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Debabrata Mukherjee
Kendriya Vidyalaya RBNM Salboni, Paschim Medinipur, West Bengal, India

Soumen Roy
Department of Zoology, City College, Kolkata, India

Tanmay Bhattacharya
Department of Zoology, Vidyasagar University Medinipur, India

Kamales Kumar Misra
Department of Zoology, Asutosh College, Kolkata, India

Correspondence
Kamales Kumar Misra
Department of Zoology, Asutosh College, Kolkata, India

Studies on the association between five insect orders, Araneae and plants in and around Falta industrial zone, West Bengal, India

Debabrata Mukherjee, Soumen Roy, Tanmay Bhattacharya and Kamales Kumar Misra

Abstract
Six arthropod orders, *viz.,* Hemiptera, Orthoptera, Hymenoptera, Lepidoptera, Coleoptera and Araneae and their associations with plant species in the Falta Export Processing Zone (FEPZ) and non-industrial area West Bengal, India, is addressed. The study was conducted in fifteen study sites of which ten are within the industrial area covering 2-10 km of aerial distance of FEPZ and five sites of non-industrial area are 20 km to 32 km away of the industrial complex. A total of 139 species of arthropods are recorded covering 5 insect orders and one arachnid order Araneae which include 121 genera, 45 families and 5 sub-families of the above mentioned orders. This arthropod community were collected from 74 species of plants belonging to 30 families. These plants are commonly distributed in all the 15 study sites. Plant families, Asclepiadaceae, Poaceae, Euphorbiaceae and Solanaceae harbour species of five arthropod orders. Caparidaceae and Cypreraceae harbour only orthopteran insects while Polygonaceae and Boraginaceae are infested by hymenopteran insects, and Chenopodiaceae and Caesalpiniaceae harbour only hemipteran insects. Plant families, Anonaceae, Saporaceae, Acanthaceae, Nyctaginaceae, Verbenaceae, Dioscoriaceae, Plamnaceae and Flacourtiaceae harbour only coleopteran insects. Two families, Amaranthaceae and Rubiaceae harbour both coleopteran insects and arachnids whereas plants of Rhamnaceae family harbour only arachnids. The study confers comparative distribution of insects among plant species depending on their trophic relationship while Araneae maintains a housing affiliation with the inhabiting plants.

Keywords: Biodiversity, industrialization, insect-plant relationship, species abundance pattern (SAD), species richness

Introduction
Expression of variability is the philosophy of life. Social mobilization is the only way to break the vicious cycle of environmental domination. Human beings are responsible for unprecedented reductions in the variety of life forms around us [1]. Estimates suggest that species extinctions caused by humans occur at up to 1,000 times the natural rate, and that one of every twenty species on the planet could be eradicated by 2060 [2]. On the onset of declaration of 2010 as the International Year of Biodiversity, the world's attention has shifted from the challenge of understanding climate change to focus on the challenge on the apprehending the world's inhabitants and pressured biosphere. The threats facing biodiversity are many, anthropogenic causes of climate change are one of the factors in a myriad of activities that adversely affect biodiversity.
At present, biodiversity is not only an issue of curiosity, but also a resource of humanity. Today, many species are under continuous threat, as many natural ecosystems are being changed, polluted, affected by climatic change, as well as exploited too heavily [3]. Biological systems are constantly changing in response to environmental stimuli, culminating in species richness [4]. Documenting changes or variations in living beings is crucial to the good management of environmental resources [5]. The ecology of a species assemblage, rather than individual species, is very useful for predicting the effects of environmental disturbance [6]. Small organisms with short generation times are sensitive to short-term environmental fluctuations more than larger ones, and are more responsive to physical features of their ambient environment. Such populations of small organisms exhibit greater potential for use in the detailed tracking of environmental fluctuations than populations of larger organisms [7].

By-products of industries can adversely affect biota and ecosystems [8, 9]. Quantitative determination of biodiversity is likely to provide tools for ranking areas by species richness to optimize conservation effort [10, 11]. Phytophagous species constitute a dominant component of the biodiversity on earth [12]. Earlier studies [13, 14, 15, 16] on the responses of insects (like ants, termites, and beetles) for degradation of tropical forests have shown that the compositions and species richness of arthropod assemblages can vary depending upon disturbance levels, regional species pools, and the temporal and spatial scales. Basically, beta diversity measures species richness [17], but it is more commonly applied to abundance or presence/absence data [18, 19]. The core factors for exploring beta diversity are range and habitat restrictions [20, 21, 22]. Based on the species richness and complementarily of beetle fauna in three sub regions of California, Caterino [23] commented that these insects show high spatial variability, amounting to greater than 40% unique species per site. Air pollutants can disrupt plant species biochemical processes after absorption through the stomata or cuticle and have significant impacts on the growth and reproduction of plants [24]. Several ecological studies on temperate vegetation have indicated that air pollution has adverse impacts on vegetation cover, biodiversity and ecosystems on a local, regional and global scale [8, 25, 26, 27, 28]. Air pollution can cause phenotypic and genotypic changes in insects [29]. Insects and other invertebrates constitute a major proportion of our biological diversity [30]. Ecological sustainable management underlies the conservation of biodiversity as a major component [31]. Insects always exhibit diversity in their form and occurrence in relation to ecological condition [32].

The Falta Export-Processing Zone (FEPZ) covers the western boundary of South 24 Parganas district of West Bengal, India. This zone is within a newly established industrial area near the bank of river Hooghly. This zone incorporates ten study sites towards north, east and south sides. Due to new industrial set up, the ecology of this area is changing very fast. The vast alteration in the ecology is also expected to take place in future. The study sites of non-industrial zone are approximately 20 km to 32 km away from industrial zone towards northern area and western side. All the study sites possess common physiography, macroclimate and vegetation.

The major industries in FEPZ are steel items, aluminium products, rubber gaskets, synthetic wool, processing fabric, plastic granules, brass photo frames, PET resins, writing and printing papers, etc., which are expected to release their air borne pollutants simultaneously. Insects always exhibit diversity in their form and occurrence in relation to ecological condition. The species abundance distribution (SAD) of insect species normally depends on their type of food habits and its relative microenvironments [19]. The present work is designed to examine the effect of industrialization on arthropod - plant relationship of several arthropod members belonging to five insect orders *viz.,* Hemiptera, Orthoptera, Hymenoptera, Lepidoptera and Coleoptera and Araneae (Arachnida) in the Falta Export-Processing Zone (FEPZ) and in adjoining non-industrial area.

It was previously cited on a biodiversity assessment of insects and their host plant as well as bioindicator and insect-plant dependencies in industrial and non-industrial areas [33, 9, 34]. Based on binary data, the authors showed that diversity of hemipteran species was 40% lower and the diversity of both lepideptoran and orthopteran species was 36.8% lower in the industrial zone [9].

The hot topic of international discourse in the 21st century has been global climate change and its accompanying effects. Misra [1] argued against the idea that we are currently witnessing one of the greatest die-offs of species in the known history. The current debate is not on whether it is taking place but rather on how much greater the extinction rates are than the background rate, with estimates ranging from less than 100 times to 1000 times greater [2]. Being the primary consumers, insects feed on plants and play a vital role in maintaining ecological balance in an ecosystem [33]. The major industries in concurrence with the recent national strategies and international treaties for the conservation of biodiversity, the present work is designed to investigate the associations of available insect orders and Araneae with inhabiting plant species in all the sites covering both industrial and non-industrial zones and to look the apparent alternation of association of arthropods with plant by industrial influences.

Study sites and physiography

Fifteen study sites were selected from north to south parts of south 24 Parganas district in West Bengal, of which ten are within the industrial area covering 10 km of aerial distance of Falta industrial zone and five sites of its adjoining non-industrial area are within 20 km to 30 km away of the industrial complex (Fig. 1) as shown in Table 1. Falta has been developing as a major industrial processing zone since 1984, Major crop is rice and minor crop is pulse. Different varieties of rice, pulses, vegetables, tomato, and potato are regularly cultivated. Similar typical tropical vegetation is found in all the study sites. Predominant South and South-East wind speed does not exceed 40 km an hour.

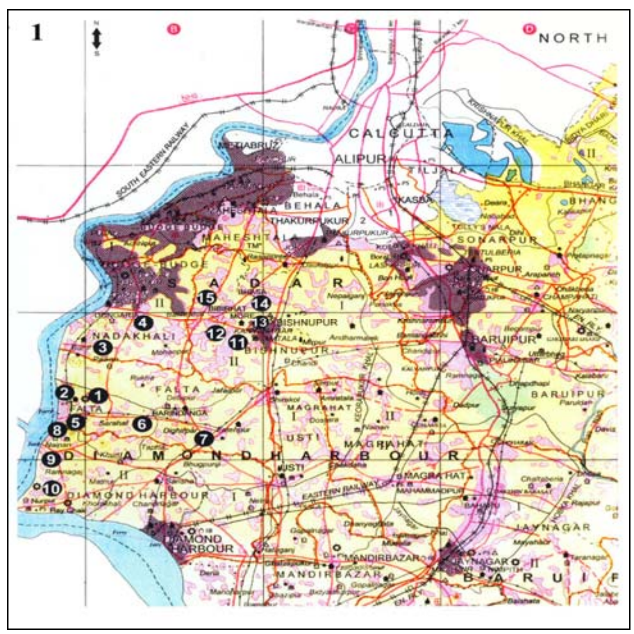

Fig 1: Map of Falta industrial areas and its associated study sites. 1. FAL; 2. FALPS1; 3. BUR; 4. DON; 5. FALPS2; 6. SAR; 7. DIG; 8. IB; 9. NAI; 10. NUR; 11. VID; 12. KHA; 13. KAN; 14. VASA; 15. BIB.

Table 1: Location of study sites in and around Falta Export Processing Zone (FEPZ).

Study sites	Geographical Coordinates		Distance from Falta industrial area
INDUSTRIAL STUDY SITES			
1. Falta (FAL)	22º17'45"(N)	88º06'30"(E)	0km
2. Falta PS1 (FALPS1)	22º18'00"(N)	88º06'30"(E)	2 km away to north
3. Burul (BUR)	22º21'30"(N)	88º06'45"(E)	5 km away to north
4. Dongaria (DON)	22º24'00"(N)	88º10'60"(E)	10 km away to north
5. Falta PS2 (FALPS2)	22º18'00"(N)	88º06'00"(E)	2 km away to east
6. Sahararhat (SAR)	22º17'10"(N)	88º09'30"(E)	5 km away to east
7. Dighirpar (DIG)	22º17'30"(N)	88º12'30"(E)	10 km away to east
8. Inspection Bunglow (IB)	22º17'00"(N)	88º06'30"(E)	2km away to south
9. Nainan (NAI)	22º16'00"(N)	88º05'55"(E)	5 km away to south
10. Nurpur (NUR)	22º12'30"(N)	88º05'00"(E)	10 km away to south
NON-INDUSTRIAL STUDY SITES			
11. Vidyanagar (VID)	21º30" (N)	88º16'45"(E)	20 km away from Falta to north
12. Khangabaria (KHA)	22º23'30"(N)	88º15'30" (E)	22 km away from Falta to north
13. Kanyanagar (KAN)	22º23' (N)	88º14'45"(E)	24 km away from Falta to north
14. Vasa (VASA)	22º24'30" (N)	88º16'30"(E)	32 km away from Falta to north
15. Bibirhat (BIB)	22º23'00"(N)	88º14'00"(E)	27 km away from Falta to west

Materials and methods

The present study comprised of monthly sampling of five insect orders *viz.,* Hemiptera, Orthoptera, Hymenoptera, Lepidoptera, Coleoptera and an arachnid order, Araneae as mentioned earlier. The binary (presence-absence) data of the arthropods of the six orders were documented from the fifteen study sites from 30 plant families. The survey work was conducted from dawn to dusk at each site for each three seasons (summer, rainy and winter) for three consecutive years (2002, 2003, and 2004). To study the effects of distance on species richness in plant species around industry, the selection of study sites were designed as 2 km, 5 km and 10 km North, East and South away from the industrial complex (0 km). All the arthropod orders (except Lepidoptera) under study are encountered from five plant families (Asclepiadaceae, Solanaceae, Poaceae, Leguminoceae and Euphorbiaceae) throughout the 15 study sites were selected to compare the effects of industrialization as host plant - insect interaction.

Insects and arachnids were collected during field survey using a variety of methods – such as handpicking, sweeping and beating, collecting with aerial nets and trapping [9]. Host plants for each insect and araneae were same at every sampling site with a view to show insect, Araneae and their host plant relationship [32, 33]. Both in industrial and non-industrial areas, climate, physiography, relief and slope, rocks and minerals, soil, inceptisols, climate conditions, irrigation, ground water hydrology and macroclimatic parameters are also similar in all the study sites. The survey was done with random mode.

Identification

The collected samples were properly preserved and were identified by the Zoological Survey of India, Kolkata.

Results

A total of 139 species of arthropods covering 5 insect orders (*viz.* Hemiptera, Lepidoptera, Coleoptera, Hymenoptera, and Orthoptera) and one arachnid order Araneae, stated earlier were collected from 15 study sites of Falta Industrial Zone and adjoining non-industrial areas. These include 121 genera, 45 families and 5 sub-families of the above-mentioned orders. This arthropod community were collected from 74 species of plant covering 30 families. These plants are distributed in all 15 study sites.

Hemiptera

The twenty seven species of host plants belonging to 13 families were investigated for registering hemipteran insects and altogether 22 species of Hemiptera of covering 22 genera under 14 families were recorded from 15 study sites. It is interesting to note that all the 22 genera of Hemiptera are represented by single species, 3 species each belong to the families Lygaeidae and Pyrrhociridae. Host-family association of hemipteran insect shows that 9 species of Hemiptera inhabit *Croton bonplandianum* (Euphorbiaceae) followed by 7 species on *Calotropis procera* (Asclepiadaceae) and 5 on *Datura metel* (Solanaceae) (Table 2). *Leptocorysa acuta* (Alydidae) inhabits only 11 species of host plant and was found in all the study sites.

Binary data of Hemiptera show that the four species, *S. hospes, C. stollii, L. acuta* and *O. tarandus* were recorded from all the 15 study sites (Supplement Table 1). Three species *viz*., *Homeocerus* sp., *C. cribrarum* and *L. indicus* were not found in all the five non-industrial study sites. Two species of the family *Pentatomidae, L. grundis* and *H. dentatus* and one species of the family *Belostomatidae, Heteroptera* sp., were recorded from only single site of the five non-industrial sites. Maximum number of species of Hemiptera was collected from BUR (16) followed by KAN (15), FAL and BIB (14 each), SAR (13) and minimum number of species, seven, were recorded from VID.

Table 2: Host-family association of Hemiptera in fifteen study sites.

Plant		Insect	Industrial									Non-industrial					
Family	**Species**	**Species**	**FAL**	**FALPS1**	**BUR**	**DON**	**FALPS2**	**SAR**	**DIG**	**I.B.**	**NAI**	**NUR**	**VID**	**KHA**	**KAN**	**VASA**	**BIB**
Asclepiadaceae	*Calotropis procera*	*Spilostithus hospes*	-	+	-	+	+	-	+	-	+	-	+	-	+	+	+
		Chrysocoris stollii	+	-	+	-	-	-	+	-	-	+	-	+	+	+	+
		Leptocorysa acuta	+	-	+	-	+	+	-	-	-	-	-	-	-	+	-
		Riptortus fuscus	+	-	+	+	-	-	-	-	-	-	-	-	+	-	+
		Clovia conifer	+	-	-	-	+	-	-	+	-	-	-	+	+	-	+
		Physopelta schlanbuschi	+	-	+	-	+	-	-	-	-	-	-	+	+	-	-
		Urolabida histrionica	+	-	-	+	-	-	+	-	-	-	-	-	+	-	-
Compositae	*Mikania cordata*	*Spilostithus hospes*	+	+	+	+	+	-	+	+	+	-	+	-	-	-	-
		Leptocorysa acuta	+	-	+	-	+	+	-	-	-	-	-	-	+	-	-
	Synedrella nodiflora	*Otinotus oneratus*	-	-	-	+	-	-	-	-	-	-	-	-	+	-	+
		Riptortus fuscus	-	+	-	+	-	-	-	-	-	-	-	+	-	+	-
	Weddelia chinensis	*Leptocorysa acuta*	+	+	+	+	+	+	-	-	-	-	-	-	+	+	+
	Blumea lacera	*Leptocorysa acuta*	+	-	+	-	+	+	-	-	+	+	-	-	-	-	-
		Otinotus oneratus	-	-	-	-	-	+	-	-	-	-	-	-	+	-	+
	Sonchus sp.	*Riptortus fuscus*	+	-	-	-	-	+	-	-	-	+	-	-	+	-	-
	Blumea villosa	*Dysdrcus koenigii*	+	-	-	+	-	-	+	-	-	-	-	+	-	+	+
		Heleroptera sp.	-	-	+	-	-	-	-	-	-	+	-	-	-	+	+
Solanaceae	*Solanum melongena*	*Spilostithus hospes*	+	+	+	+	+	+	+	+	+	+	+	+	-	+	-
		Chrysocoris stollii	+	+	+	+	+	+	+	-	-	-	-	-	+	+	-
		Leptocorysa acuta	-	-	-	-	+	+	+	+	-	-	+	+	+	+	+
		Urolabida histrionica	+	-	-	+	-	-	+	-	-	-	-	-	+	-	-
	Solanum tuberosum	*Chrysocoris stollii*	-	-	-	+	-	-	-	+	-	-	-	-	+	-	+
		Leptocorysa acuta	-	-	-	+	-	+	-	-	-	-	-	+	-	+	+
	Solanum nigrum	*Clovia conifer*	+	-	-	-	-	+	-	-	-	+	-	-	+	-	-
	Datura metel	*Spilostithus hospes*	+	+	+	-	+	+	-	+	+	-	+	+	+	+	-
		Chrysocoris stollii	-	-	-	+	-	-	-	-	-	-	-	-	+	-	-
		Clovia conifer	-	-	+	-	+	-	-	+	-	-	-	-	+	-	+
		Oxyrhachis tarandus	+	+	-	-	+	-	+	-	-	-	+	+	-	+	-
		Dysdrcus koenigii	-	+	-	-	-	+	-	-	-	-	-	+	-	-	-
	Physalis minima	*Clovia conifer*	-	+	-	+	-	-	-	-	-	-	-	+	-	-	+
Euphorbiaceae	*Croton bonplandianum*	*Spilostithus hospes*	-	+	+	-	-	+	-	-	+	-	+	+	-	+	+
		Grapatostethus argentatus	+	-	-	-	+	-	-	-	+	-	-	+	-	+	-
		Lygaeosoma bipunctatus	+	-	+	-	+	-	+	+	-	-	-	+	+	+	+
		Chrysocoris stollii	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
		Leptocorysa acuta	-	-	-	-	-	-	+	-	-	-	+	-	-	+	-
		Homeocerus sp.	-	+	+	+	+	-	-	-	+	-	-	-	-	-	-
		Riptortus fuscus	-	-	+	-	-	-	+	-	+	-	-	-	-	-	-
		Imphita limbata	+	+	-	-	+	+	-	+	-	+	+	-	+	+	-
		Dysdrcus koenigii	-	+	-	+	-	-	+	-	-	+	-	-	+	-	+
	Chrozophora sp.	*Chrysocoris stollii*	+	+	+	+	+	+	+	+	-	-	-	+	+	+	+
	Jatropha curcus	*Chrysocoris stollii*	-	-	-	+	-	+	-	-	-	-	-	-	-	+	+
Caesalpiniaceae	*Cassia alata*	*Leptocorysa acuta*	+	-	+	-	+	-	-	-	-	-	-	-	+	+	-
		Oxyrhachis tarandus	+	-	+	+	-	+	-	-	+	-	-	+	-	+	+
Convolvulaceae	*Ipomoea carnea*	*Leptocorysa acuta*	-	-	-	-	-	-	+	-	-	-	-	-	+	+	-
		Dysdrcus koenigii	+	-	-	-	+	-	+	-	-	-	-	-	+	-	-
Poaceae	*Oryza sativa*	*Lethocerus indicus*	-	-	+	-	-	+	-	-	+	-	-	-	-	-	-
		Captosoma cribrarium	+	-	+	-	-	-	-	-	-	-	-	-	-	-	-
		Leptocorysa acuta	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
		Hydrometra greeni	-	-	+	-	-	-	+	-	-	+	-	-	+	-	-
		Heteroptera sp.	-	-	-	-	-	-	-	+	-	-	-	-	-	+	-
	Cynodon dactylon	*Anisops bouvieri*	+	+	-	-	-	+	-	-	-	-	-	+	+	-	+
		Halys denttatus	-	-	+	-	-	-	+	-	-	-	-	-	-	+	-
Chenopodiaceae	*Spinacia oleraceae*	*Leptocorysa acuta*	-	+	-	-	-	+	-	-	-	-	-	-	+	+	+
Curcurbitaceae	*Momordica indica*	*Riptortus fuscus*	-	+	-	+	-	+	-	-	-	-	-	-	+	+	-
	Coccinia grandis	*Dysdrcus koenigii*	-	-	+	-	-	+	-	-	-	-	+	-	+	-	-
Moraceae	*Ficus racemose*	*Riptortus fuscus*	+	-	-	+	-	-	-	+	-	-	-	-	-	-	-
Leguminoceae	*Acasia nelotica*	*Oxyrhachis tarandus*	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
	Acasia moneformis	*Oxyrhachis tarandus*	+	+	-	-	+	-	-	+	-	-	+	+	-	+	+
Malvaceae	*Urena lobata*	*Physopelta schlanbuschi*	-	-	-	+	-	+	-	+	-	+	-	-	+	-	+
Cruciferae	*Brassica nigra*	*Luhita grandis*	-	+	-	-	+	-	-	-	-	-	-	-	+	-	-
		Halys denttatus Fibr.	-	-	+	-	-	+	-	-	-	-	-	-	-	-	+

Coleoptera

A total of 46 species of Coleoptera covering 44 genera covering 9 families were recorded from 15 study sites. Host-family association of Coleopteran insects shows that Curculionidae is represented by 11 species followed by Chrysomelidae with 10 species. Apinoidae and Tenebrioniae were represented by one species each. *Aulacophora* sp. and *Hoplasoma unicolor* (Family: Chrysomelidae) inhabit 7 and 4 species of host plants respectively (Table 3). The *Onitis* sp. (Family: Scarabaeidae) inhabits 2 species of host plant. These

3 Coleopteran species were found in all the study sites. Host-family association of Coleopteran insects shows that maximum of 16 Coleopteran species inhabit *Croton bonplandianum* (Euphorbiaceae) followed by 9 species on *Calotropis procera* (Asclepiadaceae) (Table 3).

Host-family association of Coleopteran insects shows that maximum of 16 Coleopteran species inhabit *Croton bonplandianum* (Euphorbiaceae) followed by 9 species on *Calotropis procera* (Asclepiadaceae) (Table 3). Binary data of Coleoptera show that five species, *H. unicolor, Aulacophora* sp., *P. contairei, Onitis* sp. and *Gonocephalum sp.* were recorded from all the 15 industrial and non-industrial study sites (Table 3). *Heterpnychus* sp., *Xystrocera globosa* were found in only 1 non-industrial study site each. While *C. nigritis* and *Anomla* sp. were recorded from one of the 10 sites of industrial area. Maximum Coleopteran species were recorded from the site KAN (40) followed by FALPS2 (37), FALPSI (36), in BUR, VASA and BIB (35 each). The minimum number of species was found from NUR (18).

Table 3: Host-family association of Coleoptera in fifteen study sites.

Plant		Insect					Industrial							Non-industrial			
Family	**Species**	**Species**	**FAL**	**FALPS1**	**BUR**	**DON**	**FALPS2**	**SAR**	**DIG**	**I.B.**	**NAI**	**NUR**	**VID**	**KHA**	**KAN**	**VASA**	**BIB**
Cucurbitaceae	*Lagenaria siceraria*	*Hoplasoma unicolor*	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
	Lagenaria vulgaris	*Epilachna* sp.	-	-	+	-	-	+	-	+	-	-	-	-	+	-	+
		Plotycorynus peregrinis	-	-	+	-	+	-	-	-	-	-	-	-	+	-	-
	Cucurbita pepo	*Aspidomorpha* sp.	+	+	+	+	+	+	-	+	-	-	+	-	+	+	+
		Aulacophora sp.	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
	Cucumis sativus	*Aulacophora sp.*	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
		Pheropsophus contairei	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
		Plotycorynus peregrinis	-	-	-	-	+	-	-	-	+	-	-	-	+	+	+
		Adoretus sp.	-	-	-	-	+	-	-	-	-	-	-	-	+	-	-
	Momordica charantia	*Phygasia* sp.	+	+	+	-	+	-	+	+	-	-	-	+	+	+	+
	Trichosanthes anguina	*Cicindala*sp.	-	-	-	-	+	-	-	+	-	-	-	-	+	-	+
	Trichosanthus bractiata	*Anomala* sp.	-	-	-	-	-	-	-	+	-	-	+	-	+	-	+
Convolvulaceae	*Ipomoea carnea*	*Hoplasoma unicolor*	+	+	+	-	+	+	+	+	+	+	+	+	+	+	+
		Aspidomorpha miliaris	+	-	+	+	+	-	-	+	+	-	+	-	-	-	-
		Aspidomorpha foveicollis	-	+	-	+	-	+	-	-	-	+	-	+	-	+	-
		Autoserica sp.	-	-	-	+	+	-	-	+	-	-	-	+	-	+	+
		Adoretus sp.	-	-	+	-	-	-	+	-	-	-	+	-	-	+	+
Solanaceae	*Solanum melongena*	*Hoplasoma unicolor*	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
		Coccinella transversallis	-	-	-	-	-	-	-	-	+	+	-	+	+	-	-
		Onitis sp.	-	-	+	-	+	-	-	-	-	-	+	-	-	+	+
	Solanum tuberosum	*Aspidomorpha* sp.	+	+	+	+	+	-	+	-	-	-	-	+	+	+	-
	Datura metel	*Aulacophora* sp.	+	+	-	+	-	-	+	-	-	-	-	+	-	+	-
		Onthophagus sp.	-	-	-	+	-	-	+	-	-	-	-	-	+	-	+
		Rhychophorus ferrugineus	-	+	-	+	-	-	+	-	+	-	+	-	+	+	-
		Xystrocera globosa	-	-	+	-	+	-	-	-	-	-	-	-	-	-	-
	Physalis minima	*Amblyrrinus bonicollis*	-	+	-	-	+	-	+	-	-	-	+	+	-	-	-
Euphorbiaceae	*Croton bonplandianum*	*Podonita punctata*	-	+	-	+	-	+	-	-	-	-	+	-	+	-	+
		Aspidomorpha miliaris	+	+	+	+	+	+	+	-	-	-	+	-	+	-	+
		Aspidomorpha foveicollis	+	+	-	+	+	+	-	+	+	-	+	-	-	-	+
		Aulacophora sp.	+	+	+	-	+	+	+	+	+	+	+	+	+	+	+
Euphorbiaceae	*Croton bonplandianum*	*Anthia sexguttata*	-	+	-	+	+	+	-	-	-	-	-	-	+	+	+
		Onitis sp.	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
		Autoserica sp.	+	+	+	+	-	-	-	-	-	-	+	-	+	+	-
		Orthophagus sp.	-	+	-	-	+	-	-	-	-	+	+	-	+	+	+
		Sisyphus sp.	+	+	+	+	+	+	+	+	-	+	+	+	+	-	+
		Onthophagus sp.	+	+	+	+	-	+	-	-	-	+	+	-	+	+	-
		Stromatium barbatum	+	+	-	+	+	-	+	+	+	-	-	+	+	+	+
		Cylas formicarius	+	+	+	+	+	-	+	-	+	-	+	+	+	+	+
		Rhychophorus ferrugineus	+	+	+	-	+	+	-	-	-	-	-	+	+	-	-
		Apoderus sp.	+	+	+	+	+	+	-	-	-	-	-	+	+	-	-
		Adovetus sp.	+	-	+	-	+	+	-	+	+	-	+	+	+	+	+
		Gonocephalum sp.	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
	Jatropha curcus	*Aulacophora* sp.	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
	Plucia indica	*Stromatium barbatum*	-	-	-	-	-	-	-	+	+	-	+	-	-	-	-
Anonaceae	*Artabotrys odoratissimus*	*Xystrocera globosa*	-	-	-	-	-	-	+	-	-	-	+	-	-	-	-
Saporaceae	*Bassia latifolia*	*Olenemptus bilobus*	-	+	-	-	-	-	-	-	-	-	+	+	+	+	+
Moraceae	*Ficus racemose*	*Cylas formicarius*	+	+	+	-	-	-	-	-	-	-	-	-	+	+	-
Acanthaceae	*Hygrophila spinosa*	*Adoderus* sp.	-	-	+	-	+	-	-	-	-	-	-	+	-	-	-
		Sternolophus rufipes	+	+	-	+	-	+	-	-	+	+	+	+	+	+	+
	Pungia peelinata	*Caccobius* sp.	+	-	+	-	+	-	-	-	-	-	-	-	+	+	-
Nyctaginaceae	*Bacrhaavia repens*	*Caccobius* sp.	-	+	-	-	-	+	-	+	-	-	-	+	-	-	-
Verbenaceae	*Clerodendrum* sp.	*Apogonia* sp.	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Dioscoriaceae	*Dioscoria bulbifera*	*Adovetus* sp.	-	-	+	+	-	-	+	-	-	-	-	+	+	-	-
Leguminaceae	*Gliricidia* sp.	*Odoiporus longicollis*	-	+	-	+	-	-	-	+	-	-	+	+	+	-	-
	Vicia faba	*Isotomus* sp.	-	-	-	-	+	+	+	-	-	-	-	+	+	-	-
		Teteragonothorax sp.	-	-	-	+	+	-	-	+	-	-	-	-	+	-	+
	Pisum sativum	*Isotomus* sp.	-	+	+	+	-	-	-	-	-	+	+	-	-	+	-
		Teteragonothorax sp.	-	-	+	-	-	+	-	-	+	-	-	+	-	+	-
Plamnaceae	*Ziziphus mauritiana*	*Amblyrrinus bonicollis*	+	-	-	+	-	+	-	+	-	-	-	+	+	+	+
Rubiaceae	*Ixora coccinea*	*Gonocephalum* sp.	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Flacourtiaceae	*Flacaurtia indica*	*Cicindala* sp.	-	-	-	+	-	-	+	-	-	-	-	-	-	+	-
Amaranthaceae	*Arena* sp.	*Olenemptus bilobus*	-	-	-	-	-	+	-	-	-	+	-	-	-	-	-

Hymenoptera
Seventeen species of host plant under 11 families harbour hymenopteran insects (Table 4). Table 4 shows that 6 hymenopteran species inhabit *Croton bonplandianum* (Euphorbiaceae) followed by 5 species on *Solanum melongena* (Solanaceae). Binary data depict that among 18 species of Hymenoptera, 13 were found in all the 15 study sites. *T. rufonigra* was found only in 1 industrial study site (NAI). A little variation in the distribution of Hymenoptera is observed in both industrial and non-industrial study sites. Eighteen species are collected from KAN and BIB, followed by VASA (17), BUR and NAI (16) and minimum 14 from FAL, FAL PS1, DON, FALPS2, IB, NUR, KHA. Host-family association in Table 4 shows that 6 hymenopteran species inhabit *Croton bonplandianum* (Euphorbiaceae) followed by 5 species on *Solanum melongena* (Solanaceae).

Table 4: Host-family association of Hymenoptera in fifteen study sites.

Plant		Insect Species	Industrial											Non-industrial			
Family	Species		FAL	FALPS1	BUR	DON	FALPS 2	SAR	DIG	I.B.	NAI	NUR	VID	KHA	KAN	VASA	BIB
Asclepiadaceae	*Calotropis procera*	*Camponotus paira*	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
		Camponotus compressus	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
		Polystes stigma	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Euphorbiaceae	*Jatropha curcus*	*Camponotus compressus*	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
		Polistes stigma	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
	Croton bonplandianum	*Polyrhachus* sp.	-	-	+	-	-	-	+	-	-	-	-	-	+	-	+
		Camponotus compressus	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
		Camponotus sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		Monomorium sp.	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
		Meranoplus sp.	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
		Rhycium sp.	+	+	+	-	+	+	+	-	+	+	+	+	+	+	+
Convolvulaceae	*Ipomoea carnea*	*Camponotus compressus*	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
		Tetraponera rufonigra	-	-	-	-	-	-	-	-	+	-	-	-	+	+	+
		Diacamma rugosum	-	-	+	+	-	-	-	+	-	-	-	-	+	+	+
		Pheidole sp.	-	-	-	-	+	-	+	-	+	-	-	-	-	+	+
Polygonaceae	*Polygonum hydropiper*	*Camponotus compressus*	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
		Tapinoma melanocephalum	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
		Apis indica	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
		Nomia sp.	-	-	-	-	-	+	-	-	+	-	+	-	+	+	+
Solanaceae	*Solanum tuberosum*	*Camponotus compressus*	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
	Solanum melongena	*Camponotus compressus*	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
		Camponotus sp.	+	+	+	+	+	-	+	+	+	-	+	+	+	-	+
		Crematogaster sp	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
		Pheidole sp.	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
		Meranoplus sp.	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Solanaceae	*Datura metel*	*Camponotus compressus*	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Compositae	*Mikania cordata*	*Camponotus compressus*	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
		Apis indica	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
	Tegetes palula	*Camponotus compressus*	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
	Blumea lacera	*Crematogaster hodgsoni*	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
		Monomorium sp.	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
		Apis indica	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
		Polistes stigma	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Cucurbitaceae	*Cucurbita pepo*	*Camponotus compressus*	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
		Pheidole sp.	-	-	-	-	-	-	-	-	+	+	-	+	+	-	+
		Apis sp.	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
		Polistes stigma	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Poaceae	*Cynodon dacatylon*	*Pachycondyla rufipes*	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Boraginaceae	*Heliotropium indicum*	*Camponotus paira*	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
		Camponotus sp.	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Cruciferae	*Brassica nigra*	*Apis indica*	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Leguminoceae	*Vigna sinensis*	*Apis indica*	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
		Polistes stigma	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
	Pisum sativum	*Polistes stigma*	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+

Orthoptera
Altogether 20 species of 17 genera under 5 families were collected from all the industrial and non-industrial study sites. These insects harbour 16 host species under 9 families (Table 5). *Oxya* (Acrididae) and *Atractomorpha* (Pyrgomorphidae) were represented by 3 and 2 species respectively. Acrididae has 9 species followed by 5 species of Tettigoniidae. Tabulated data on host plant-insect association exhibits that 7 species of Orthoptera inhabit *Oryza sativa* and *Cynodon dactylon* (Poaceae), followed by 6 species on *Solanum tuberosum* (Solanaceae) (Table 5). The compiled binary data reveals that none of the 20 species were recorded from all the 15 study sites (Table 6).The *Euconocephallus pallidus* (Tettigonidae) was absent in all the five non-industrial sites, while, *P. infumata, G. punctiforms, A. exllata, Catantop sp.* and *G. sigillatus* were recorded from only one of the five non-industrial sites. Moreover, some species were recorded in only 2 to 3 sites of the industrial zone. The number of species is minimum in NUR (1) and maximum in KAN (13).

Table 5: Host-family association of Orthoptera in fifteen study sites.

Plant		Insect Species	Industrial										Non-industrial				
Family	**Species**		**FAL**	**FALPS1**	**BUR**	**DON**	**FALPS2**	**SAR**	**DIG**	**I.B.**	**NAI**	**NUR**	**VID**	**KHA**	**KAN**	**VASA**	**BIB**
Solanaceae	*Solanum melongena*	*Aiolopus thalassinus tomulus*	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-
		Oxya fuscovittata	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-
		Atractomorpha cremulata	-	-	-	-	-	+	+	+	+	-	+	+	+	+	+
	Solanum tuberosum	*Phlaeoba infumata*	+	-	-	+	-	-	+	-	-	-	-	-	-	-	-
		Oxya fuscovittata	-	-	-	+	-	+	-	+	-	-	+	+	-	+	-
		Trilophidia annulata	+	+	-	+	-	-	-	-	-	-	+	-	-	+	-
		Atractomorpha crenulata	+	-	-	+	-	-	-	-	-	-	-	+	-	-	-
		Hedotettix sp.	-	+	+	-	+	-	-	+	-	-	+	-	+	+	-
		Thoracondonta sp.	-	-	-	-	+	-	+	-	+	-	-	+	-	+	-
	Datura metel	*Atractomorpha crenulata*	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-
Malvaceae	*Abelmoschus asculentus*	*Aiolopus thalassinus tomulus*	+	-	-	-	-	-	+	-	+	-	+	-	-	+	+
Cruciferae	*Brassica napus*	*Aiolopus thalassinus tomulus*	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-
		Phalaeoba infumata	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-
		Atractomorpha crenulata	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-
		Gesonula punctifrons	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Caparidaceae	*Cappris sepraria*	*Aiolopus thalassinus tomulus*	-	-	-	-	+	-	-	-	+	-	-	-	-	-	-
		Gryllodes sigillatus	-	-	+	-	-	-	-	-	-	+	-	+	-	-	-
Poaceae	*Oryza sativa*	*Gesonula punctifrons*	+	-	-	-	+	-	-	-	-	-	-	-	+	-	-
		Oxya fuscovittata	-	-	-	-	-	+	-	-	-	-	-	-	+	-	-
		Holochlora indica	+	-	-	-	+	-	-	+	-	-	+	-	+	+	-
		Atractomorpha crenulata	-	-	-	+	-	-	+	-	+	-	-	-	+	+	-
		Gryllotalpa africana	-	+	-	+	-	+	-	-	+	-	-	+	-	+	-
		Gryllus sp.	+	-	+	-	+	-	+	-	+	-	-	+	+	+	+
		Oxya hyla hyla	+	+	-	+	-	+	-	-	-	-	-	-	-	-	-
	Sporobolus sp.	*Oxya fuscovittata*	+	+	-	-	-	-	-	-	-	-	-	-	-	-	+
		Oxya nitidula	-	-	-	+	-	-	-	-	-	-	+	-	-	-	-
	Imperata sp.	*Oxya fuscovittata*	-	-	-	-	-	+	-	-	+	-	-	-	-	-	-
	Cynodon dactylon	*Oxya fuscovittata*	-	-	-	+	+	-	+	-	-	-	-	-	+	+	-
		Oxya hyla hyla	-	-	-	-	-	-	-	-	-	+	-	-	-	+	-
		Oxya nitidula	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-
		Acrida exaltata	-	-	-	-	-	+	-	-	+	-	-	-	+	-	-
		Catantop sp.	-	-	-	-	-	+	-	-	-	-	+	-	-	-	-
		Holochlora indica	-	+	-	+	-	-	-	-	-	-	-	+	-	-	-
		Mecopoda elongata	-	+	-	+	-	-	-	-	-	-	-	+	+	+	+
	Poa sp.	*Euconocephallus pallidus*	+	-	-	+	+	-	-	-	-	-	-	-	-	-	-
Araceae	*Colocasia antiquorum*	*Gesonula punctifrons*	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-
		Atractomorpha sp.	+	-	+	-	-	-	+	-	-	-	-	+	+	-	+
	Colocasia esculenta	*Oxya hyla hyla*	-	+	-	+	-	-	+	-	+	-	-	-	-	-	-
Asclepiadaceae	*Calotropis procera*	*Oxya fuscovittata*	-	-	+	-	-	-	-	-	+	-	-	-	+	-	-
		Oxya hyla hyla	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-
		Atractomorpha crenulata	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-
Euphorbiaceae	*Jatropha sp.*	*Oxya fuscovittata*	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-
Cypreraceae	*Fimbristylus sp.*	*Oxya fuscovittata*	-	-	-	+	+	-	+	-	-	-	-	+	+	+	-
		Oxya nitidula	-	-	-	-	+	-	-	-	-	-	-	-	+	+	-
		Spathostermum prasiniferum	-	-	-	-	-	+	-	+	-	-	+	-	+	-	-

Table 6: Host family association of Araneae in fifteen study sites.

Plant		Spider species	Industrial										Non-industrial				
Family	**Species**		**FAL**	**FALPS1**	**BUR**	**DON**	**FALPS2**	**SAR**	**DIG**	**I.B.**	**NAI**	**NUR**	**VID**	**KHA**	**KAN**	**VASA**	**BIB**
Convolvulaceae	*Ipomoea carnea*	*Marapissa* sp.	+	-	-	+	-	-	+	-	-	-	+	-	+	-	-
		Phidippus indicus	-	-	-	+	-	-	-	+	-	-	-	-	+	+	-
		Unidentified species	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-
		Neoscona theis	+	-	-	-	-	-	-	-	-	-	+	-	-	-	-
		Thomisus sp.	+	-	-	-	+	-	+	-	-	-	-	+	+	-	-
Asclepiadaceae	*Calotropis procera*	*Marapissa* sp.	+	-	-	+	-	-	+	-	-	-	+	-	+	-	-
		Theridion sp.	+	-	-	-	-	-	-	-	-	-	-	-	+	-	-
		Castianeiria sp.	-	-	-	-	-	-	-	+	-	-	-	-	-	+	-
Poaceae	*Cynodon dactylon*	*Oxyopes* sp.	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-
	Oryza sativa	*Oxyopes* sp.	-	-	+	-	-	-	-	-	-	-	-	+	-	-	-
	Paspahum sp.	*Oxyopes* sp.	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-
	Sporobolus sp.	*Oxyopes* sp.	-	-	-	-	-	-		-	-	-	-	-	+	-	-
Euphorbiaceae	*Croton bonplandianum*	*Leucage* sp.	-	-	-	+	-	+	+	+	-	-	+	+	+	+	-
		Neoscona sp.	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		Xysticus sp.	+	-	+	-	-	+	-	-	-	-	+	-	+	-	-
		Castianeria sp.	-	+	+	-	+	-	+	-	-	-	-	-	+	-	-
Araceae	*Colocasia esculenta*	*Neoscona* sp.	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-
	Colocasia antiquorum	*Theridion* sp.	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-
Compositae	*Syndrella nodiflora*	*Marpissa* sp.	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-
		Leucage sp.	-	-	-	-	+	-	-	-	-	-	-	+	-	-	-
	Grangia mediraspatana	*Leucage* sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-
	Wedelia calendulacia	*Marpissa* sp.	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-
	Wedelia chinensis	*Neoscona theis*	+	-	+	+	-	-	+	-	-	-	+	+	+	-	-
	Mikania cordata	*Theridion* sp.	-	-	+	-	-	-	-	-	-	-	-	-	-	+	-
	Blumea villosa	*Thomisus* sp.	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-
Solanaceae	*Solanum nigrum*	*Phidippus inducus*	+	-	-	-	+	-	-	-	-	+	-	-	-	+	+
		Neoscona theis	-	+	-	+	-	-	+	+	-	-	-	+	+	-	-
		Thomisus sp.	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-
Solanaceae	*Datura metel*	*Thomisus* sp.	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-

Malvaceae	*Hibisus rosa sinensis*	Unidentified species	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-
	Carena sp.	*Thomisus* sp.	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-
Moraceae	*Ficus racesomose*	*Leucage* sp.	-	-	-	+	-	-	+	-	-	-	-	+	+	-	-
Amaranthaceae	*Achitanthes aspara*	*Neoscona* sp.	-	-	-	+	-	-	+	-	-	-	-	-	-	-	-
Rubiaceae	*Ixora coccinea*	*Neoscona theis*	-	+	-	-	-	-	-	-	-	-	-	+	+	-	-
Rhamnaceae	*Zizyphus jujuba*	*Xysticus* sp.	+	-	+	-	+	-	-	-	-	-	-	+	+	-	-
Leguminaceae	*Vicia faba*	*Xysticus* sp.	-	-	-	-	-	+	-	-	-	-	-	+	-	-	-
	Acasia monoformis	*Castianeiria* sp.	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Labiatae	*Plucia* sp.	*Xysticus* sp.	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-

Lepidoptera

A total of 23 species of Lepidopteran insect comprising 6 families were recorded from the 15 study sites. *Junonia allitis* was totally absent in all the industrial sites, while 7 species viz., *P. lemomias, L. nina, A. cyssea, Euchromia* sp. and all the 3 species of the genus *Graphium* were absent in all the non-industrial sites (Table 3). Binary data shows that least number of Lepidoptera was recorded from IB and NUR (3 each) followed by NAI (4). Maximum of 10 species were collected form FALPS2 and KAN (Fig.2).

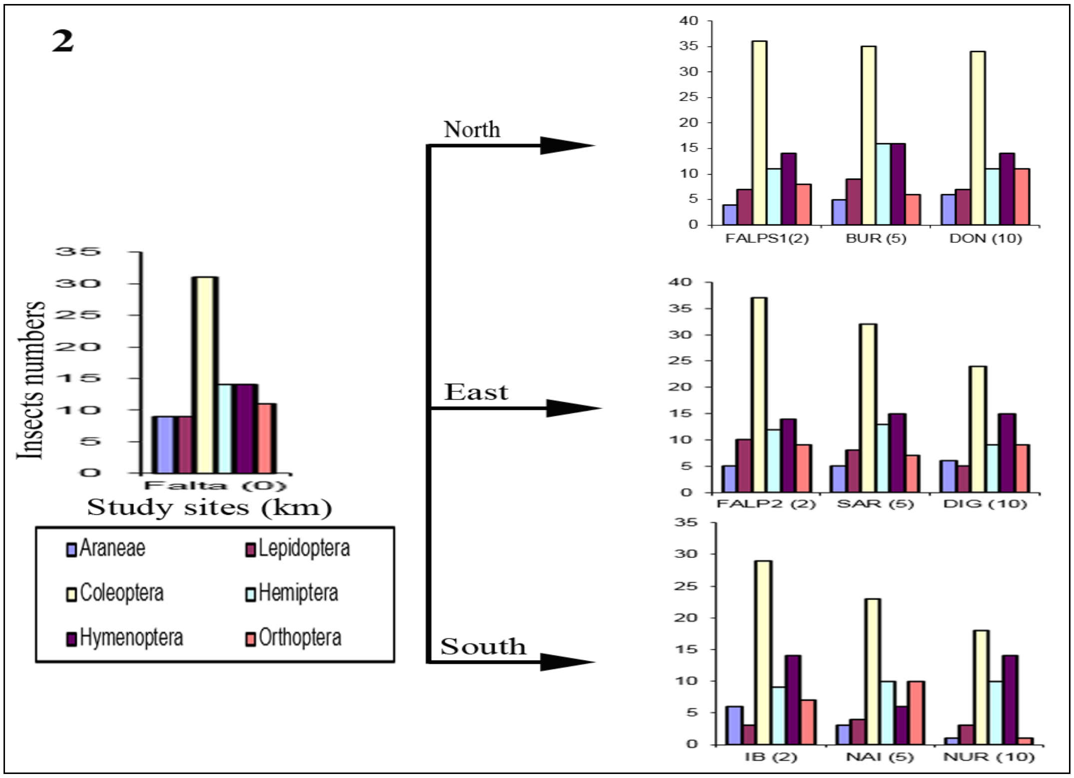

Fig 2: Comparisons of distribution pattern of arthropods in all industrial study sites.

Araneae

A total of 11 species of Araneae covering 9 genera of 6 families were recorded during the present investigation. These spiders were found to form web snares on 26 species of host plant belong to 15 families (Table 6). The *Neoscona* is represented by 2 species. Other genera are represented by single species. Family Araneidae comprised a maximum number of 3 species. Salticidae and Thomisidae represented by two species each. *Theridon* sp. (Therididae) formed web on 3 species of host plant (Table 6). Spiderling were also recorded from 3 species of host plants. Host-family association of Araneae shows that *Ipomoea carnea* (Convolvulaceae) shelters a maximum of 5 species followed by 4 species on *Croton bonplandianum* (Euphorbiaceae). *Neoscona* sp. was the only species recorded from a single non-industrial site. No species of Arachnida was found in all the 15 study sites (Table 7). The binary data shows that only one species is found from NUR and BIB and 9 species are recorded from FAL followed by 8 KAN.

Table 7: Number of insect species recorded in plant families both in industrial and non-industrial areas.

Plant family	Hemiptera			Coleoptera			Hymenoptera			Orthoptera			Araneae		
	Ind	Non-Ind	Com	Ind	Non-Ind	Com	Ind	Non-Ind	Com	Ind	Non-Ind	Com	Ind	Non-Ind	Com
Asclepiadaceae	7	7	7	9	9	9	3	3	3	1	3	1	3	3	3
Araceae	*	*	*	*	*	*	*	*	*	3	1	1	1	1	0
Acanthaceae	*	*	*	3	3	3	*	*	*	*	*	*	*	*	*
Anonaceae	*	*	*	1	1	1	*	*	*	*	*	*	*	*	*
Amaranthaceae	*	*	*	1	0	0	*	*	*	*	*	*	1	0	0
Boraginaceae	*	*	*	*	*	*	2	2	2	*	*	*	*	*	*
Compositae	1	1	2	2	2	2	2	2	2	*	*	*	2	1	1
Caesalpiniaceae	2	2	2	*	*	*	*	*	*	*	*	*	*	*	*
Convolvulaceae	2	2	2	5	5	5	4	4	4	*	*	*	5	4	4
Chenopodiaceae	1	1	1	*	*	*	*	*	*	*	*	*	*	*	*

Curcurbitaceae	2	2	2	12	12	12	4	4	4	*	*	*	*	*	*
Cruciferae	2	2	2	1	1	1	1	1	1	2	2	0	*	*	*
Caparidaceae	*	*	*	*	*	*	*	*	*	2	1	1	*	*	*
Cypreraceae	*	*	*	*	*	*	*	*	*	3	3	3	*	*	*
Dioscoriaceae	*	*	*	1	1	1	*	*	*	*	*	*	*	*	*
Euphorbiaceae	11	9	9	17	17	17	7	7	7	1	0	0	4	3	3
Flacourtiaceae	*	*	*	1	1	1	*	*	*	*	*	*	*	*	*
Labiateae	*	*	*	1	1	1	*	*	*	*	*	*	0	1	0
Leguminoceae	2	2	2	5	5	5	3	3	3	0	0	0	2	2	1
Malvaceae	1	1	1	2	2	2	*	*	*	1	1	1	1	1	0
Moraceae	1	0	0	1	1	1	*	*	*	*	*	*	1	1	1
Nyctaginaceae	*	*	*	1	1	1	*	*	*	*	*	*	*	*	*
Plamnaceae	*	*	*	1	1	1	*	*	*	*	*	*	*	*	*
Poaceae	7	5	5	3	3	3	1	1	1	13	10	9	3	2	1
Polygonaceae	*	*	*	*	*	*	4	4	4	*	*	*	*	*	*
Rhamnaceae	*	*	*	*	*	*	*	*	*	*	*	*	1	1	1
Rubiaceae	*	*	*	1	1	1	*	*	*	*	*	*	1	1	1
Solanaceae	13	13	13	9	8	8	7	7	7	10	6	6	3	3	2
Saporaceae	*	*	*	1	1	1	*	*	*	*	*	*	*	*	*
Verbenaceae	*	*	*	1	1	1	*	*	*	*	*	*	*	*	*
Total	52	47	48	78	77	77	38	38	38	36	27	22	28	24	18

Species Richness

Comparative account of occurrence of arthropods in all the 15 study sites shows that Coleoptera is the most common order in all the study sites followed by Hymenoptera and Hemiptera (Figs. 2 and 3). Maximum number of species has been recorded from KAN (104) of non-industrial zone and minimum from NUR (47) in industrial area. The abundance of Coleopteran species is comparatively larger close to the industrial areas while decreases towards South and East (Fig. 2). The distribution of Lepidoptera decreases towards East while Araneae decreases towards the South. The distribution patterns of arthropods of non-industrial study sites are shown in Figure 3.

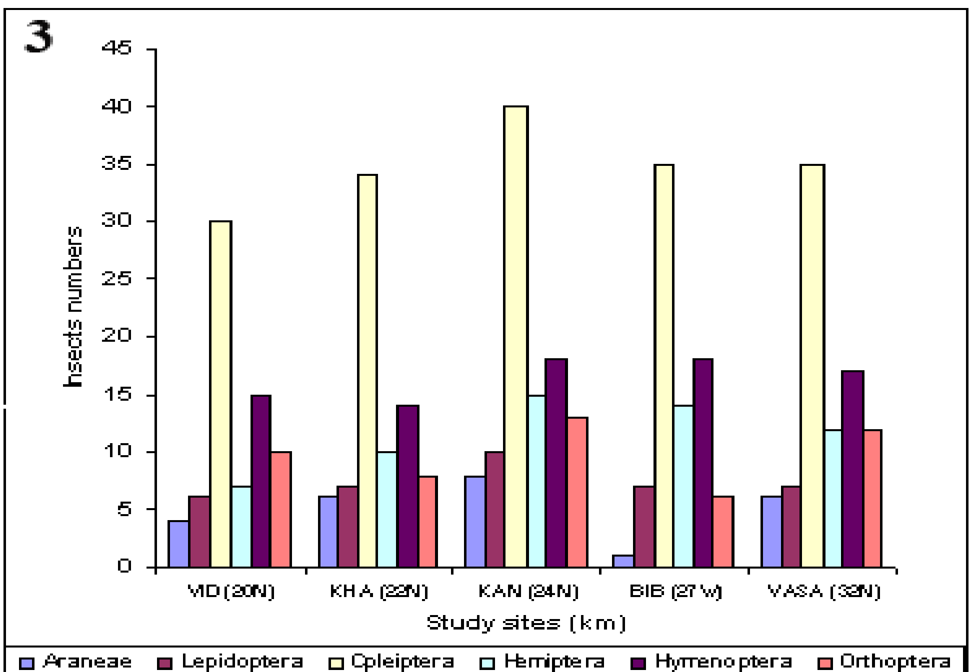

Fig 3: Comparisons of distribution pattern of arthropods in all non-industrial study sites.

The relative abundance of arthropod species is documented in Table 8. Out of thirty plant families, only five are found to harbour by all the arthropod orders except Lepidoptera. The SAD patterns of Hemiptera, Coleoptera, Hymenoptera, Orthoptera and Araneae are expressed in figure 4 (a – e). The SAD patterns of these arthropod orders show a close similarity in Euphorbiaceae, Leguminoceae, Asclepiadaceae and Poaceae in both industrial and non-industrial study sites (Figs. 4a - 4c). In all study sites, only coleopteran insects are predominant on Euphorbiaceae, Leguminoceae, and Asclepiadaceae families whereas only orthopteran insects are abundant than other arthropods in Poaceae and Solanaceae plants (Figs. 4d – 4e). Number of individuals is always higher in non-industrial area than those of industrial zone in four plant families (Figs. 4 a-d). However this is reverse in the plant family Solanaceae (Fig 4e).

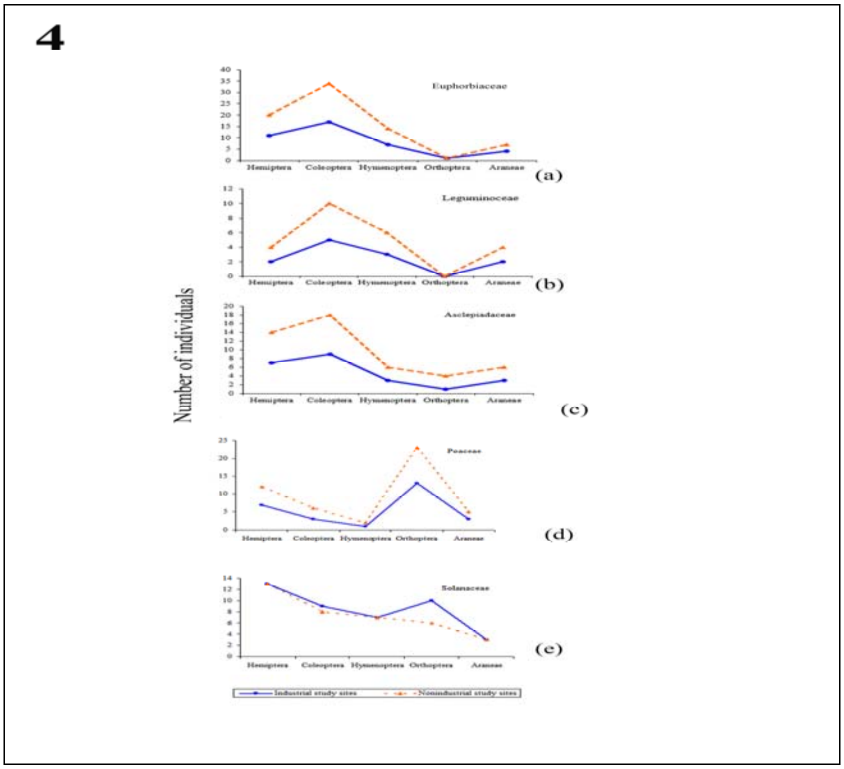

Fig 4: Abundance pattern of arthropod orders in five host plant families in industrial and non-industrial study sites.
a) Euphorbiaceae; b) Leguminoceae; c) Asclepiadaceae; d) Poaceae; e) Solanaceae.

Table 8: Relative abundance of arthropod orders in both industrial and non-industrial study sites.

	Relative abundance (%)														
	Industrial study sites										Non-industrial study sites				
Orders of arthropods	**FAL**	**FALPS1**	**BUR**	**DON**	**FALPS2**	**SAR**	**DIG**	**I.B.**	**NAI**	**NUR**	**VID**	**KHA**	**KAN**	**VASA**	**BIB**
Araneae	10.2	5.00	5.75	7.23	5.75	6.25	8.82	8.82	4.55	2.13	5.56	7.59	7.69	6.74	1.23
Lepidoptera	10.2	8.75	10.34	10.84	11.49	10.00	7.35	4.41	6.06	6.38	8.33	8.86	9.62	7.87	8.64
Coleoptera	35.2	45.00	40.23	40.96	42.53	40.00	35.29	42.7	34.85	38.30	41.67	43.04	38.46	39.33	43.21
Hemiptera	15.90	13.75	18.39	13.25	13.79	16.25	13.24	13.2	15.15	21.28	9.70	12.66	14.42	13.48	17.28
Hymenoptera	15.90	17.50	18.39	16.87	16.09	18.75	22.06	20.6	24.24	29.79	20.83	17.72	17.31	19.10	22.22
Orthoptera	12.5	10.00	6.90	13.25	10.34	8.75	13.24	10.3	15.15	2.13	13.89	10.13	12.50	13.48	7.41

Discussion

Burgeoning knowledge on biodiversity studies from various parts of the globe, points to the fact that human interference is the root cause of biodiversity crisis. Biodiversity studies are important to document and understand the influence of habitat disturbance on the species composition and diversity. Such studies will help us to assess how biological communities react to human habitat destruction as well as fragmentation and it is important to ecosystem management [35, 36]. The arthropods are usually associated with plants for either feeding or housing purpose. The insects enjoy a trophic relationship to the respective plants whereas Araneae exhibit a spatial relationship with the plants. The abundance of insect species contingent to trophic relationship with the plants and normally is affected by industrial and non-industrial areas. Binary data on Hemiptera shows that the mean abundance value of insects from industrial and non-industrial areas is 11.5 and 11.6 respectively. This indicates that abundance pattern remain more or less similar between the two groups of study sites. Jana *et al.* [9] reported about the occurrence of 15 species of Hemiptera covering 14 genera of 8 families from the Haldia industrial belt and adjoining non-industrial areas. In the present study 22 species of 14 families are recorded from the FEPZ and adjoining non-industrial area. Thus the species richness is more in the present study sites than those from Haldia. Such variation may be due to the difference of the type of industries in both the areas. Falta is situated at 50 km North to Haldia and the categories of industries are not similar in both the places. The nature of emission might also differ in these two places. The species richness of Coleoptera species is found to be higher in the present study as compared to that in Haldia [9]. It is believed that Coleoptera prefer polluted areas for which their infestation is likely to be high in industrial areas [33]. It is presumed that the disparity of arthropod load may possibly due to wind direction which spreads industrial pollutants. The species abundance distribution (SAD) patterns of arthropod orders in five plants families exhibit similarity in both industrial and non-industrial zones. It is clear from the Figure 4 that distribution pattern of insects in plant families reflects influence of industrialization in FEPZ of Falta. Insects have the ability to recognise and respond chemical cues released by the plant [37]. Plants absorb pollutants from the soil and surroundings and are also identified by the insects. Less number of occurrence of insects in industrial area than those of non-industrial zones may be related with this fact. Little variation in the SAD pattern of Araneae suggests that these arachnids are not feeding on plants but rely on the type of food pray for which they are dependent.

It is found that 19 species from four families *viz.*, Cerambicidae, Apionidae, Curculionidae and Hydrophilidae were recorded from FEPZ and adjoining zone in contrast to

Haldia. The distribution pattern and nature of the insect-host plant association also show marked variation between the present observation from FEPZ and that of Haldia. The relative abundance of Coleoptera is higher in 15 study sites than those of other arthropod orders. Insects like ants, termites, beetles respond to the degradation of habitat and exhibit change in species assemblage [13, 38, 39, 40, 41]. Land use and management influence the Coleoptera assemblage [42]. It might be that beetles are too tolerant as compared to other groups of insects. Caterino [23] studied the species richness and complementarity of beetle faunas in a Mediterranean-type biodiversity hotspot. He found that diversity of Mediterranean insect faunas show high spatial variability. Relationships between beetles and plants have been used in estimates of global biodiversity [43]. However, recent study on meta-analysis yielded an overall weak relationship among species richness of a variety of taxa [44].

There is little variation on the occurrence of Hymenoptera in the present study to those from Haldia. There exist similarities in the distribution pattern and insect-host plant association between the present study and those from Haldia. The mean abundance value in FEPZ (14.6) is less than that in non-industrial areas (16.4). Thus it appears the species richness in industrial area is affected. Jana *et al*. [9] recorded three species of Orthoptera from the two plant families Gryllidae and Mogoplistidae from Haldia, which are not found in the present study area. The distribution pattern and insect-host plant association in the two studies differ. The mean abundance value of Orthoptera is also much less in FEPZ (7.6) than that in non-industrial zone (9.8). This could be due to the effect of industrialization on species richness.

The species richness of Lepidoptera is much less in FEPZ and adjoining non-industrial areas than those recorded from Haldia. Jana *et al*. [9] recorded 41 species of Lepidoptera under 10 families and 32 genera, whereas; in the present study only 23 species of 16 genera covering 6 families are collected. The mean abundance value of FEPZ is 6.5 and that of non-industrial site is 7.4. Variation in Lepidopteran diversity was investigated in northern Borneo under different disturbance regimes and habitat gradients [45, 46, 47, 48] Establishment of FEPZ in Falta resulted in major change in landscape pattern. The depleted abundance value in FEPZ may be due to habitat destruction in and around Falta. Binary data of Araneae revealed 10 species under 6 families. Value is 5.0 from both FEPZ and non-industrial areas. This shows that apparently there is no impact of industrial set up on species richness of Araneae.

Present study thus reveals that the impact of industrialization on species richness is obvious only in Coleoptera, Hymenoptera, Orthoptera and Lepidoptera. In Hemiptera and Araneae virtually there is no impact of industrialization. The overall mean abundance value of all the arthropod fauna of FEPZ is 69.1 to that of 83.0 from non-industrial areas, which indicate a reduction of 13.9% fauna in FEPZ. Jana *et al*. [9] recorded overall decline of 23.33% fauna in an industrial zone. Decline in abundance of arthropod assemblage in FEPZ might be due to habitat degradation consequent to change in land use pattern.

Effect of industrial pollutant is more in Haldia because of the establishment of a large number of major industries [9], whereas in the present study area small-to-medium scale processing industries are prevailed. Sikdar *et al*. [49] reported that Calcutta-Falta area is polluted where SPM, NOx and SO_2 levels are very high during summer end it is quite low during winter months. Hubálek [50] evaluated both theoretically and empirically the coefficients of association and similarity based on binary data. He considered 43 coefficients and remarked that Jackard, Dice-Sørensen, Kulezyński, Driver-Kroeber-Ochiai and with some reservation Pearson Tetrachoric and Baroni-Urbani-Buser measures work well for analysing interspecific association. The abundance of arthropod species of 6 orders does not reflect effect of industrialization in FEPZ. The dominant status of the arthropod community also fails to provide any definite conclusion. This may be due to the alteration of host plant by the insects and arachnids. All the three species of Orthoptera and Araneae are found in FAL. These species are either absent or marginally present in other sites. There are similarities of some spider genus between FEPZ of Falta and forest of Dooars, West Bengal [51]. Influence of human habitation may be one of the reasons. It is already referred that habitat disturbance causes decrease in population of invertebrates. Pyle *et al*. [52] commented that urbanization is associated with a variety of effects on arthropod population, which includes pollution, habitat fragmentation and loss, etc. They considered urbanization as one of the primary causes for the declines in arthropod population. Urbanization also affected synanthropic arthropods [53]. Human impacts negatively affect biodiversity. Gaston and Spicer [54] identified four main causes, *viz.,* direct exploitation, habitat loss and degradation, introduced species, and extinction cascades, for species loss and declines in biodiversity due to negative human impacts. McIntyre [55] is of the opinion that arthropods are greatly affected by urbanization at an unprecedented rate. Evidence suggests that overall richness and abundance arthropod communities, inhibiting creosote bush, were lower in urban deserts than in fringe deserts [56]. It is now considered that urbanization is a major driving force of biodiversity loss as well as biological homogenisation in both developing and underdeveloped country [57, 58]. The high abundance of coleopteran species in industrial areas than other arthropod orders because these insects might have a preference to pollutants over other arthropod species.

Now-a-days underdeveloped countries, besides urbanization, are establishing Special Economic Zone (SEZ), where human interference is exceedingly high. The present work is in agreement to the above concept that urbanization including SEZ areas negatively affects arthropod communities. The whole work reflects the impact of industrialization on the local and regional biodiversity pattern of six arthropod orders in the Falta Export Processing Zone (FEPZ) and in non-industrial area of South 24 Parganas district. The present work not only indicate a new aspect of biodiversity but also measures partially the quality of environment with regard to the bioindicator study recording the seasonal /monthly abundance pattern of these insects.

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