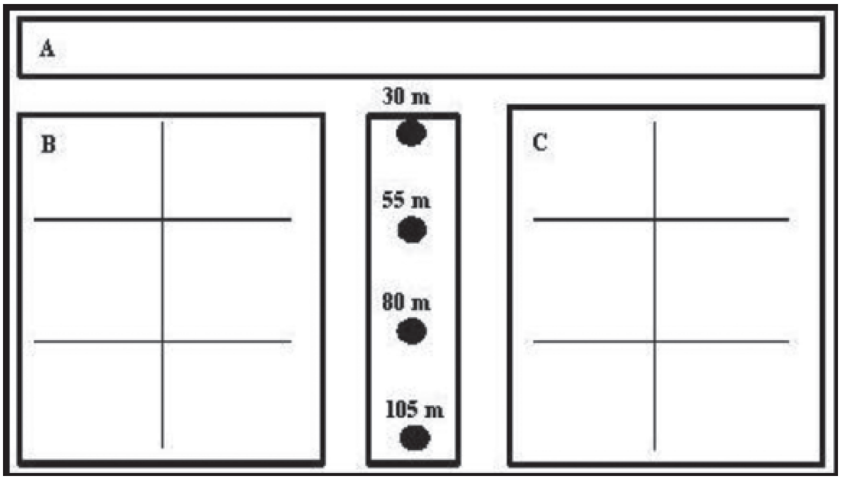

Figure 2. A schematic diagram of the experimental design (plan view). A: housing areas; B and C: rice fields; 30 m, 55 m, 80 m and 105 m are the UV light traps that were placed biweekly for attracting beetles.

Light traps were set up just before dusk on the unplanted levee of the rice fields and were switched on to attract beetle 30 minutes before the first collection of *P. fuscipes*. Beetles were collected from all light traps (n = 4) and each light trap collection was replicated for three times (for three days) once every two weeks (also known as biweekly).

Beetles were captured for five times, every 30 minutes, from 20:15 to 22:15 hours to evaluate their dispersal flight time. The half hourly study was replicated for three times (with a total of 3 replicates). Collection of *P. fuscipes* at each light traps lasted for five to ten minutes, to make sure no beetle was missed out.

Rice field phenology

Description of the various rice cultivation phases based on the physical rice field conditions is followed after Che Salmah *et al.* (1998) and Bong *et al.* (2013b). A complete cycle of rice cultivation phase consisted of four main stages; the (1) ploughing stage; where the soil is machine ploughed before seeding of rice seeds with very little water remaining in the field, (2) seeding stage; where sowing of rice seeds occurs, (3) growing stage; seeds germination until maturity then finally ripening of the rice plant, and (4) harvesting stage; where straws are harvested and burned as to fertilize the soil. Fallow is also included at this stage because harvesting takes only a few days. Fallow is the uncultivated stage, filled with short hygrophilous weeds immediately after harvesting.

Meteorological data

Half hourly temperature (°C), relative humidity (%), and speed of wind (km/h) were recorded using a wireless weather station (Ambient Weather WS-1090, Shenzhen, China) throughout the study period. Amount of rainfall per daily precipitation (mm) was obtained from the Malaysian Meteorological Department (MMD) based on the recordings from the Butterworth station (5° 27' N 100° 23' E; altitude 3.3m), Penang, Malaysia which is located 8.1 km away from the study site.

Statistical analysis

Data for biweekly captured *P. fuscipes* were analyzed separately between rice main season and rice off season in order to examine the number of beetles between two rice seasons. Multivariate analysis of variance (MANOVA) was then conducted to compare the effects of the rice cultivation phases during main season and off season on the abundance of *P. fuscipes*.

To assess the abundance of beetle based on rice cultivation phases, biweekly captures from all traps (n = 4) were pooled and averaged by three days study. Biweekly averages were used for the environmental variables. All data were tested for normality at 0.05 significance level using Shapiro-Wilk Normality test. Data were then subjected to Pearson rho analysis to assess the correlation between captures and mean environmental variables (temperature, relative humidity, wind speed and rainfall). For non-parametric test, we used Spearman rho analysis to correlate *Paederus* presence with rice cultivation phases. Each rice activity (stage) such as ploughing, seeding, growing and harvesting was numerically scored with 1 (*Paederus* present) or 0 (*Paederus* absent).

To determine the distribution of insect between each collection point in the rice field based on rice cultivation phases, biweekly captures at each trap (n = 3) were pooled and averaged by three days study. Two-way analysis of variance (ANOVA) was conducted to examine the effect of rice cultivation phases and the distance of UV light traps in the rice field. Further analysis of Post hoc multiple comparisons using Tukey's honestly significant difference (HSD) test was applied to separate the means at $\alpha = 0.05$.

To determine the influence of environmental variables on insect dispersal time, biweekly captured insects and environmental variables at each dispersal time (n = 5) were pooled and averaged separately by three days study. We then use Pearson correlation to determine the relation between dispersal times of *P. fuscipes* and half hourly environmental variables (temperature, relative humidity and wind speed). All analyses were performed using SPSS analysis version 20.0 (SPSS Inc., Chicago, IL, USA).

RESULTS

Effects of rice cultivation phases and environmental variables on insects abundance

A total of 22,936 individuals of the *P. fuscipes* species were captured throughout a year sampling period (from October 2013 until October 2014). In one complete rice cycle of the main rice season, which consisted of four rice stages, 7,035 individuals of *P. fuscipes* beetles were collected. Whereas during the off rice season, the total number of collected *P. fuscipes* significantly rose to two times-fold with an overall of 15,901 individuals. The present results indicated that there was a significant difference among captured *P. fuscipes* beetles between the main and off rice season of the rice cultivation phases throughout the course of one year sampling period (F = 3.95, df = 6,14, P = 0.02).

Abundance of *P. fuscipes* in the rice field was primarily influenced by the rice cultivation phase in both main and off rice seasons. During the main season, beetle abundance was positively correlated with the rice harvesting stage (r = 0.80, P = 0.00) with the highest mean number (±SE) of 1610 ± 766.01 captured individuals (Figure 3). Conversely, in the off season, greatest mean number of beetles were also captured throughout the harvesting stage with a highly significantly positive correlation coefficient (r = 0.71, P = 0.00). The number of *P. fuscipes* collected at this stage was mean of 1906 ± 1259.81 individuals (Figure 3).

The correlation coefficient between environmental variables and insect abundance was relatively low in contrast to rice cultivation phases. During the main season, only temperature was found to have marginally positive correlation against the abundance of beetles (r = 0.38, P = 0.04). Interestingly, both temperature and RH showed significant positive correlations with *P. fuscipes* abundance during the off season (r = 0.59, P = 0.00).

Effects of rice cultivation phases and light trap distance on insects' distribution

During main and off rice season, it was observed that the number of captured beetles was highest during the harvesting stage (P < 0.05; Figure 4a and 4b). The greatest beetle collection made at this stage was on the light trap located at the 105 m and 55 m distance with 520.33 ± 243.69 and 567.67 ± 340.87 captured individuals during main and

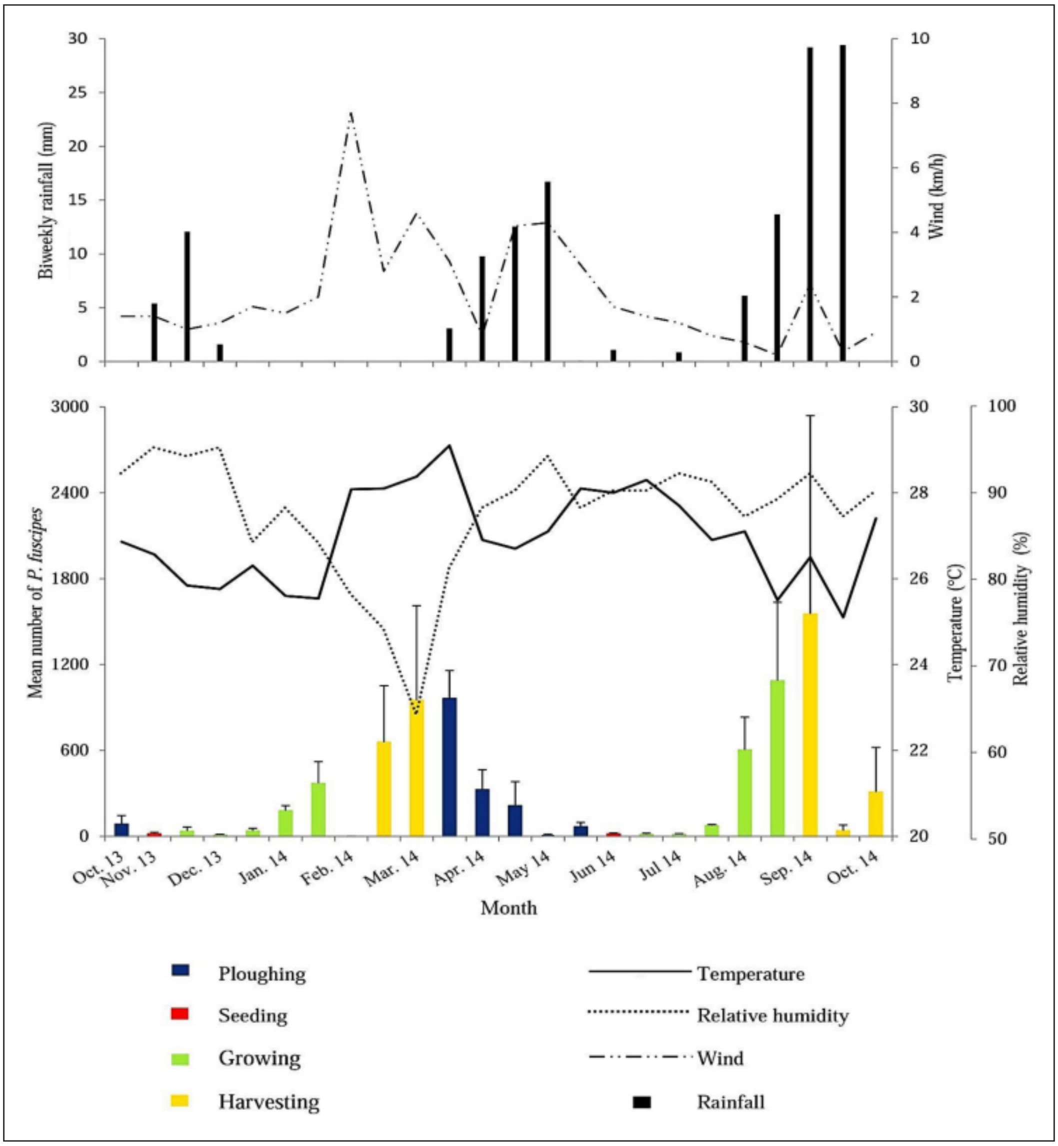

Figure 3. Mean number (± SE) of *P. fuscipes* captured biweekly for a year period during main rice season (October 2013 – March 2014) and off rice season (March 2014 – October 2014) of the rice cultivation phases versus average environmental variables.

off rice seasons (Figure 4a and 4b). Although there was no statistical difference in both main (F = 0.26; df = 3,32; P = 0.86) and off (F = 1.214; df = 3,32; P = 0.32) rice seasons based on the sampling point at each light trap distance. Interestingly, the current results showed that the distribution of beetles was in the direction of the light trap placed nearer to the residential premises throughout the harvesting stage in the off rice season (Figure 4b).

Influence of the environmental variables on insects' dispersal time

Intriguingly, we found that the captured *P. fuscipes* were also related to the environmental variables. During the main rice season, the peak time for the flight

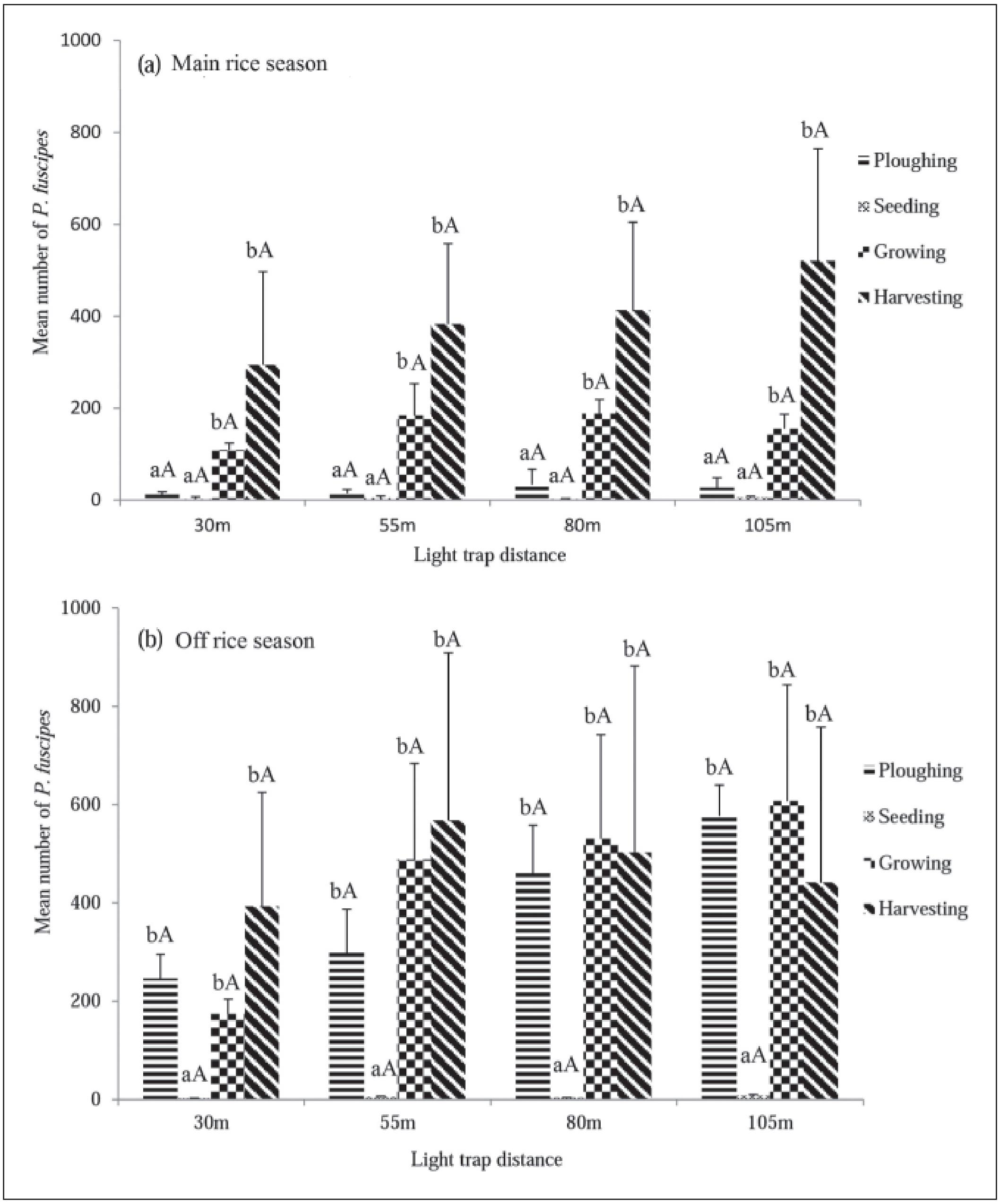

Figure 4. Mean number (± SE) of *P. fuscipes* collected in relation to (a) main rice season and (b) off rice season of the rice cultivation phases and light trap distance. The lowercase letter refers to the comparison between four rice cultivation phases on the abundance of *P. fuscipes*, whereas the uppercase letter refers to the comparison between light trap distances. Bars with same letters are not significantly different (Tukey's HSD; $P > 0.05$).

dispersal of *P. fuscipes* intensified after 21:15 hours. Perhaps it was due to the low temperature, high RH and at slower wind speed of 2.19 km/h (Table 1 and Figure 5). The Pearson correlation indicated that the *P. fuscipes* dispersal flight was negatively correlated with temperature ($r = -0.96$, $P < 0.01$) but correlated positively with the relative humidity ($r = 0.98$, $P < 0.01$). Hence, it was evident that most flights started at

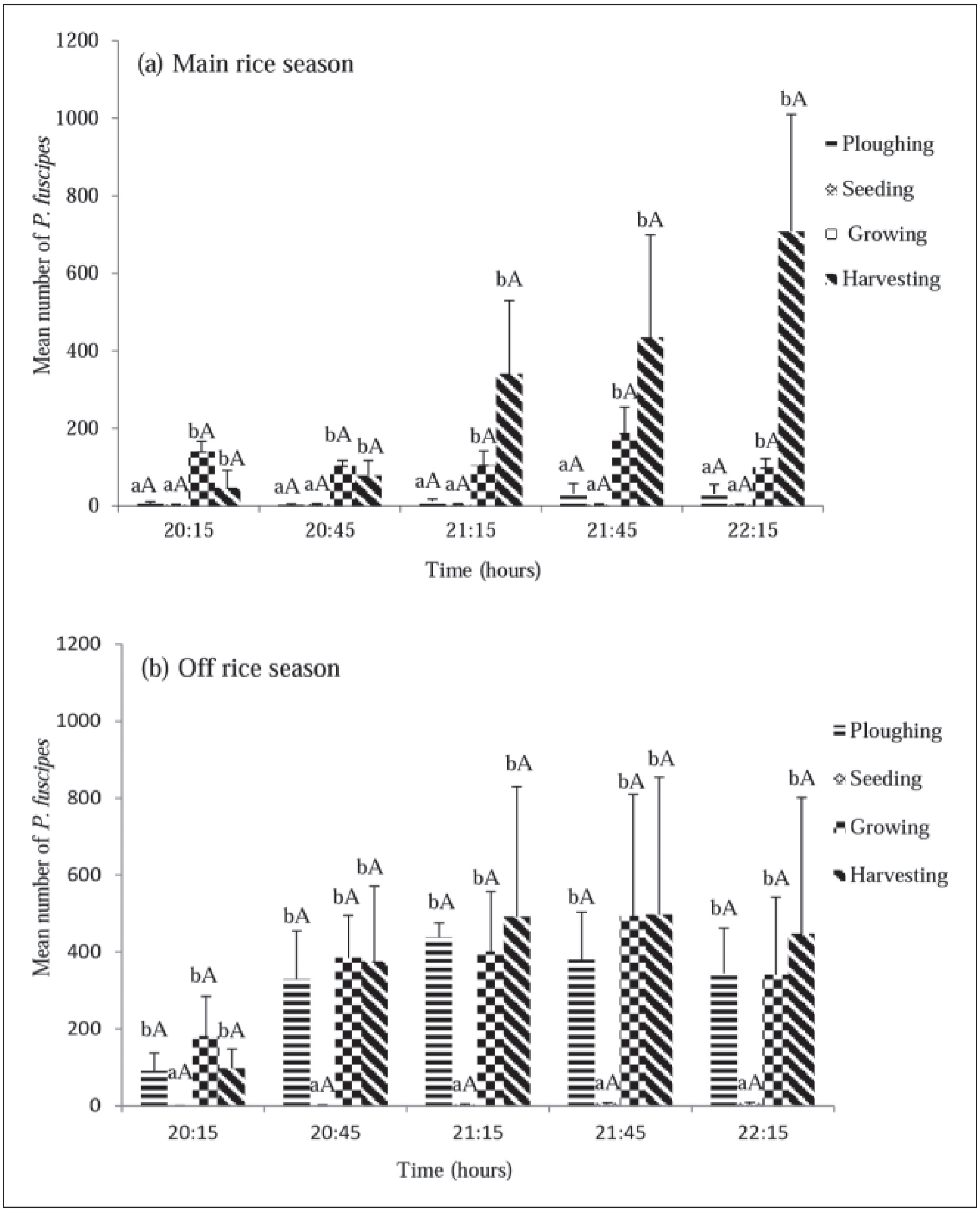

Figure 5. Mean numbers of *P. fuscipes* collected in relation to (a) main rice season and (b) off rice season of the rice cultivation phases and dispersal time. The lowercase letter refers to the comparison between four rice stages on the abundance of *P. fuscipes*, whereas the uppercase letter refers to the comparison between dispersal time of *P. fuscipes* beetle. Bars with same letters are not significantly different (Tukey's HSD; P > 0.05).

night with lower temperatures of 26°C and with higher RH ranging from 85–88% (Table 1). There was a negative correlation between wind speed and *P. fuscipes* dispersal (r = -0.77, P > 0.05), but no significant interaction was found.

Table 1. Total captures of *P. fuscipes*, dispersal time, and its associated environmental variables according to rice cycles

Rice cycle	Time (hours)	Mean captures ± SE	Temperature (°C) ± SE	Humidity (%) ± SE	Wind (km/h) ± SE
Main rice season	20:15	19.6 ± 10.64	27.5 ± 0.58	81.7 ± 2.79	2.59 ± 0.69
	20:45	18.8 ± 12.16	26.9 ± 0.66	82.9 ± 3.04	2.91 ± 1.03
	21:15	46.1 ± 41.0	26.7 ± 0.72	84.8 ± 2.97	3.08 ± 1.07
	21:45	65.8 ± 48.1	26.3 ± 0.68	86.7 ± 2.78	2.19 ± 0.70
	22:15	84.2 ± 39.4	26.1 ± 0.60	88.4 ± 1.91	2.02 ± 0.53
Off rice season	20:15	26.2 ± 20.12	28.4 ± 0.64	81.9 ± 2.77	2.50 ± 1.08
	20:45	77.7 ± 53.50	27.5 ± 0.57	88.7 ± 1.87	2.10 ± 0.97
	21:15	95.1 ± 54.89	26.9 ± 0.49	91.2 ± 2.09	1.06 ± 0.48
	21:45	98.3 ± 71.52	26.6 ± 0.53	93.5 ± 2.19	1.45 ± 0.73
	22:15	84.3 ± 56.3	26.4 ± 0.45	94.2 ± 1.84	1.64 ± 0.55

During the off rice season, *P. fuscipes* flight occurred at an earlier time with peak time starting at 20:45 hours onwards due to the great amount of beetles found. Their dispersal flight was further influenced by suitable environmental variables with considerably higher humidity level (88–94% RH) and significantly lower wind speeds that occurred only between 1.06–1.45 km/h (Table 1). A positive correlation was found between the relative humidity and *P. fuscipes* dispersion ($r = 0.93$, $P < 0.05$). In the current work, results showed a negative correlation between wind speed and *P. fuscipes* dispersal ($r = -0.72$) However, the effect of wind on *P. fuscipes* dispersion was not significant ($P > 0.05$). Pearson correlation analysis indicated that there was a negative significant correlation on temperature against *P. fuscipes* onset flight dispersal in the rice field ($r = -0.89$, $P < 0.05$).

DISCUSSION

The most essential observation in this study was that warm temperatures with higher relative humidity are ideal conditions for dispersal of *P. fuscipes*. Our study revealed that the highest number of collected *P. fuscipes* was observed primarily during the harvesting stages in both main and off rice seasons. Secondly, with the disturbance caused by humans during harvesting activities and the attraction of light sources from nearby residential premises caused adult beetles to fly from rice field closer to human setting. Previous study by Bong *et al.*, (2013b) also found that rice harvesting triggered *P. fuscipes* dispersal.

Furthermore, we observed that more beetles were captured during the off rice season in comparison to the main rice season. Nearly sixteen thousands of *Paederus* beetles found during the off rice season, suggesting that the crop yields during this season are of higher yields compared to the main rice season. According to Najim *et al.* (2010), irrigation water used in the off season due to the dry weather condition has given better yield production. Rice plants are vulnerable to insect pests throughout sowing until harvesting stage (Nasiruddin & Roy, 2012). With the intensification of irrigated rice production during the off rice season, rice pests increased massively in numbers (Way & Heong, 1994). Consequently, it causes an increased in *Paederus* beetle population density in the rice field areas due to the availability of their food sources (Bong *et al.*, 2013b).

The present study discovered that *P. fuscipes* abundance was mostly prompted by the rice cultivation phases, especially during the harvesting stage. Bong *et al.*, (2013b) stated that severely disturbed and destroyed rice habitats by human activities stimulate *P. fuscipes* flight dispersal.

Consequently, farmer's preparation for the rice fields, especially during ploughing and harvesting influences greater abundance of beetles to disperse widely. In addition to irrigated land, soil that was initially broken, turned over and flooded with water before it was further puddled and leveled during the plough stage eventually deteriorated the agricultural landscape which makes the habitat inappropriate for insect harborage. In Spain, for instance, frequent ploughing activity destroyed the nests site and soil structure which ultimately caused the harvester ants to seek refuge in a more stable habitat of field margins (Di´az, 1991).

Once rice grains had reached the physiological maturity stage, rice stalks and straws were cut down and the chopped hay was then burnt to fertilize the land for the following seeding process (Bong *et al.*, 2013b). As a result, this subsequently caused adult beetles to flee from their natural main habitats due to the unfavourable hot condition and high disturbance level such as dense smog produced from the burnt rice hay. The harvesting activity which includes cutting, stacking, handling, threshing and burning practices deprived *P. fuscipes* beetles of their foraging sites in the rice field area (Manley, 1977). Thus, the current study showed that the number of collected beetles drastically increased during the rice harvesting stage compared to other rice stages in both seasons of rice cultivations.

During the seeding stage, low number of beetles were captured due to very little amount of available food resources were available subjected to the recent sowing of rice seeds. A predator of rice pest, *P. fuscipes* controlled a number of insect pest populations in the rice field (Manley, 1977; Ghahari *et al.*, 2009). The increment of *P. fuscipes* was accompanied by the availability of food resources such as rice pests. They preyed on the leafhoppers, thrips, planthoppers and other rice pests, including drivers such as Collembola (Bilde *et al.*, 2000). *P. fuscipes* beetles will only migrate back to the rice field towards the young tillers of the rice plants, shortly after seeding, especially during the vegetative stage of rice and remain among the rice crop all through the rice cultivation period (Manley, 1977). The ability of *P. fuscipes* beetles to reorganize and reestablish following disturbance is known as ecosystem resilience. Ecosystem resilience is the amount of disturbance a system can absorb and still remain within the same state or domain of attraction (Holling, 1973).

The present study revealed that in the off rice season, higher number of beetles were found distributed closer to the housing areas during harvesting. This suggests that adult beetles started to disperse towards human residential premises predominantly once the rice was harvested. In fact, in Malaysia, most beetle infestations were particularly reported during the harvesting season, as in the incident that took place in Terengganu which involves 36 primary school students with blistering skin lesions caused by *Paederus* beetles (Rahmah & Norjaiza, 2008). Moreover, thousands of residents living in apartments and hostels were affected by dermatitis linearis caused by *P. fuscipes* rove beetles in September 2002 in Penang (Raju, 2002) which was also during the off season of the rice cultivation phase. More recently, student hostels in Selangor were also infested with *Paederus* beetles (Heo *et al.*, 2013). Ever since, multiple outbreaks have been mainly reported, and in the Northern region of the Peninsular Malaysia the number of beetle invasion in housing premises is expected to be of greater numbers (Bong *et al.*, 2015).

Besides rice seasons, environmental factors also play a role on insect abundance in the rice field area. The captured time of *P. fuscipes* at variants times of the night was most closely associated with the abiotic factors. Environmental factors have long been known as important determinants for insect flight initiation (Neoh & Lee, 2009). As the present work found that the dispersal time of beetle was correlated with the environmental variables of temperature and relative humidity. Consequently agreed with previous study done by Davidson *et al.* (2009) in Iraq, where the number of *Paederus* observed at hourly intervals showed that the beetle's dispersal activity peaked within 2100 to 2300 hours. This suggested that temperature and RH factors at this time range is optimum for *P. fuscipes* flight's activity. A study conducted in Northern Brazil on *Lutzomyia longipalpis* showed that the increase in sand flies population density was during conducive environmental condition of warm dry seasons with respect to RH and precipitations (Lewnard *et al.*, 2014).

We postulated that the abundance of *P. fuscipes* was the highest during warmer and humid months of the year, which eventually caused the greatest number of beetle infestations, especially during rice harvesting stage at a peak flight time of 20:45 hours onwards. Climatic conditions are an important determining factor for *P. fuscipes* dispersal time. The findings of the present study provide the first glimpse of the abundance, distribution and dispersal time of *Paederus* beetles and its association to human settings. Further studies are however necessary to ensure a detailed information on *Paederus* beetle flight dispersion to human residential premises. A capture-mark-release method using appropriate marking devices is recommended for a better understanding of the distance traveled by marked *P. fuscipes* to human settings.

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REFERENCES

Ahmad, A., Dianita, R. & Abdul-Hamid, M.W. A study on *Paederus* species (Coleoptera: Staphylinidae) ecology and *Paederus* dermatitis skin disease outbreak in Permatang Pauh, Pulau Pinang. Institut Pengurusan Penyelidikan, Universiti Teknologi Mara, 40450 Shah Alam, Selangor, Malaysia, **2010**, 23pp.

Al-Dhalimi, M.A. (2008). *Paederus* dermatitis in Najaf province of Iraq. *Saudi Medical Journal* **29(10)**: 1490-1493.

Alexander, J.O.D. (1984). Skin eruptions caused by beetles (Coleoptera). In Arthropods and Human Skin. *Springer London* 75-85.

Ali, A., Sujitha, K., Devika, T., Sivasankaran, M.P., Balan, K., Praveen, G.S.K., Saleem, M., Joseph, P.I. & Vijayalakshmi, T.S. (2013). A Study on *Paederus* Dermatitis Outbreak in a Suburban Teaching Research Hospital, Kanchipuram, India. Medicine Science. *International Medical Journal* **2(3)**: 764-9.

Assaf, M., Nofal, E., Nofal, A., Assar, O. & Azmy, A. (2010). *Paederus* dermatitis in Egypt: a clinicopathological and ultrastructural study. *Journal of the European Academy of Dermatology and Venereology* **24(10)**: 1197-1201.

Bilde, T., Axelsen, J.A. & Toft, S. (2000). The value of Collembola from agricultural soils as food for a generalist predator. *Journal of Applied Ecology* **37(4)**: 672-683.

Bong, L.J., Neoh, K.B., Jaal, Z. & Lee, C.Y. (2013a). Influence of temperature on survival and water relations of *Paederus fuscipes* (Coleoptera: Staphylinidae). *Journal of Medical Entomology* **50(5)**: 1003-1013.

Bong, L.J., Neoh, K.B., Jaal, Z. & Lee, C.Y. (2013b). Dispersal pattern of *Paederus fuscipes* (Coleoptera: Staphylinidae: Paederinae) in relation to environmental factors and the annual rice crop cycle. *Environmental Entomology* **42(5)**: 1013-1019.

Bong, L.J., Neoh, K.B., Jaal, Z. & Lee, C.Y. (2015). *Paederus* Outbreaks in Human Settings: A Review of Current Knowledge. *Journal of Medical Entomology* **52(4)**: 517-526.

Che Salmah, M.R., Hassan, S.T.S., Abu Hassan, A. & Ali, A.B. (1998). Influence of physical and chemical factors on the larval abundance of *Neurothemis tulia* (Drury) (Odonata: Libellulidae) in a rain fed rice field. *Hydrobiologia* **389(1)**: 193-202.

Claborn, D.M., Polo, J.M., Olson, P.E., Earhart, K.C. & Sherman, S.S. (1999). Staphylinid (rove) beetle dermatitis outbreak in the American Southwest? *Military Medicine* **164(3)**: 209-213.

Davidson, S.A., Norton, S.A., Carder, M.C. & Debboun, M. (2009). Outbreak of dermatitis linearis caused by *Paederus ilsae* and *Paederus iliensis* (Coleoptera: Staphylinidae) at a military base in Iraq. *US Army Medical Department Journal* Jul-Sep: 6-15.

Di'az, M. (1991). Spatial patterns of granivorous ant nest abundance and nest site selection in agricultural landscapes of Central Spain. *Insectes Sociaux* **38**: 351-363.

Frank, J.H. (1988). *Paederus* sensu lato (Coleoptera: Staphylinidae): an index and review of the taxa. *Insecta Mundi* **2**: 97-159

Frank, J.H. & Kanamitsu, K. (1987). *Paederus* sensu lato (Coleoptera: Staphylinidae): natural history and medical importance. *Journal of Medical Entomology* **24(2)**: 155-191.

Ghahari, H., Anlas, S., Sakenin, H., Ostovan, H. & Tabari, M. (2009). A contribution to the rove beetles (Coleoptera: Staphylinoidea: Staphylinidae) of Iranian rice fields and surrounding grasslands. *Linzer Biologische Beiträge* **41**: 1959-1968.

Ghoneim, K. (2013). Human dermatosis caused by vesicating beetle products (Insecta), cantharidin and paederin: An overview. *World Journal of Medicine and Medical Science* **1(1)**: 01-26.

Grebennikov, V.V. & Newton, A.F. (2009). Good-bye Scydmaenidae, or why the ant-like stone beetles should become megadiverse Staphylinidae sensu latissimo (Coleoptera). *European Journal of Entomology* **106(2)**: 275-301.

Haddad, V., Cardoso, J.L.C., Lupi, O. & Tyring, S.K. (2012). Tropical dermatology: Venomous arthropods and human skin: Part I. Insecta. *Journal of the American Academy of Dermatology* **67(3)**: 331.

Heo, C.C., Latif, B., Hafiz, W.M. & Zhou, H.Z. (2013). Dermatitis caused by *Paederus fuscipes* Curtis, 1840 (Coleoptera: Staphilinidae) in student hostels in Selangor, Malaysia. *The Southeast Asian Journal of Tropical Medicine and Public Health* **44(2)**: 197-205.

Holling, C.S. (1973). Resilience and stability of ecological systems. *Annual review of Ecology and Systematics* **4**: 1-23.

Kamaladasa, S.D., Perera, W.D.H. & Weeratunge, L. (1997). An outbreak of *Paederus* dermatitis in a suburban hospital in Sri Lanka. *International Journal of Dermatology* **36(1)**: 34-36.

Kellner, R.L. & Dettner, K. (1996). Differential efficacy of toxic pederin in deterring potential arthropod predators of *Paederus* (Coleoptera: Staphylinidae) offspring. *Oecologia* **107**: 293-300.

Lewnard, J.A., Jirmanus, L., Júnior, N.N., Machado, P.R., Glesby, M.J., Ko, A.I., Carvalho, E.M., Schriefer, A. & Weinberger, D.M. (2014). Forecasting Temporal Dynamics of Cutaneous Leishmaniasis in Northeast Brazil. *PLoS Neglected Tropical Disease* **8**: e3283.

Lott, D.A. & Anderson, R. (2011). The Staphylinidae (rove beetles) of Britain and Ireland. Part 7 and 8: Oxyporinae, Steininae, Euaesthetinae, Pseudopsinae, Paederinae, Staphylininae. *Royal Entomological Society London.*

Manley, G.V. (1977). *Paederus fuscipes* (Col.: Staphylinidae): a predator of rice fields in West Malaysia. *Entomophaga* **22**: 47-59.

Mokhtar, N., Singh, R. & Ghazali, W. (1993). *Paederus* dermatitis among medical students in USM, Kelantan. *Medical Journal of Malaysia* **48**: 403-406.

Morsy, T.A., Arafa, M.A., Younis, T.A. & Mahmoud, I.A. (1996). Studies on *Paederus alfierii* Koch (Coleoptera: Staphylinidae) with special reference to the medical importance. *Journal of the Egyptian Society of Parasitology* **26(2)**: 337-51.

Najim, M.M.M., Haque, M.A. & Bockari-Gevao, S.M. (2010). Irrigation energy consumption in a tropical lowland rice field. *Journal of Agricultural Sciences* **5(1)**: 1-8.

Nasir, S., Akram, W., Ahmed, F. & Sahi, S.T. (2011). Biodiversity of staphylinids in cropped area of the Punjab (Pakistan). *Pakistan Journal of Agricultural Sci*ences **48(2)**: 125-128.

Nasiruddin, M. & Roy, R.C. (2012). Rice field insect pests during the rice growing seasons in two areas of hathazari, chittagong. *Bangladesh Journal of Zoology* **40(1)**: 89-100.

Neoh, K.B. & Lee. C.Y. (2009). Flight activity of two sympatric termite species, *Macrotermes gilvus* and *Macrotermes carbonarius* (Termitidae: Macrotermitinae). *Environmental Entomology* **38(6)**: 1697-1706.

Rahmah, E. & Norjaiza, M.J. (2008). An outbreak of *Paederus* dermatitis in a primary school, Terengganu, Malaysia. *Malaysian Journal of Pathology* **30(1)**: 53-56.

Raju, M. (2002). Information on rove beetle. Seberang Perai Municipal Council Bull [Cited 2014 Dec 10]. Available from: URL: http://www.mpsp.gov.my/image/roveeng.pdf

Sendur, N., Savk, E. & Karaman, G. (1999). *Paederus* dermatitis: A report of 46 cases in Aydýn, Turkey. *Dermatology* **199(4)**: 353-355.

Todd, R.E., Guthridge, S.L. & Montgomery, B.L. (1996). Evacuation of an aboriginal community in response to an outbreak of blistering dermatitis induced by a beetle (*Paederus australis*). *The Medical Journal of Australia* **164(4)**: 238-240.

Verma, S. & Gupta, S. (2012). Ocular manifestations due to econda (*Paederus sabaes*). *Medical Journal Armed Forces India* **68(3)**: 245.

Way, M.J. & Heong, K.L. (1994). The role of biodiversity in the dynamics and management of insect pests of tropical irrigated rice. A review. *Bulletin of Entomological Research* **84(4)**: 567-588.

Willers, J. (2003). Two now *Paederus* Fabricius sensu lato (Coleptera: Staphylinidae: Paederinae) from Guinea and South Africa. *Cimbebasia* **19**: 25-30.

Zargari, O., Asadi, A.K., Fathalikhani, F. & Panahi, M. (2003). *Paederus* dermatitis in northern Iran: A report of 156 cases. *International Journal of Dermatology* **42(8)**: 608-612.