

Assessment of Hymenoptera and Non-Hymenoptera Insect Bite and Sting Allergy Among Patients of Tropical Region of West Bengal, India

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Abstract

West Bengal, India, is inhabited by abundance and variety of insects that triggers sensitization in some humans to inhalant allergens and/or insect stings/venoms. Lack of research on this topic prevented accurate diagnosis and proper follow-up treatments to patients suffering from insect-induced allergies. The aim of our study was to identify the allergy-causing insects and evaluate resulting sensitization among a study population in West Bengal, India. The skin prick test (SPT) evaluated sensitivity of 450 patients who sought treatment at the Allergy and Asthma Research Center from July 2017 to June 2018. Eight insect allergens were tested: Common Black Ant (*Lasius niger*, Linnaeus 1758), Fire Ant (*Solenopsis invicta*, Buren 1972), Honey Bee (*Apis cerana indica*, Fabricius 1798), Common Wasp (*Vespula vulgaris*, Linnaeus 1758), Mosquito (*Aedes aegypti*, Linnaeus in Hasselquist 1762), American Cockroach (*Periplaneta americana*, Linnaeus 1758), House Fly (*Musca domestica*, Linnaeus 1758), and Grasshopper (*Gesonula punctifrons*, Stal 1861). From a total of 450 patients evaluated, 370 patients had positive SPT reaction from at least one of the 8 insect allergens tested. Sensitivity to some Hymenoptera insects (common black ant, 87.62%; fire ant, 84.59%; and honey bee, 67.02%) was found in higher proportion than non-Hymenoptera group (mosquito, 66.67%; American cockroach, 33.33%; house fly, 10.41%; and grasshopper, 5.14%). There was significant difference in sensitivity among child, adolescent, and adult ($P < 0.001$). While female patients showed more sensitivity than males to SPT, the difference was statistically insignificant. In regards to occupation, farmers and bee keepers were most sensitive of field workers sensitive to Hymenoptera-derived allergens.

Key Words: black ant, mosquito, insect allergen, skin prick test, urticaria

Insects, accounting for a large proportion of multicellular biodiversity on the Earth (Stork et al. 2015), are ubiquitous in the environment. Many insects are responsible for a variety of different allergic symptoms in human. For instance, venom from the insects of the order Hymenoptera can cause allergic reactions that are usually resolved, yet can create serious allergic problems, such as urticaria, palpitation, breathlessness, bronchial asthma, anaphylaxis, etc., requiring immediate treatment. The extent of these insect-induced allergic reactions varies with different geographical regions and ethnic groups. Yellow jacket and honey bee stings mostly induce allergic reactions in Central and Western Europe, whereas the paper wasp sting reactions are predominant in Southern Europe (Spillner et al. 2014). Cockroaches, especially

the American cockroach (*Periplaneta americana*, Linnaeus 1758), moths, butterflies, and silk worms (Araujo et al. 2014) are the most common non-Hymenoptera insects that also elicit different allergic manifestations in human. Immediate hypersensitivity reactions to cockroach allergens can occur in some urban inhabitants, which may result in bronchial asthma (Arruda and Pomés 2013), presumably due to the prevalence of cockroaches in the urban environment and the continual exposure to the allergens. In Asian countries, such as India, the bites or stings of the mosquitoes, honey bees, as well as inhalant allergens of house flies and grasshoppers trigger type-I hypersensitivity reactions resulting allergic diseases to both the urban and rural population (Kausar et al. 2005, Bhattacharya et al. 2018, Mehta et al. 2018).

Occupational exposure to different insects, like honey bees, wasps, and ants, frequently triggers allergic sensitization (Bilo and Bonifazi 2009). Globally, 5–7.5% of the total population generally suffer from hypersensitivity reactions and 32% of the honey bee keepers get affected owing to honey bee and wasp stings (Antolín-Amérigo et al. 2014, Ludman and Boyle 2015). The allergic reactions triggered by the insects may be countered by the accurate diagnosis and proper management that depend on precise identification of the causative insects. The accurate prognosis could guide us in future to set up the avoidance strategy for preventing further sensitization. In this context, the skin prick test (SPT) results are generally regarded as “gold standard” (Bousquet et al. 2012) for the diagnosis of allergic sensitization.

Recently, the insect-induced allergic diseases have become a serious health concern in the Western countries (Spillner et al. 2014), yet developing countries, such as India, are ill-prepared to address this health concern. Therefore, to evaluate the allergies triggered by various insects, a large pool of data is required from the patients of this country. West Bengal, a large province in India with >40 million inhabitants, has tropical wet and dry climatic regions creating a variety of habitats that are ideal for insect numbers and diversity. In this study, we assessed the sensitization to different insects among the study population, occupational as well as general, who visited the Allergy & Asthma Research Centre, West Bengal, India, during July 2017 to June 2018 having complaints of different allergic symptoms caused by insect bites, stings, or inhalation. Also investigated was whether different demographic factors, such as age, sex etc., play any role to the insect allergen sensitivity of the patients and the inter-relation between the insect-borne allergic diseases and the habitat and the occupation of the patients. This work, therefore, could provide a much-needed insight into the epidemiology and the sensitization rate against some Hymenoptera and non-Hymenoptera insect allergens and the related prophylactic measures, especially in the context of developing countries.

Materials and Methods

Patients and Control

In total, 450 patients seeking treatment at Allergy and Asthma Research Centre, West Bengal, India, from July 2017 to June 2018, were selected for the study. The patients, suffering from various allergic manifestations such as urticarial rash, bronchial asthma due to insect bites and venomizations, were grouped into three different age groups [child (5–12 yr), adolescent (13–19 yr), and adult (20–50 yr)]. Patients unwilling to participate or suffering from other chronic diseases were excluded. Personal histories of the patients were recorded from a questionnaire that requested age, sex, habitat, house condition (old/new, humid/dry), occupation, and clinical features: running nose, persistent cough, sneezing, wheezing, breathlessness, itching of eyes, and skin rash. Based on the available reports (Bureau of Applied Economics and Statistics, Department of Statistics and Programme Implementation 2015) regarding the density of population, development, amenities, employment opportunities, education level, nature of vegetation, and human settlements, the home environments of the patients were categorized as urban, semi-urban, or rural.

Skin Prick Test

The SPT wheal diameter of 450 patients were recorded for 8 insect allergens: Common Black Ant, *Lasius niger*, Linnaeus 1758 (Hymenoptera: Formicidae); Fire Ant, *Solenopsis invicta*, Buren 1972 (Hymenoptera: Formicidae); Honey Bee, *Apis cerana indica*,

Fabricius 1798 (Hymenoptera: Apidae); Common Wasp, *Vespula vulgaris*, Linnaeus 1758 (Hymenoptera: Vespidae); Mosquito, *Aedes aegypti*, Linnaeus in Hasselquist 1762 (Diptera: Culicidae); American Cockroach, *Periplaneta americana*, Linnaeus 1758 (Blattodea: Blattidae); House Fly, *Musca domestica*, Linnaeus 1758 (Diptera: Muscidae); and Grasshopper, *Gesonula punctifrons*, Stal 1861 (Orthoptera: Acrididae). The allergenic extracts were supplied by Credisol, Mumbai, India. The selection of the allergens was done on basis of the SPT reports of the nasobronchial allergic patients in western part of India (Patel and Choudhary 2012) and the presence of specific insect species within West Bengal, India (Jana et al. 2006). Histamine (10 mg/ml) acid phosphate and 0.9% normal saline were used as positive and negative controls, respectively. The skin reactions were recorded after 15 min of pricking and regarded as positive if wheal diameter was found greater than that of the positive control i.e., 3 mm (Bousquet et al. 2012). According to the intensity of the SPT reaction, the patients were further categorized into three groups, such as mild (wheal diameter between 3 and 5 mm), moderate (above 5–7 mm), and severe (>7 mm).

Statistical Analysis

The independent mean two-sample *t*-test was performed to determine any significant differences between the male and female patients. The one-way analysis of variance (ANOVA) followed by post-hoc Tukey's test were done to determine the significance of the SPT sensitivity differences among the three age groups. The inter-relation between the insect-borne allergic diseases and the habitat of the patients were also determined using the one-way ANOVA. Independent mean two sample *t*-test was used to find whether there was any association between the occupation and insect sensitivity. All statistical analysis was carried out using Prism ver. 7 (Graph Pad Prism, San Diego, CA).

Results

Attributes of the Patients

Patients suffering from insect sting allergy mostly showed urticarial symptoms, whereas those suffering from insect bite predominantly showed bronchial asthma (Table 1). Other factors like the area of living and the detailed occupation (Table 2) of the patients were also recorded; the majority of the patients were coming from the semi-urban areas (48.44%) and mostly were field-workers (73.11%) in occupation living in old and humid houses (85.78%). The clinical and demographic characteristics of the patients are given in Table 1 along with the odds ratio (OR) and 95% CI. OR defines the measurement of association that compares the ratio of odd of one event in the presence of another event to the odd of first event in the absence of second event (Szumilas 2010). In Table 1, the odds ratio in favor of the female patients has been compared with the male patients for the risk of insect allergy; the female patients were found 1.75 times more likely to be allergic than the male patients. Similarly, as the OR shows, adults are 4.5 and 3.5 times more prone to allergy than adolescents and children, respectively. The risk of field workers is more likely than the corporate ones by an OR of 20.22. The odds of exposed risk in old and humid houses are much higher (OR= 37.69) than new and dry houses.

Incidence of Sensitization Toward Insect Allergens by SPT

Among 450 subjects, 370 (82%) patients had positive reactions against any one of the above 8 insect allergens tested out of which

Table 1. Demographic and clinical characteristics of patients ($n = 450$)

Characteristics	n (%)	95% CI, P -value	OR = odds ₁ /odds ₂
Sex			
Female	246 (54.67), Odds = 2.66	95% CI = [2.07, 3.41], $P < 0.0001$	OR _{female/male} = 1.75
Male	204 (45.33), Odds = 1.52	95% CI = [1.19, 1.93], $P = 0.0007$	
Age group			
Child (5–12 yr)	47 (10.44), Odds = 0.13	95% CI = [0.09, 0.18], $P < 0.0001$	OR _{adult/child} = 3.5
Adolescent (13–19 yr)	39 (8.67), Odds = 0.10	95% CI = [0.07, 0.15], $P < 0.0001$	OR _{adult/adol} = 4.5
Adult (20–50 yr)	364 (80.89), Odds = 0.45	95% CI = [0.36, 0.56], $P < 0.0001$	OR = 1 (Reference)
Diagnosis			
Rhinitis	159 (35.43), Odds = 1.83	95% CI = [1.45, 2.31], $P < 0.0001$	OR _{rhin/asth} = 1.21
Bronchial asthma	179 (39.71), Odds = 1.51 (147- insect bite)	95% CI = [1.20, 1.90], $P = 0.0004$	OR = 1 (Reference)
Atopic dermatitis/ Urticaria	112 (24.86), Odds = 3.02 (95- insect sting)	95% CI = [2.35, 3.88], $P < 0.0001$	OR _{rhin/urti} = 0.61
Area of living			
Semi-urban	218 (48.44), Odds = 1.82	95% CI = [1.43, 2.32], $P < 0.0001$	OR = 1 (Reference)
Rural	125 (27.78), Odds = 0.53	95% CI = [0.41, 0.68], $P < 0.0001$	OR _{Semi-urban/rural} = 3.43
Urban	107 (23.78), Odds = 0.41	95% CI = [0.31, 0.53], $P < 0.0001$	OR _{Semi-urban/urban} = 4.44
Occupation			
Field workers	329 (73.11), Odds = 10.11	95% CI=[7.57, 13.50], $P < 0.0001$	OR _{field/corp} = 20.22
Corporate workers	121 (26.89), Odds = 0.50	95% CI=[0.39, 0.65], $P < 0.0001$	
House condition			
Old and humid	386 (85.78), Odds = 6.03	95% CI = [4.49, 8.10], $P < 0.0001$	OR _{old/new} = 37.69
New and dry	64 (14.22), Odds = 0.16	95% CI = [0.12, 0.22], $P < 0.0001$	

The ratio of odd of one event in the presence of another event to the odd of first event in the absence of second event is compared in form of OR. P -value indicates the significance of the above comparison in each case.

Table 2. Summary of patients' occupation

Field workers ($n = 329$)			Corporate workers ($n = 121$)		
Occupation	Number	%	Occupation	Number	%
Bee keeper	105	31.91	Serviceman/woman	95	78.51
Construction worker	13	3.95	Large shop owner	26	21.49
Farmer	124	37.69			
Salesman/woman	19	5.77			
Small shop owner	56	17.02			
Courier service delivery man/woman/postman	12	3.65			

13% patients showed sensitivity toward fire ant only. Among the Hymenoptera insects, positive response was found highest for the common black ant (87.62%), followed by the fire ant (84.59%), honey bee (67.02%), and common wasp (30.27%). Interestingly, in case of non-Hymenopterans, the sensitivity to the mosquito (*Ae. aegypti*) was found highest (66.67%), rather than the American cockroach (33.33%), house fly (10.41%), and grasshopper (5.14%) (Table 3).

A significant variation was found in terms of number of patients presenting with mild and severe SPT reactions ($F = 4.436$, $df = 23$, $P = 0.0247^*$), whereas difference between moderate to either mild or severe reactions were found nonsignificant. Figure 1 depicts the intensity of skin reactions to the aforementioned eight allergens. Here, no error bars could be seen in the figure as they are smaller than the minimum of the scale of the graph. This points to the precision of the measurement of the wheal diameter (within the errors of ± 0.1 mm only).

The cross-reaction among the above allergens has been shown in Fig. 2 using Venn diagram as per the general formula: $n(A \cup B \cup C) = n(A) + n(B) + n(C) - n(A \cap B) - n(B \cap C) - n(C \cap A) + n(A \cap B \cap C)$, where $n(A)$, $n(B)$, and $n(C)$ are individual probabilities of the events A, B, and C (in Fig. 2, we omit the alphabet n),

Table 3. No. of sensitivity against eight insect allergens by SPT

Allergen name	No. of positive reactions (%)
Common black ant	324 (87.62)
Fire ant	313 (84.59)
Honey bee	248 (67.02)
Mosquito	247 (66.67)
Common wasp	112 (30.27)
American cockroach	123 (33.33)
House fly	39 (10.41)
Grasshopper	19 (5.14)

respectively. From the recorded data of each event ($n(A)$, $n(B)$, $n(C)$), their intersection (common events, i.e., $n(A \cap B \cap C)$) and unions (at least any one event, i.e., $n(A \cup B \cup C)$), this Venn diagram is drawn. The number of sensitized patients in the figure is shown as proportional to the area of corresponding portion of the ellipses. In the figure, ABC denotes $n(A \cap B \cap C)$, while ab, bc, and ca indicate $n(A \cap B)$, $n(B \cap C)$, and $n(C \cap A)$, respectively. The cross-sensitization among the three Hymenopterans such as the black ant, fire ant, and honey bee has been found much higher (45% of total sensitization) than the non-Hymenoptera insects, i.e., the mosquito, American cockroach,

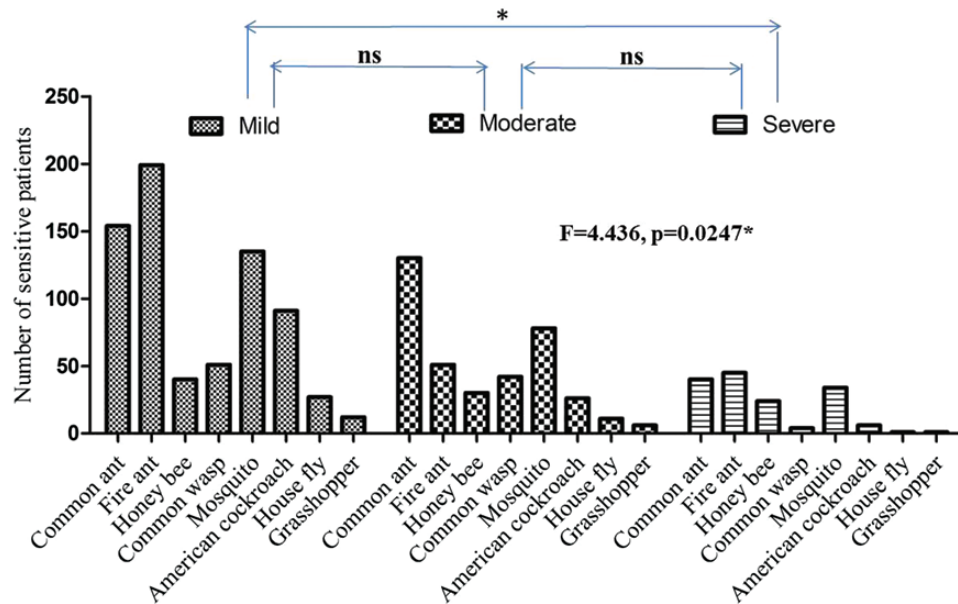


Fig. 1. Intensity of skin reactions against eight insect allergens (**P*-value significant).

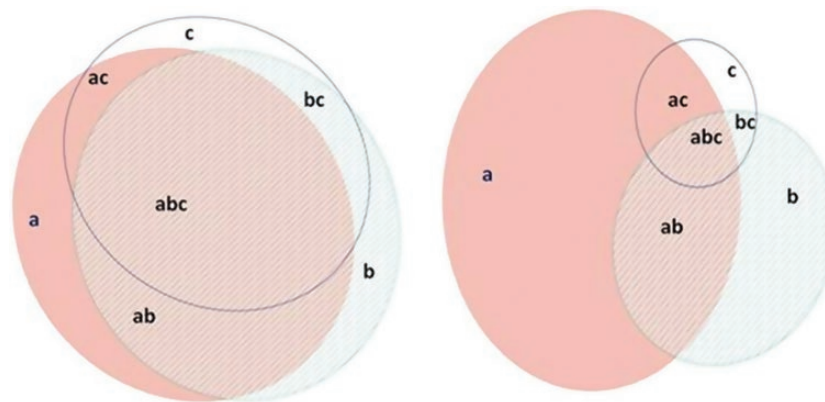


Fig. 2. Proportional Venn diagram showing the cross-reactivity in Hymenoptera (left panel) and non-Hymenoptera (right panel) insects. For the left panel, the three ellipses denote sensitivity to black ant (pink ellipse), fire ant (white filled shaded ellipse), and honey bee (shown by blue elliptical curve without any filling inside). The areas are given as $a = 51$, $b = 33$, $c = 20$, $ab = 69$, $bc = 24$, $ca = 17$, $abc = 175$. For the right panel, the three ellipses denote sensitivity to mosquito (pink ellipse), American cockroach (white filled shaded ellipse) and house fly (blue elliptical curve without any filling inside). The areas are given as $a = 170$, $b = 58$, $c = 8$, $ab = 49$, $bc = 3$, $ca = 15$, $abc = 13$. Color version of the figure is available online.

and house fly (only 4% of total sensitization), which is also evident from the Venn diagram. The three circle Venn diagram has only been shown here, while the cross-sensitization among four or more components has been neglected, the latter being much smaller in values.

Patient Sensitization in Accordance with Age and Sex

The one-way ANOVA study indicated that the difference of allergen sensitivity (for the complete set) among different age groups (Table 4) was statistically significant ($F = 12.29$, $df = 23$, $P < 0.001$). However, a posteriori test like post-hoc Tukey's test was run to differentiate which groups actually differed. Post-hoc Tukey's Honestly Significant Difference (HSD) test showed that there was a statistically significant difference between the groups, child and adult ($Q = 6.50$, $P = 0.001$). Similar result was also found between the

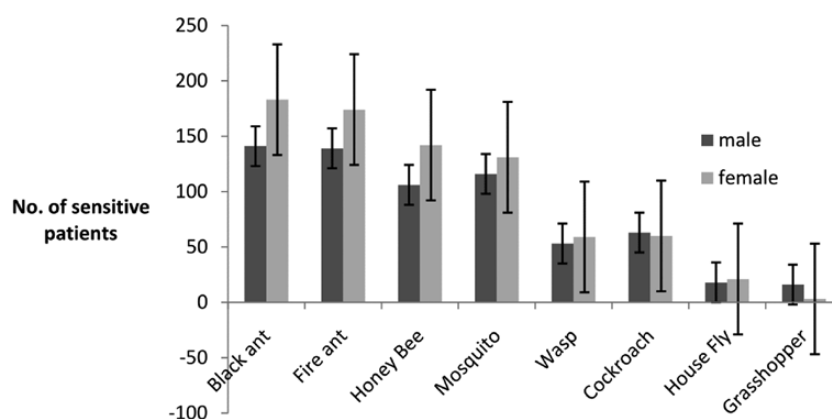
adolescent and adult ($Q = 6.74$, $P = 0.001$), whereas the pairs child and adolescent differed insignificantly ($Q = 0.24$, $P = 0.90$). It should be noted that if individual allergens were selected, no significant difference could be found among the different age groups. One-way ANOVA followed by Tukey's HSD and pairwise Scheffe statistics also showed similar trend. In case of skin sensitivity between the male and female patients, two-sample *t*-test was performed, but no significant differences was detected ($t = 0.49$, $df = 7$, $P = 0.09$). The gender-based number of sensitive patients for different allergens has been shown in Fig. 3. The error bars in the figure demonstrate the SE.

Allergic Response According to Habitat and Occupation of the Patients

The sensitivity of the patients living in different habitats (Table 5) did not show any significant variation ($F = 2.636$, $df = 23$, $P = 0.09$) as revealed by one-way ANOVA test. Post-hoc Tukey's HSD test also found insignificant association when compared in pairs. However,

Table 4. SPT sensitivity against eight insect allergens among different age groups

Age groups	Common black Ant	Fire ant	Honey bee	Mosquito	Common wasp	American cockroach	House fly	Grass-hopper
Child ($n = 39$)	33 (84.62%)	33 (84.62%)	25 (64.10%)	17 (43.59%)	11 (28.21%)	5 (12.82%)	4 (10.26%)	6 (15.38%)
Adolescent ($n = 32$)	27 (84.38%)	25 (78.13%)	20 (62.50%)	12 (37.50%)	7 (21.88%)	3 (9.37%)	0	1 (3.13%)
Adult ($n = 299$)	264 (88.29%)	255 (85.28%)	203 (67.89%)	218 (72.91%)	94 (31.44%)	115 (38.46%)	35 (11.70%)	12 (4.01%)
P -value	$F = 12.29$, $df = 23$, $P = 0.0003^{***}$ (One way ANOVA) * P -value significant							
Child and adolescent	Tukey's HSD $Q = 0.24$, $P = 0.90$, p -value not significant							
Child and adult	Tukey's HSD $Q = 6.50$, $P = 0.001^*$, * P -value significant							
Adolescent and adult	Tukey's HSD $Q = 6.74$, $P = 0.001$, * P -value significant							
For individual allergens	Insignificant association by one-way ANOVA and Tukey's HSD							

**Fig. 3.** Insect allergens sensitivity between two sexes (P -value not significant).

a significant difference in sensitivity between corporate and field workers was detected ($t = 4.158$, $df = 7$, $P = 0.004^*$; Table 6).

Discussion

Allergy incidence in India due to insects is widespread in both indoor and outdoor environments, and therefore, there is a public health need to recognize the most likely insect allergens so that proper treatments can be initiated. The present study focused on the common insects and their sensitization toward the patients of West Bengal, India. Other research has established that the intensity of allergic reactions to some common insects is different in certain Asian and Indian populations (Prasad et al. 2009, Bemanian et al. 2012). These differences may be attributed to the different geographical climates and the variation of flora therein.

This study has indicated that >66% of the total study population have been sensitized to the mosquito (*Aedes aegypti*). This mosquito's saliva consists of at least eight heterogeneous allergens (Peng et al. 2016) and can sensitize individual human being through inhalation and bites, which may induce local and systemic allergic reactions. Earlier studies had also established the inhalational allergies to cockroaches (Bernton and Brown 1964, Schal and Hamilton 1990). Interestingly, the American cockroaches (*Periplaneta americana*) have adapted the art of cohabitation with humans, acting as a major source of indoor allergens in urban and lower socioeconomic settings (Slater et al. 2007, Arruda and Pomes 2013), particularly in the study area of India (Dey and Chakraborty 2016, Bhattacharya et al. 2018). The excretory products of the cockroaches contain several allergens that may remain in the indoor environment for several months even after the removal of cockroaches from the houses. In our present study,

allergic sensitivity to cockroaches has been found in 33% of the patients. For Hymenoptera, this study revealed that the maximum sensitivity is due to the common black ant (87%) followed by fire ant (84%). The most prevalent stinging ants are fire ants, known for their aggressive attacking behavior (Partridge et al. 2008, dos Santos Pinto et al. 2012, Touchard et al. 2016). In West Bengal, the maximum sensitivity against common black ants and fire ants are anticipated as the majority of the patients belong to semi-urban or rural areas, where the houses are in damp conditions, highly favorable for multiplications of those insects. Honey bees are generally not aggressive and sting only when they sense danger to the nest or the queen and the reactions results local to anaphylactic shock and even death (Alaux et al. 2009). Interestingly, our study revealed that >66% of the patients were sensitive toward the honey bee venom. However, according to Bilo and Bonifazi (2009), the prevalence of systemic reactions in adults against honey bee stings ranges from 0.5 to 3.3% only in the United States and 0.3 to 7.5% in Europe. In this study, this huge difference could be due to the fact that majority of patients keep bee colonies at the house due to their involvement in such occupation. In Table 6 among 329 patients, 181 were honey bee-sensitive field workers. Among 181 field workers, 105 were associated with apiculture in their houses and 63 were general farmers. They were reported to be stung one or more times, during their outdoor activities. This study has also indicated that >30% of the subjects have allergies against wasps that, unlike honey bees, are aggressive, therefore may have resulted in frequent exposure (Przybilla and Rüff 2012, Ludman and Boyle 2015).

Table 5 shows that the urban patients are less sensitive to all the insect allergens than the rural and semi-urban patients. The reason could be that the urban people are less exposed to insects than the

Table 5. SPT sensitivity against eight insect allergens according to habitat

Habitat	Common black ant	Fire ant	Honey bee	Mosquito	Common wasp	American cockroach	House fly	Grass-hopper
Semi-urban (<i>n</i> = 218)	157	152	120	128	54	60	19	9
Rural (<i>n</i> = 125)	90	87	69	54	31	34	11	5
Urban (<i>n</i> = 107)	77	74	59	65	27	29	9	5
<i>P</i> -value	$F = 2.636$, $df = 23$, $P = 0.09$ (one-way ANOVA); <i>P</i> -value not significant							
Semi-urban versus Rural	Tukey's HSD $Q = 2.65$, <i>p</i> -value not significant							
Semi-urban versus Urban	Tukey's HSD $Q = 2.95$, <i>P</i> -value not significant							
Rural versus Urban	Tukey's HSD $Q = 0.3$, <i>P</i> -value not significant							
For individual allergens	Insignificant association by one way ANOVA and Tukey's HSD							

Table 6. SPT sensitivity against eight insect allergens according to occupation

Occupation	Common black Ant	Fire ant	Honey bee	Mosquito	Common wasp	American cockroach	House fly	Grass-hopper
Field workers (<i>n</i> = 329)	237	229	181	195	82	90	29	14
		105 Bee keepers	63 Farmers	13 Others				
Corporate workers (<i>n</i> = 121)	87	84	67	52	30	33	10	5
<i>P</i> -value	$t = 4.158$, $df = 7$, $P = 0.004^*$ (* <i>P</i> -value significant)							

rural and semi-urban people. However, no significant difference of sensitivity exists for individual allergens in the three habitat groups, similar to the findings of Mahesh et al. (2010).

This study revealed the co-existence of sensitization (45% of total) against the Hymenoptera insects possibly due to the presence of the two members of the Formicidae family. The cross-reaction may be explained by the close phylogeny. Hoffman et al. (1988) reported that the patients found radioallergosorbent test (RAST) reactive to fire ant venom had also been RAST (containing IgE antibodies bounded to *S. invicta* I (Sol i I)) reactive to the honey bee venom. Although understanding the difference between clinically relevant true cross-sensitization and clinically irrelevant cross-reacting carbohydrate determinants is not possible without RAST; yet on a preliminary basis, this work has showed high degree of cross-sensitivity among Hymenoptera group that may be helpful for the choice of venoms for immunotherapy (Muller et al. 2013). Among the non-Hymenoptera, the sensitization to the cockroach has often been extended to the house fly and also to other insects. This cross-reactivity could possibly evolve due to the presence of tropomyosin found in the allergen extracts (Wittman et al. 1994).

This study also revealed the significant differences of sensitivity among different age groups. We found adults (20–50 yr) more sensitive to insects than children (5–12 yr) and adolescents (13–19 yr), similar to the findings of Ghosh et al. (2017). The reason behind this observation could be due to the frequent exposure to insects during their field work. Warpinski and Bush 1990 also reported that the allergic reactions to insects were more significant and fatal in adults, though the most systemic reactions occurred in children and the adolescents. Besides, children were found highly sensitive against the insect allergens, especially for ants, as shown in earlier literature (Bahna et al. 1988). However, in our study, the individual allergen based ANOVA followed by Tukey's test did not yield significant results. But, this result may be an artifact due to smaller sample size, when we test the data for the individual allergens in comparison to the whole group. Nevertheless, the ANOVA may show significant differences in sensitivity in case of factoring the entire data rather than a part of it.

In this study, the female patients were found to be more sensitive to all the eight insect allergens than the male patients, although the difference of sensitivity was found to be statistically nonsignificant.

This observation is in concurrence with Alimuddin et al. (2018). This discrepancy in sensitivity could be attributed to the expression of female sex hormone receptors on mast cell (Zierau et al. 2012).

This study has limitations as some of the clinical properties could not be recorded completely. Several patients did not follow-up at the hospital for treatment due to financial problems. People without any history of insect allergy were not selected for this study. Moreover, the study did not concentrate on allergic medication in the questionnaire.

In conclusion, the study highlighted the sensitization to inhalant allergens or insect venom in a cohort of patients from West Bengal, India. This work also analyzed the demographic characteristics of the patients and thereby explored the role of occupation, habitat, sex and age on the different insect-driven allergic symptoms, especially in a developing country. The study is perhaps the first conducted in West Bengal, India, on the topic of the problem of sensitization to insect bite and stings or inhalant allergens. Further studies in different parts of India are needed for the development of strategies against the insect stings and bites and also to adopt therapeutic measures.

Statement of Ethics

The Human Ethics Committee of Allergy and Asthma Research Centre, West Bengal, India approved this study (CREC-AARC Ref: 004/17). Written or thumb-printed informed consent was obtained from patients.

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