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Insect visitors of pumpkin, *Cucurbita maxima* Duch., in relation to temperature and relative humidity

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Globally, cross pollinating insects are vulnerable to environmental and climate change, in particular warmer winter and wetter summer has a major impact on pollinators. In this we analyzed the environmental factors that adversely affect some insect pollinators. Seven insect visitors were observed on pumpkin plants during the study period. Among the seven insect visitors the ant, *Camponatus compressus* (34.39%), was most prevalent, followed by the cucurbit leaf beetle (33.90%) Minimum numbers of insect visitors including the house fly, followed by small branded swift. Hymenopterans depleted and deposited more pollen compared to other orders. During cloudy day activity of these insects was found to be high from 0800 hrs to 10:00 hrs. On rainy days, activity of these insects was found to be high from 08:00 hrs to 12:00 hrs. On sunny days, the activity of these insects was found to be high from 09:00 hrs to 10:00 hrs. Foraging activity of insect visitors showed mostly negative correlation with temperature and positive correlation with relative humidity on cloudy days and sunny days. Rainy days showed negative correlation to temperature both positive, negative correlation with relative humidity in terms of insect activity. Elevated temperatures may affect the plant pollinator interaction and reduce the overall food production that leads to food crisis. Food production could be increased with the help of reducing the global warming.

Key words: Pollination, Pumpkin, Diurnal activity, Pollen depletion and deposition, Temperature, Relative humidity

Introduction

Pumpkins (*Cucurbita*) grow as seasonal crops, although they can grow wild out of season, mixed with natural vegetation. All of the *Cucurbita* species are annuals, and the plants are monoecious (Roulston *et al*., 1996). The Cucurbitaceae have long been cultivated and used by humas in many ways.

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They are introduced into cultivation more and more readily due to their dietetic fruit (Demianowicz, 1953). Successful pollination is the result of the most favorable interactions between factors which help in the synchronization of pollen liberation, stigma receptivity and pollinator activity (Baskaran and Kasthuri, 1999). The effectiveness of pollination is determined by floral structure, nectar volume, concentration and constituents, as well as the distribution of nectar among flowers (Kevan and Baker, 1983). Insects pollinate approximately 90% of flowering plant species worldwide (Bachmann and Nabahan, 1996). More than 10,000 kinds of flowers on this planet are assumed to be dependent on honey bees (Tiwari and Singh, 1983). Honey bees are reported to play an important role in boosting the yield of seeds both quantitatively and qualitatively (Goyal and Atwall, 1973), and also increase weight of seeds (Mahindra, 1979), length of siliqua, and number of seeds per pod (Kakkar and Sharma, 1991). Honey bees are the main crop pollinators in the United States, contributing $14.6 billion in the pollination service annually and wild bees are estimated to be responsible for $3.07 billion in pollination of agricultural crops each year (Morse and Galderone, 2000; Losey and Vaughan, 2006). Bees visit greater number of flowers per unit time than flies (Kitroo and Abrol, 1996). Pollen is an important biotic component of the environment which makes it a vital component in the reproductive success of plants (Haydak, 1935; Kitroo and Abrol, 1996). The number of insect visitors is directly related to temperature and inversely to relative humidity. The flower visiting speed of honey bees has been shown to increase with temperature (Cirudarescu, 1971). Physical environmental factors that influence the flower visitors are light, light intensity, temperature, humidity, rainfall, cloudiness, wind and rain (Kevan and Baker, 1983). Hence, in this study we examined the effect of environmental factors specifically on insect pollinators of *Cucurbita maxima* Duch.

Materials and methods

The investigation was carried out at Ayya Nadar Janaki Ammal College, Sivakasi, Tamilnadu situated at 9.28 N and 77.48 E. The town is located at an altitude of 100.07m comprises an area of 6.89 sq.km and has population of 65,593. Sivakasi experiences dry and relatively hot weather throughout the year. The town gets scanty rainfall during the monsoon season. It contains 5.88% of industrial area has a vast amount of agricultural crops (62.10 %) for the food source of the industrial town. The maximum temperature during summer is 39^0C and during winter it is 23^0C. The mean humidity is 76.2%. The annual rainfall is very low, average of 812 mm. insufficient rain and ground water drive most of the farmers to cultivate vegetables, like the Cucurbitaceae

family, which do not require much irrigation. Hence our choice of investigated plant became pumpkin, *Cucurbita maxima* Duch.

Composition and relative abundance of flower visitors

Pumpkin fields were visited during December, 2008 to March, 2009 to study the following parameters. The composition and relative abundance of flower visitors was determined following method of Jyothi *et al*. (1990). The relative abundance of each insect visitor was calculated by watching the number of visits by each insect visitor for 10 minutes/hr from 0600 hrs to 1800 hrs. The insect visitors to the flowers available in one square meter were studied. From this data the total number of visits per day was calculated.

Pollen depletion and deposition

Pollen depletion and deposition was studied following the method of Solomon (1945). The collected insects were anaesthetized immediately by placing chloroform soaked cotton plug over the mouth of specimen tube. The specimen tubes were taken to the laboratory and insects were taken out for examination with the help of stereo microscope - OPTIK India (ASN-66). A fine jet of 70% ethyl alcohol was sprayed over entire surface of insects and brushed with a small camel hair (Camlin 001300) brush. Then this sample was poured into a counting chamber (Weber England, B.S.748). The pollen was counted using pollen grain chamber. Pollen deposition represents the amount of pollen deposited on stigma by an insect. To assess the amount of pollen deposited on a stigma, the flowers bagged with polythene cover (28cm x 20cm) just before anthesis were opened one by one for the insect to visit following the method of (Reddi and Reddi, 1983). When such flowers received first visit, their stigmas were plucked and examined for number of pollen deposited following the pollen count method as mentioned earlier.

Pollen carrying capacity

The bees collecting pollens were trapped randomly, anaesthetized with chloroform and weighed. Later the pollen loads were brushed from their bodies on to a watch glass and weight of the bees were determined again (Snedecor and Cochran, 1967).

Diurnal activity of insect visitors

Diurnal activity is foraging activity of insect visitors during day time from 06:00 hrs to 18:00 hrs. This was studied following the method suggested by (Abrol, 1987). Measurements of environmental factors such as temperature and relative humidity were calculated using Fischer Polyam Engs. Pvt. LTD, Germany. The data were analysed correlation co- efficient.

Results

Composition and relative abundance of flower visitors

The inflorescence of *Cucurbita maxima* was found to be visited by seven species of insects viz; little bee, *Apis florea;* Indian bee , *Apis cerana indica;* ants *Camponotus compressus*; digger bee, *Anthophora accidentalis;* cucurbit leaf beetle, *Aulacophora femoralis;* small branded swift, *Pelopidas mathias* (Hesperiidae)*;* and housefly, *Musca domestica.* The results indicate that the ant *C. compressus* (34.39%); cucurbit leaf beetle, *A. femoralis* (30.90%) and little bee, *A. florea* (22.97%) were dominant visitors of flower. Small branded swift, *P. mathias* (0.75%) was less dominant visitor, followed by digger bee and housefly (Table. 1).

Pollen depletion and deposition

Comparatively, hymenopterans depleted and deposited more amount of pollen. The amount of pollen depleted by little bee, *A. florea* was high (520 Pollen grains/Insect visit); and it was followed by the Indian bee, *A. c. indica* (470); digger bee, *A. accidentalis* (360); cucurbit leaf beetle, *A. femoralis* (320). The ants, *C. compressus* (300) and house fly, *M. domestica* were found to deplete lower numbers of pollen grains. The amount of pollen deposited by *A.c. indica* was high (450 pollen grains /stigma/insect visit) followed by, *A. florea* (350) and *A. femoralis* (320). Generally the hymenopterans were found to deposit higher number of pollen grains. Regarding the efficiency of pollen deposition, the Indian bee, *A. c. indica* deposited more amount of pollen (96%) followed by cucurbit leaf beetle, *A. femoralis* (78%) and the little bee, *A. florea* (67%). The housefly was found to be less efficient in pollen deposition (Fig. 1)

Pollen carrying capacity

Comparatively, hymenopterans carried a greater amount of pollen load than other taxa (Table 2). Amount of pollen load carried by ants, *C. compressus* was high (9 mg), followed by little bee and Indian bee, *A. florea* (4 mg). The housefly *M .domestica* (0.5), carried the least pollen load.

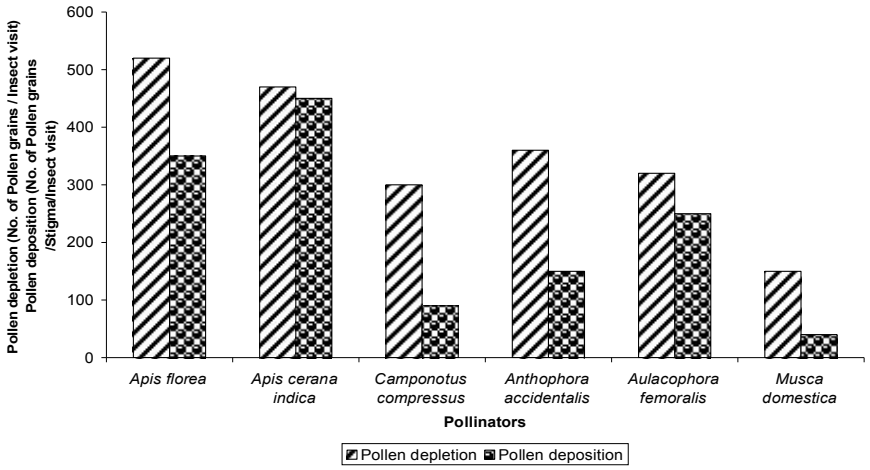

Fig. 1. Pollen depletion and deposition by different insect visitors of pumpkin, *Cucurbita maxima* Duch

Diurnal activity of insect visitors

Diurnal activity of insect visitors on cloudy days

The diurnal activity of *A. florea*, *A.c. indica, A. femoralis*, and *C. compressus*, was observed to begin around 0700 hrs and cease around 1800 hrs on cloudy days. Activity of these insects was found to be high from 0800 hrs to 1000 hrs when the temperature ranged from 25-32^{o}C and relative humidity 81-85%. The activity of these insects was found to decrease after 1400 hrs, when the temperature ranged from 24-34^{o}C and relative humidity 67-86% (Table. 3 & Fig. 2)

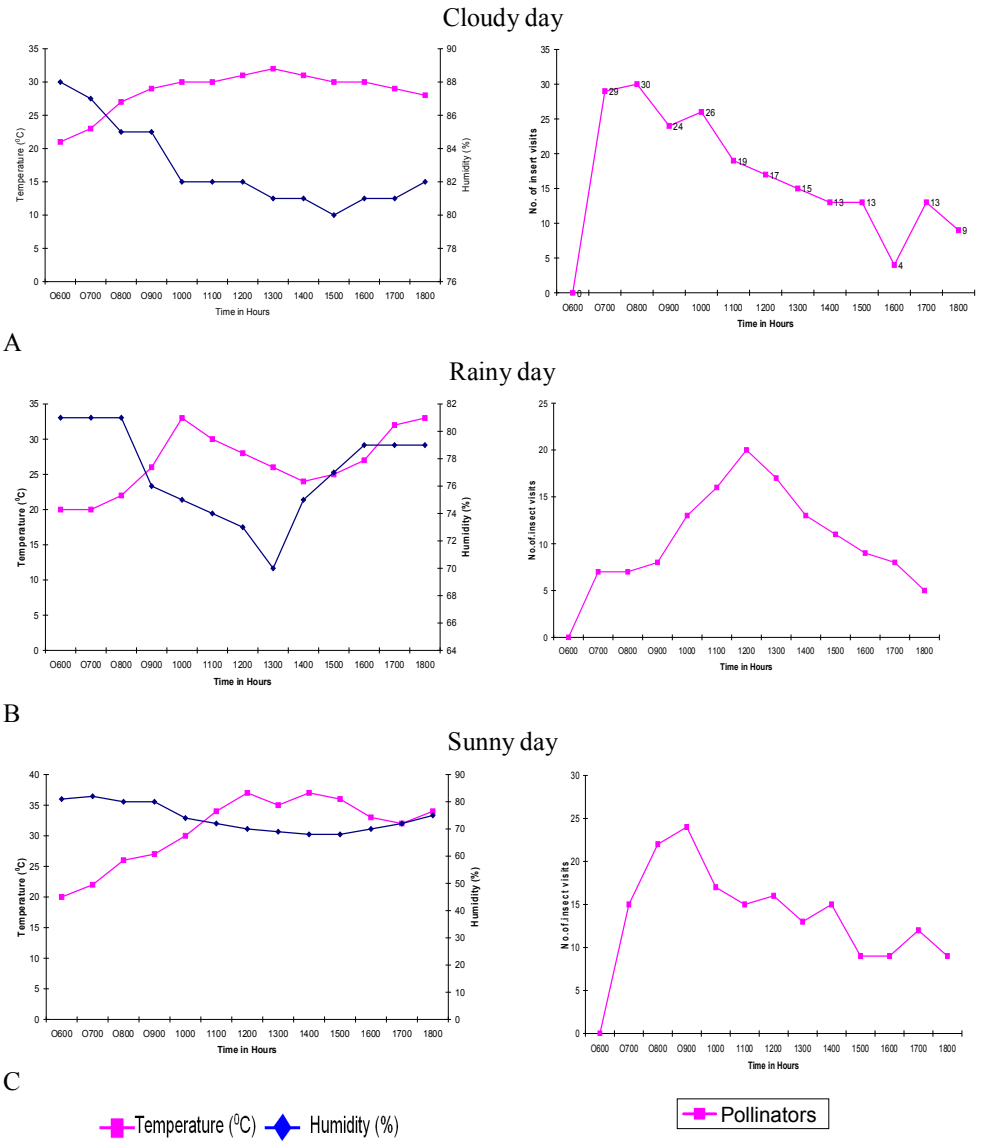

Fig. 2. Diurnal activity of various pollinators of pumpkin, *Cucurbita maxima* Duch. in relation to temperature and relative humidity. Figs 1a, 2a & 3a show correlation between temperature and relative humidity and Figs 1b, 2b & 3b show insect visitor time based on cloudy days, sunny days and raindy days

Diurnal activity of insect visitors on rainy days

Diurnal activity of *A florea, A c. indica, A. femoralis* and *C. compressus*; *P. mathias*, and *M. domestica* was observed to begin around 0700 hrs and cease

around 1800 hrs on rainy days. On rainy days, the activity of these insects was found to be high from 0800 hrs to 1200 hrs when the temperature ranged from 24-30^{o}C and relative humidity was 75-83%. Activity of these insects was found to decrease after 1300 hrs, when temperature ranged from 27-33^{o}C and relative humidity was 69-80%.

Diurnal activity of insect visitors on sunny days

The diurnal activity of the *A. florea, A. c. indica*, *A. femoralis* and *C. compressus* was observed to begin around 0700 hrs and cease around 1800 hrs on sunny days. On sunny days, activity of these insects was found to be high from 0900 hrs to 1000 hrs, when the temperature ranged from 27-30^{o}C and relative humidity 75-83%. Activity of these insects was found to decrease after 1500 hrs, when temperature ranged from 23-34^{o}C and relative humidity 69-78%.

Correlation co-efficient analysis of insect visitors of pumpkin

Activity of the little bee showed negative correlation with temperature and positive correlation with relative humidity on rainy days, cloudy days and sunny days (Table 4). Activity of the Indian bee, *A. c. indica,* showed negative correlation with temperature, and positive correlation with relative humidity on cloudy days. On rainy days, the activity showed both positive and negative correlation with temperature and negative correlation with relative humidity. On sunny days, the activity showed negative correlation with temperature, and positive and negative correlation with relative humidity. The activity of flower visitors like cucurbit leaf beetle showed positive correlation with temperature and relative humidity on cloudy days. The activity of insects showed positive correlation with temperature, and negative correlation with relative humidity on rainy days. On sunny days, the activity of insects showed positive and negative correlation with temperature and positive correlation with relative humidity. The ant, *C. compressus,* showed both negative and positive correlation with temperature and relative humidity. The activity of digger bee, *A. accidentalis,* showed negative correlation with temperature and positive correlation with relative humidity on cloudy days.

Discussions

The present investigation is an attempt to study the insect pollinators of pumpkin, *Cucurbita maxima* Duch. The flowers of *C. maxima* were found to be visited by seven insect species. Similar results were reported by Kevan and

Baker (1983) and showed that Hymenoptera is the most important order of anthophilous insects. According to Baskaran *et al*. (1997), hymenopterans comprised 98% of the foragers in ridge gourd, *Luffa accutangula* Roxb. The ants, *C. compressus*; little bee, *A. florea;* the cucurbit leaf beetle, *A. femoralis*; digger bee, *A. accidentalis* and the housefly, *M. domestica*, were found to be the most abundant visitors of pumpkin. Similar results were obtained followed by Solomon Raju and Ezradanam (2002) who reported that Formicidae were frequent flower visitors. Honey bees, like *A. florea*, *A. c. indica* and *A. dorsata* were main pollinators of the red sandalwood *Pterocarpus santalinus* F. In sunflower, *Helianthus annuus*, dominant visitors were *A. florea*, *A.c. indica* and *A. dorsata* (Panda *et al*., 1991).

Coleopterans are considered to be the most primitive pollinators (Dieringer *et al*., 1998). The Diptera are also considered primitive pollinators. In the present study, the honey bees were found to deplete and deposit more pollen grains in pumpkin compare to other orders of insects. Pollen is the most sought floral reward. It is a vital food for many insects, especially Apidae, many beetles, flies, thrips, springtails, butterflies and some other arthropods. *Apis dorsata* (865 pollen grains/insect visits) carried more pollen than the other two honey bee species.i.e. *A. cerana indica* (530 pollen grains/insect) and *A. florea* (240 pollen grains/insect) in red sanders (Rao and Solomon Raju, 2002). In the case of ridge ridge gourd, *Luffa accutangula,* honeybees, such as *A. dorsata, A. cerana indica* and *A. florea,* were found to deplete and deposit most pollen grains (Baskaran *et al*., 1997). Nagaraja and Rajagopal (2000) reported that maximum pollen carried by rock bee were 36.71 mg.

Activity of the seven species of insects was found to be high from 0800 hrs to 1000 hrs. On rainy days activity of these insects was found to be high from 0800 hrs to 1200 hrs. Activity of insects was found to be high from 0900 hrs to 1000 hrs in sunny days. Weather characteristics play an important role in determining the frequency of insect visits (Mc Call and Primack, 1992). The insect visits commenced early in the morning and were most active from 0800-1200hrs in *Withania somnifera* (L.) (Kaul *et al*., 2005). The foraging activity of honey bees showed negative correlation with temperature and positive correlation with relative humidity on cloudy days, rainy days and sunny days in the case of pumpkin plant. The foraging activity of ants showed positive correlation with temperature and negative correlation with relative humidity on cloudy days in pumpkin. Abrol and Kapil (1986) reported that foraging activity of *Megachile lanata* on *Crotalaria juncea* L. flowers showed positive correlation with air temperature, light intensity, solar radiation and nectar sugar concentration fluctuation, but was negatively correlated with relative humidity, soil temperature and wind velocity.

Further studies are needed to explore stigma receptivity, temporal variation in floral rewards, influences of light intensity, solar radiation and wind speed on foraging activity of insects. These may reveal new and valuable plants in terms of increased the productivity of vegetables. It may also aid conservation of the plants.

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Table 1. Composition and relative abundance of flower visitors of pumpkin, *Cucurbita maxima* Duch

Pollinators	Number of visits per day															Total	Relative Abundance (%)
	December 2008									January 2009							
	3rd	7th	9th	13th	14th	15th	16th	21st	25th	1st	4th	8th	11th	18th	19th		
HYMENOPTERA																	
Little bee, *Apis florea*	65	50	67	45	20	48	25	27	24	24	22	12	47	39	38	553	22..97
Indian bee *Apis cerana indica*	16	9	11	10	6	23	6	6	2	5	5	-	3	3	9	114	4.73
Digger bee *Anthophora accidentalis*	6	5	18	15	-	6	-	-	-	13	-	-	4	4	7	78	3.23
Ants *Camponotus compressus*	34	-	59	29	56	34	92	80	80	77	89	59	66	48	25	828	34.39
COLEOPTERA																	
Cucurbit leaf beetle *Aulacophora femoralis*	56	-	42	28	69	31	55	65	47	64	51	89	63	57	27	744	33.90
LEPIDOPTERA																	
Small branded swift *Pelopidas mathias*	1	8	2	5	-	1	1	-	-	-	-	-	-	-	-	18	0.75
DIPTERA																	
House fly *Musca domestica*	4	5	14	-	-	15	-	6	-	-	-	3	-	6	20	73	3.03

Table 2. Pollen carrying capacity of insect visitors of pumpkin

Insect visitors	Body weight with pollen (mg)	Body weight with out pollen (mg)
HYMENOPTERA		
Little bee, *Apis florea*	366 *	360
Indian bee *Apis cerana indica*	356.5	352.5
Ants *Camponatus compressus*	241.25	232
COLEOPTERA		
Cucurbit leaf beetle *Aulacophora femoralis*	385.75	383.5
DIPTERA		
House fly *Musca domestica*	245.5	245

*Mean of three replicates

Table 3. Diurnal activity of insect visitors of Pumpkin, *Cucurbita maxima* Duch

Time in hours	03.12.2008 (Cloudy day)								
	A	**B**	**C**	**D**	**E**	**F**	**G**	**T(^{O}C)**	**RH (%)**
0600	-	-	-	-	-	-	-	22	83
0700	9*	3	1	3	-	-	-	24	82
0800	12	2	1	4	4	-	-	26	84
0900	9	-	-	3	3	-	-	25	86
1000	7	-	-	2	3	-	-	24	86
1100	8	-	-	5	2	-	-	24	87
1200	9	-	1	7	3	1	-	26	87
1300	2	2	1	6	7	-	-	26	87
1400	2	2	1	5	10	-	-	28	86
1500	4	4	1	5	2	-	4	28	85
1600	3	2	-	4	-	-	-	27	85
1700	-	1	-	7	-	-	-	26	85
1800	-	-	-	5	-	-	-	24	86

* Value indicates the numbers of insect visits over 10 minutes during one hour along with temperature and relative humidity

Table 4. Correlation analysis of the certain environmental factors influencing the flower visitors on rainy days, cloudy days and sunny days

Pollinators	Rainy days					Cloudy days								Sunny days	
	03.12.2008	**09.12.2008**	**13.12.2008**	**11.01.2009**	**18.01.2009**	**07.12.2008**	**15.12.2008**	**01.01.2009**	**04.01.2009**	**08.01.2009**	**14.12.2008**	**06.12.2008**	**21.12.2008**	**25.12.2008**	**19.01.2009**
HYMENOPTERA	-0.6140 *	-0.7502	-0.7088	-0.6936	-0.7948	-0.7948	-0.6229	-0.2444	-0.8541	-0.9546	-0.7145	-0.8222	-0.8139	-0.8749	0.3063
	-0.5403●	0.8809	0.5867	0.4394	0.3484	0.9392	0.8416	0.3900	0.7468	0.9694	0.6179	0.6102	0.1773	0.8659	0.4298
Little bee *Apis florea*															
Indian bee	-0.0573	0.7872	0.7163	-	0.3692	0.3442	0.4933	+1	0.7412		-0.6187	0.4236	-0.8029		-0.4193
Apis cerana indica	-0.0456	0.7872	0.7163		0.3692		0.4933	+1	-0.4684	-	0.3454	-0.5703	-1	-	0.4205
Digger bee	-	-0.6777	-0.7271	-0.4568	-0.6520	1	0.2465	0.7559							
Anthophora accidentalis		0.8724	0.6864	0.3499	0.6482	-1	0.9684	0.1889	-	-	-	-	-	-0.4562	-
Ants	0.3769	-0.4415	0.2688	0.3892	0.1555	-0.1889	-0.3316	0.0180	0.7187	0.3969	0.3439	0.6955	-0.0274	1.5516	-0.7276
Camponotus compressus	0.3769	0.2593	-0.1650	0.3892	0.2364	0.1889	0.6185	-0.2432	0.0216	-0.8494	0.0133	-0.6196	-0.3220	0.4163	0.6963
COLEOPTERA	0.4983	0.0480	0.4336	0.1588	-	1	0.4382	-0.1887	-0.4472	0.1381	0.2112	-0.4973	-0.2442		0.0834
Cucurbit leaf beetle *Aulacophora femoralis*	0.5632	0.0602	-0.4955	-0.2537	-0.4555	-1	0.6525	0.2112	-0.4384	-0.8617	0.0822	0.4302	0.2664	-	-0.0357
LEPIDOPTERA	-	-	+1	-	-	-	-	-							-0.4595
			-1					0.2112	-	-	-	-	-	-	0.4375
Small branded swift *Pelopidas mathias*															
DIPTERA	-	0.2335	-	-	-	-	0.2469	-			-	-	-		
House fly *Musca domestica*		0.2169		0.6965			0.7163		-	-				0.6914	-

*Value indicates the correlation coefficient analysis of temperature and ● Indicates correlation coefficient relative humidity in relation to rainy, cloudy and sunny days