

---

## Results and Discussion

### Phase - I

#### 4.1 Diversity of Orthopterans

Orthopterans are the most diverse and a major part of the global biodiversity. The diverse ecological roles of Orthopterans in ecosystem processes at multiple levels of the biological organization can also be used to assess and monitor the overall health of biodiversity and the state of the total environment. Orthopterans provide easy, cost-effective and sensitive means to measure the effects of anthropogenic stress on biodiversity and the environment. Orthopteran conservation aims at saving both endangered and the dynamics of the environmental process in an ecosystem. The faunal survey of Orthopterans provides the inventory and assessment of biological heterogeneity and contributes to developing a comprehensive description of the composition, richness and abundance from different ecological sites and seasons.

The families, subfamilies, tribes, genera and species of the Orthopterans collected are shown in table - 7. A total of 45 Orthopterans belonging to 35 genera, 26 tribes and 16 subfamilies were collected from five different sites of Coimbatore, Tamil Nadu, India from August, 2018 to March, 2020 (Table - 7 and Plates I to V). All the collected Orthopterans were classified under four families viz., Acrididae, Pyrgomorphidae, Tettigoniidae and Gryllidae. These four families were collected under two suborders. Acrididae and Pyrgomorphidae having a place with the suborder Califera (short-horned grasshopper); Tettigoniidae and Gryllidae having a place with the suborder Ensifera (long-horned grasshopper).

#### Orders of Orthopterans

Among the two suborders, Califera was the most species rich suborder with 34 species (29 acridids and five pyrgomorphids) of short-horned Orthopterans grouped under 25 genera and 19 tribes under 12 subfamilies, which amounted to 75.55% of the total species recorded. Suborder Ensifera had 11 species (eight tettigoniids and three gryllids), 10 genera and seven tribes under four subfamilies, which contributed to 24.44% of the total collected species (Table - 8).

### **Families of Orthopterans**

With respect to the total number of species found, Acrididae was the most species rich family with 29 species of acridids grouped under 21 genera, 15 tribes and 10 subfamilies, which accounted for 64% of the total species collected. The second dominant family was Tettigoniidae had eight species, seven genera and six tribes under three subfamilies, which contributed 18% of the total collected species. Family Pyrgomorphidae was ranked third with five species, four genera, four tribes and two subfamilies, which amounted to 11% of total species, while Gryllidae family had the least with three species under three genera, one tribe and one subfamily, which contributed only 7 % of total recorded species (Table - 9 & Fig - 7).

### **Subfamilies of Orthopterans**

Among the 16 subfamilies of Orthopterans, Oedipodinae was found to be the most dominant subfamily with 13 species amounting to 27.27% of the total collected species. Next in order of dominant families were Pyrgomorphae with five species contributing 15% of total numbers and Phaneropterinae with four species constituting 13.4%. Subfamilies, Coptacrinae, Cyrtacanthacridinae, Eypreocnemidinae, Hemiacridinae and Spathosterninae from Acrididae family, Orthacridinae from Pyrgomorphidae family, Pseudophyllinae from Tettigoniidae family were constituted of only one species of Orthopterans (Fig - 8 & 9).

### **Tribes of Orthopterans**

Among the 26 tribes of Orthopterans, Acrotlyini and Locustini were the most dominant tribes with four species, which amounted to 14.81% of the total collected species. Next in order of dominant tribes were Oxyini and Gryllini with three species contributing 11.11% of total numbers. Totally, 15 identified tribes and three unidentified tribes from the family of Acrididae, four tribes from the family of Prgomorphidae, six tribes from the family of Tettiogoniidae and one tribe from the family of Gryllidae were recorded in the study area. Among them, 15 tribes from the study area constitute only one Orthopterans species (Table - 10). Acrididae comprises the largest number of tribes compared to other families.

**Table - 7**  
**Checklist of Orthopterans diversity in the study area**

Family	Subfamily	Tribe	Species
Acrididae	Acridinae	Acridini	<i>Acrida exaltata</i> (Walker, 1859)
			<i>Acrida turrita</i> (Linnaeus, 1758)
	Coptacrinae	-	<i>Epistaurus sinetyi</i> (Bolívar, 1902)
			<i>Diabolocatantops pinguis</i> (Stal, 1861)
	Catantopinae	Catantopini	<i>Xenocatantops humilis</i> (Serville, 1838)
			<i>Cyrtacanthacris tatarica</i> (Linnaeus, 1758)
	Cyrtacanthacridinae	Cyrtacanthacridini	<i>Cyrtacanthacris tatarica</i> (Linnaeus, 1758)
	Eyprepocnemidinae	Eyprepocnemidini	<i>Eyprepocnemis alacris</i> (Serville, 1838)
	Gomphocerinae	Arcypterini	<i>Crucinotacris decisa</i> (Walker, 1871)
			<i>Aulacobothrus luteipes</i> (Walker, 1871)
		Dociostaurini	<i>Leva indica</i> (Bolívar, 1902)
	Hemiacridinae	Hieroglyphini	<i>Hieroglyphus banian</i> (Fabricius, 1798)
	Oedipodinae	Acrotlyini	<i>Acrotylus longipes</i> (Charpentier, 1845)
			<i>Acrotylus humberianus</i> (Saussure, 1884)
			<i>Acrotylus insubricus</i> (Scopoli, 1786)
			<i>Acrotylus patruelis</i> (Herrich-Schäffer, 1838)
		Epacromiini	<i>Aiolopus thalassinus</i> (Fabricius, 1781)
		-	<i>Ditopternis venusta</i> (Walker, 1870)
		Locustini	<i>Gastrimargus africanus</i> (Saussure, 1888)
			<i>Gastrimargus marmoratus</i> (Thunberg, 1815)
<i>Oedaleus abruptus</i> (Thunberg, 1815)			
<i>Oedaleus infernalis</i> (Saussure, 1884)			
-		<i>Morphacris fasciata</i> (Thunberg, 1815)	
Trilophidiini		<i>Trilophidia annulata</i> (Thunberg, 1815)	

Contd...

Family	Subfamily	Tribe	Species	
	Oxyinae	Sphingonotini	<i>Sphingonotus longipennis</i> (Saussure, 1884)	
		Oxyini	<i>Oxya velox</i> (Fabricius, 1787)	
			<i>Oxya hyla</i> (Serville, 1831)	
	Spathosterninae	Spathosternini	<i>Oxya fuscovittata</i> (Thunberg, 1824)	
Pyrgomorphidae	Pyrgomorphinae	Atractomorphini	<i>Spathosternum prasiniferum</i> (Walker, 1871)	
		Chrotogonini	<i>Atractomorpha crenulata</i> (Fabricius, 1793)	
			<i>Chrotogonus oxypterus</i> (Blanchard, 1836)	
	Tagastini	<i>Chrotogonus trachypterus</i> (Blanchard, 1836)		
	Orthacridinae	Orthacridini	<i>Tagasta indica</i> (Bolivar, 1905)	
Tettigoniidae	Conocephalinae	Copiphorini	<i>Orthacris maindroni</i> (Bolivar, 1905)	
			<i>Conocephalus maculatus</i> (Le Guillou, 1841)	
	Phaneropterinae	Holochlorini	Letanini	<i>Euconocephalus pallidus</i> (Redtenbacher, 1891)
				<i>Holochlora spectabilis</i> (Walker, 1869)
		Phaneropterini	Trigonocoryphini	<i>Himertula kinneari</i> (Uvarov, 1924)
				<i>Himertula vidhyavadhiaie</i> (Ingrisch and Muralirangan, 2004)
	Pseudophyllinae	Cymatomerini	<i>Phaneroptera gracilis</i> (Burmeister, 1838)	
Gryllidae	Gryllinae	Gryllini	<i>Trigonocorypha unicolor</i> (Stoll, 1787)	
			<i>Sathrophyllia rugosa</i> (Linnaeus, 1758)	
			<i>Teleogryllus mitratus</i> (Burmeister, 1838)	
			<i>Gryllus bimaculatus</i> (De Geer, 1773)	
			<i>Gryllodes sigillatus</i> (Walker, 1869)	
4	16	26	35 genera and 45 species	



*A. exaltata*



*A. turrita*



*P. infumata*



*E. sinetyi*



*D. pinguis*



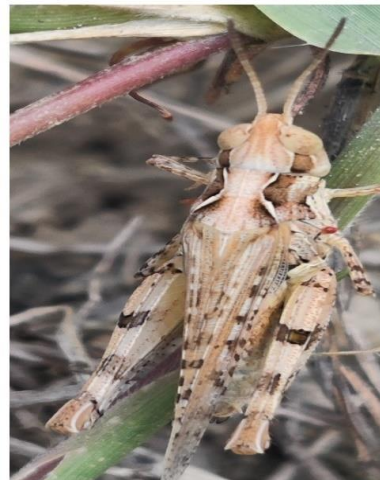
*X. humilis*



*C. tatarica*



*E. alacris*



*C. decisa*

Plate – I  
Orthoptera fauna



*A. luteipes*



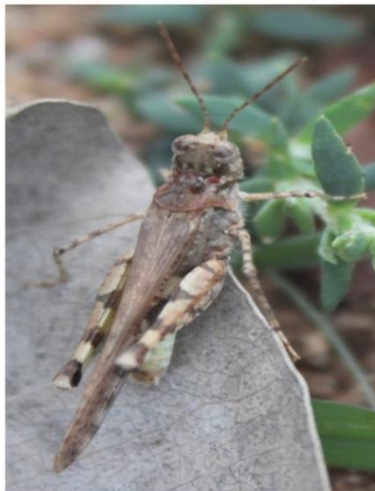
*L. indica*



*H. banian*



*A. longipes*



*A. humberianus*



*A. insubricus*



*A. patruelis*



*A. thalassinus*



*D. venusta*

Plate - II  
Orthopteran fauna



*G. africanus*



*G. marmoratus*



*O. abruptus*



*O. infernalis*



*M. fasciata*



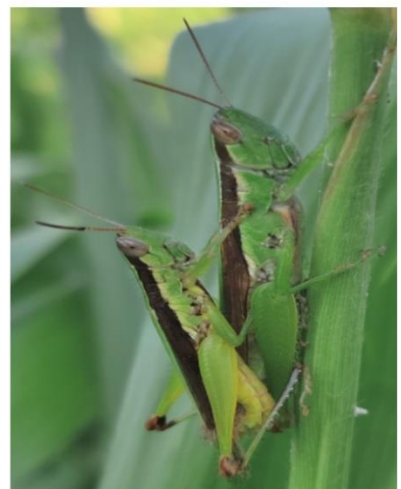
*T. annulata*



*S. longipennis*

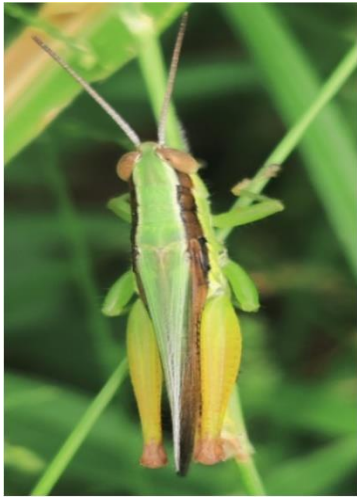


*O. velox*



*O. hyla*

**Plate - III**  
**Orthopteran fauna**



*O. fuscovittata*



*S. prasiniferum*



*A. crenulata*



*C. oxypterus*



*C. turanicus*



*T. indica*



*O. maindroni*



*C. maculatus*



*E. pallidus*

Plate – IV  
Orthopteran fauna



*H. spectabilis*



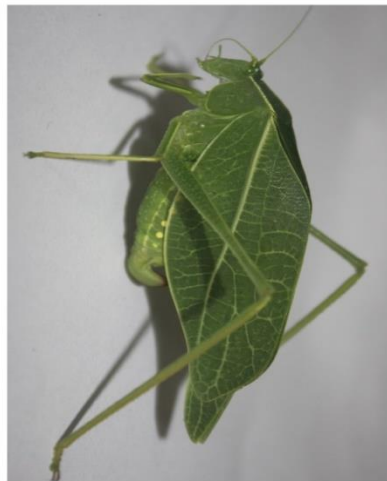
*H. kinneari*



*H. vidhyavadhiaae*



*P. gracilis*



*T. unicolor*



*S. rugosa*



*T. mitratus*



*G. bimaculatus*



*G. sigillatus*

Plate - V  
Orthopteran fauna

Table - 8

Total number of Orthopterans among suborders

Suborders	Number of families	Number of subfamilies	Number of tribes	Number of genera	Number of species	Percentages of suborders
Califera	2	12	19	25	34	75.55%
Ensifera	2	4	7	10	11	24.44%

Table - 9

Total number of Orthopterans taxon among different families

S. No	Family	Number of subfamilies	Number of tribes	Number of genera	Number of species
1.	Acrididae	10	15	21	29
2.	Pyrgomorphidae	2	4	4	5
3.	Tettigoniidae	3	6	7	8
4.	Gryllidae	1	1	3	3
Total	4	16	26	35	45

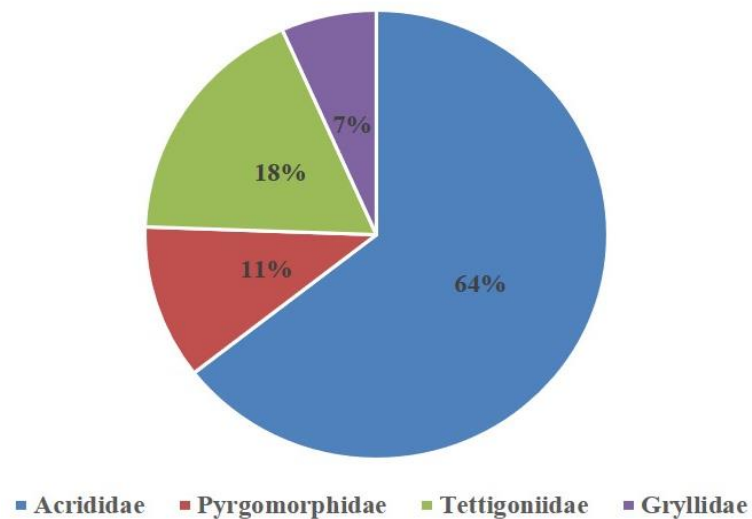


Figure - 7

Percentages of Orthopteran family in the study area

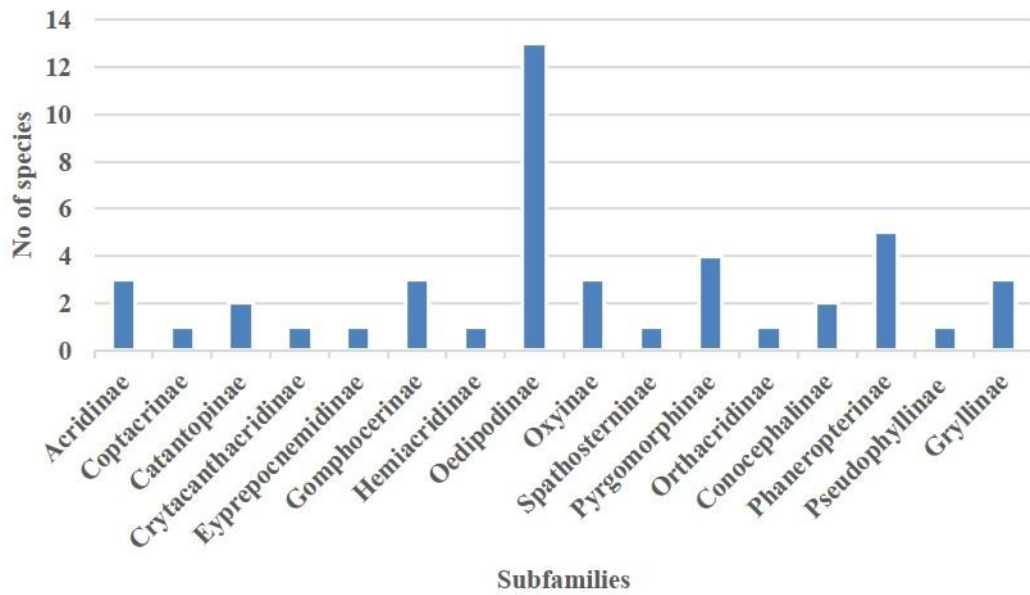


Figure - 8

Number of Orthopteran subfamilies collected from the study area

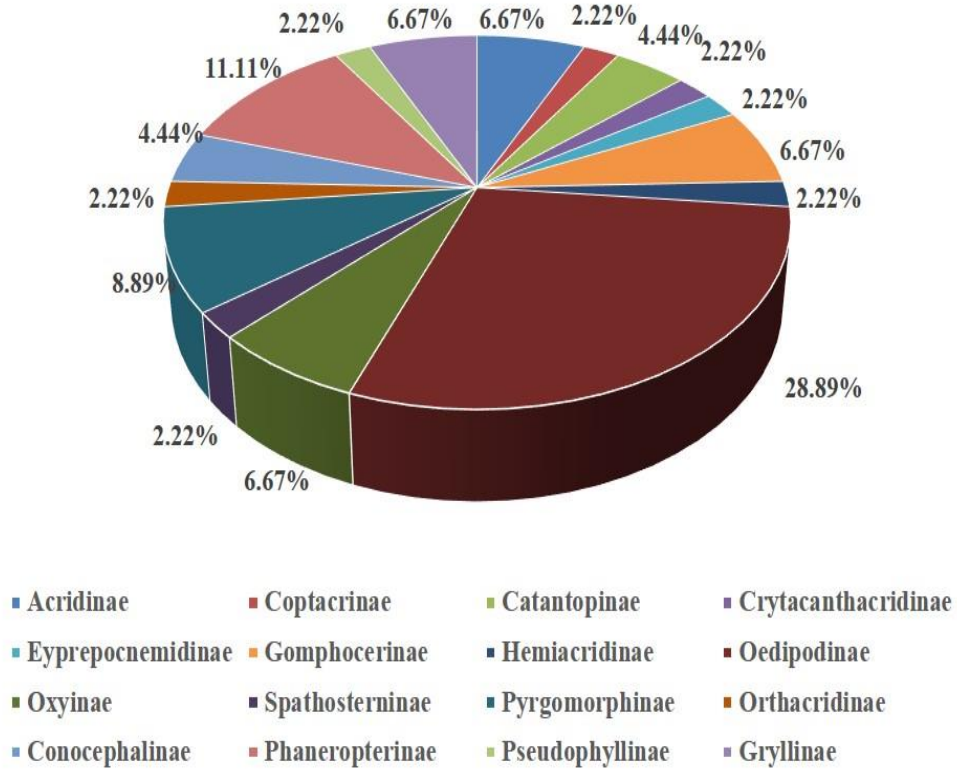


Figure - 9

Percentages of subfamilies of Orthopterans

Table - 10

## Total number of species collected from different tribes

Family	Tribes	Number of Species	Percentages of Tribes
<b>Acrididae</b>	Acridini	2	7.40%
	Phlaeobini	1	3.70%
	Catantopini	2	7.40%
	Cyrtacanthacridini	1	3.70%
	Eyprepocnemidini	1	3.70%
	Arcypterini	2	7.40%
	Dociostaurini	1	3.70%
	Hieroglyphini	1	3.70%
	Acrotylini	4	14.81%
	Epacromiini	1	3.70%
	Locustini	4	14.81%
	Trilophidiini	1	3.70%
	Sphingonotini	1	3.70%
	Oxyini	3	11.11%
	Spathosternini	1	3.70%
	Unidentified	3	11.11%
<b>Pyrgomorphidae</b>	Atractomorphini	1	3.70%
	Chrotogonini	2	7.40%
	Tagastini	1	3.70%
	Orthacridini	1	3.70%
<b>Tettigoniidae</b>	Copiphorini	2	7.40%
	Holochlorini	1	3.70%
	Letanini	2	7.40%
	Phaneropterini	1	3.70%
	Trigonocoryphini	1	3.70%
	Cymatomerini	1	3.70%
<b>Gryllidae</b>	Gryllini	3	11.11%

**Orthopterans diversity in different sites**

During the study period, the number of collected Orthoptera species among different genera, tribes, subfamilies and families were greatly varied from one region to another region of the study area (Fig - 10).

**Site I: Marudhamalai**

Overall, 41 species of Orthopterans belonging to 32 genera, 24 tribes and 15 subfamilies under four families were collected from the site I (Fig - 10). Out of 45 species collected from the study area, only four acridids species were absent in site I. Family Acrididae with 25 species and subfamily Oedipodinae with 12 species were most dominant, which contributed to 60.98% and 29.27% of the total collected species. Hemiacridinae was the only subfamily absent in site I (Fig - 11).

**Site II: Saibaba Colony**

Totally, 27 Orthopterans species belonging to 26 genera, 19 tribes and 12 subfamilies under four families were collected from site II (Fig - 10). In overall collected Orthopterans, 13 species from Acrididae, one species from Pyrgomorphidae and four species from Tettigoniidae were absent in site II. Family Acrididae with 14 species and subfamily Oedipodinae with seven species were most dominant, which amounted to 60.98% and 29.93% of the total collected species. Subfamilies, Coptacrinae, Cyrtacanthacridinae, Hemiacridinae and Pseudophyllinae were absent in site II (Fig - 12).

**Site III: Thenkarai**

In total, 36 species of Orthopterans belonging to 35 genera, 26 tribes and 15 subfamilies under four families were collected from the site I (Fig - 10). Four species from Acrididae, one species from Pyrgomorphidae and two species from Tettigoniidae were absent in site III. Family Acrididae with 25 species and subfamily Oedipodinae with 11 species were most dominant, which constituted 65.79% and 28.95% of the total collected species. Pseudophyllinae was the only subfamily absent in site III (Fig - 13).

**Site IV: Thudiyalur**

A total of 31 Orthopterans species belonging to 27 genera, 21 tribes and 13 subfamilies under four families were collected from the site I (Fig - 10). Nine species from Acrididae, one species from Pyrgomorphidae, three species from Tettigoniidae and one species from Gryllidae were absent in site I. Family Acrididae with 20 species and subfamily Oedipodinae with nine species were most dominant, which accounted for 64.52% and 29.03% of the total collected species. In site IV, three subfamilies, Cyrtacanthacridinae, Hemiacridinae and Pseudophyllinae were absent (Fig - 14).

### Site V: Singanallur

Altogether, 20 species of Orthopterans belonging to 19 genera, 17 tribes and 12 subfamilies under four families were collected from the site I (Fig - 10). Out of 45 species collected from the study area, 14 species from Acrididae, three species from Pyrgomorphidae, six species from Tettigoniidae and two species from Gryllidae were absent in site I. Family Acrididae with 15 species and subfamily Oedipodinae with seven species were most dominant, which contributed 75% and 35 % of the total collected species. Four subfamilies, Coptacrinae, Cyrtacanthacridinae, Hemiacridinae and Pseudophyllinae were absent in site V (Fig - 15).

Overall, the maximum number of Orthopterans were observed in site I (41 species), which amounted to 26% of the total collected species followed by site III (38 species), site IV (31 species), site II (27 species) and site V (20 species) (Table - 11 & Fig - 16).

During the study period, *P. infumata*, *D. pinguis*, *E. alacris*, *A. luteipes*, *L. indica*, *A. patruleis*, *D. venusta*, *G. africanus*, *M. fasciata*, *T. annulata*, *O. fuscovittata* and *S. prasiniferum* from Acrididae family, *A. crenulata* and *O. maindroni* from Pyrgomorphidae family, *C. maculatus* and *P. gracilis* from Tettigoniidae family and *T. mitratus* from the family of Gryllidae were found in all the sites of the study area. Orthopterans, *A. turrita*, *X. humilis*, *H. banian*, *O. infernalis* and *S. longipennis* from Acrididae, *C. trachypterus* from Pyrgomorphidae, *H. kinneari* and *S. rugosa* from Tettigoniidae were found in particular sites of Coimbatore (Table - 11).

### Species similarity and dissimilarity among different sites

The similarity of species composition among different sites were performed based on cluster analysis as presented in figure - 17. Clusters were numbered in ascending order based on species composition. The similarity matrix from the quantitative data showed that Orthopterans composition between site I and site III (0.91); site III and site IV (0.86); site I and site IV (0.83); site II and site III (0.83); site II and site IV (0.82); site II and site V (0.80); site I and site II (0.79); site IV and site V (0.70); site III and site IV (0.65) and site I and site V (0.62) site were similar to each other. Site V was formed of a single cluster and species composition had many dissimilarities with other sites of the study area (Fig - 17).

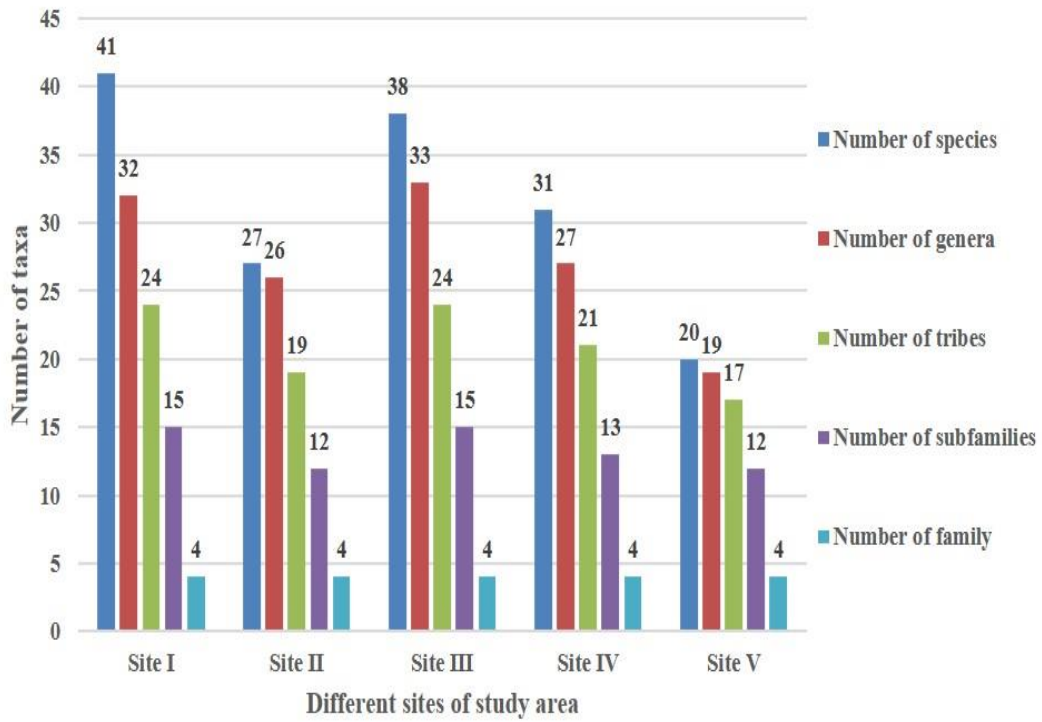


Figure - 10

Total number of taxa collected from the different sites of the study area

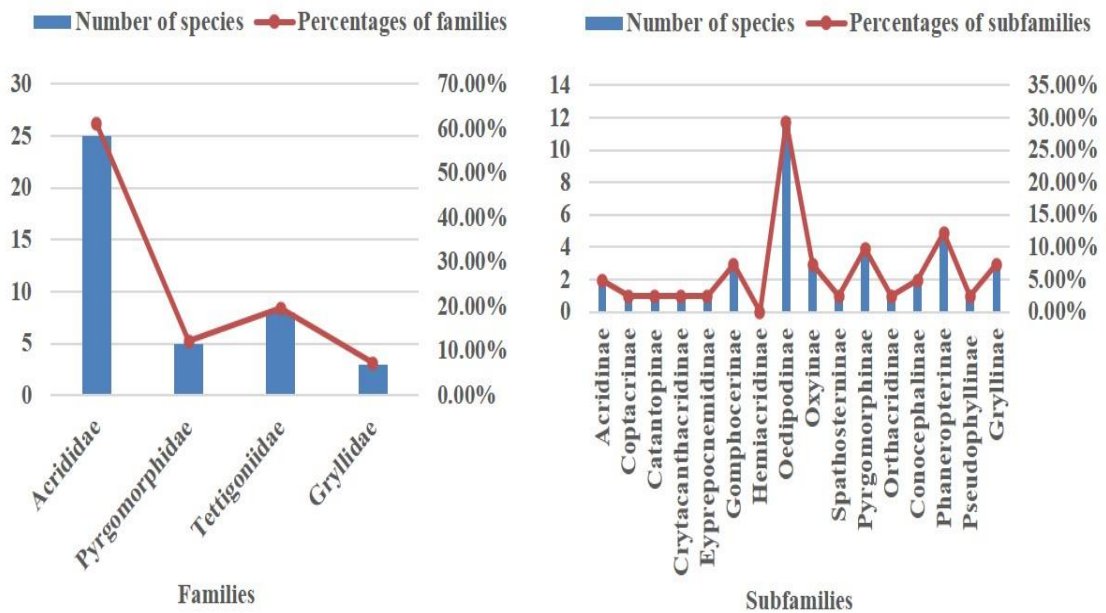


Figure - 11

Species rich families and subfamilies of Orthopterans in site I

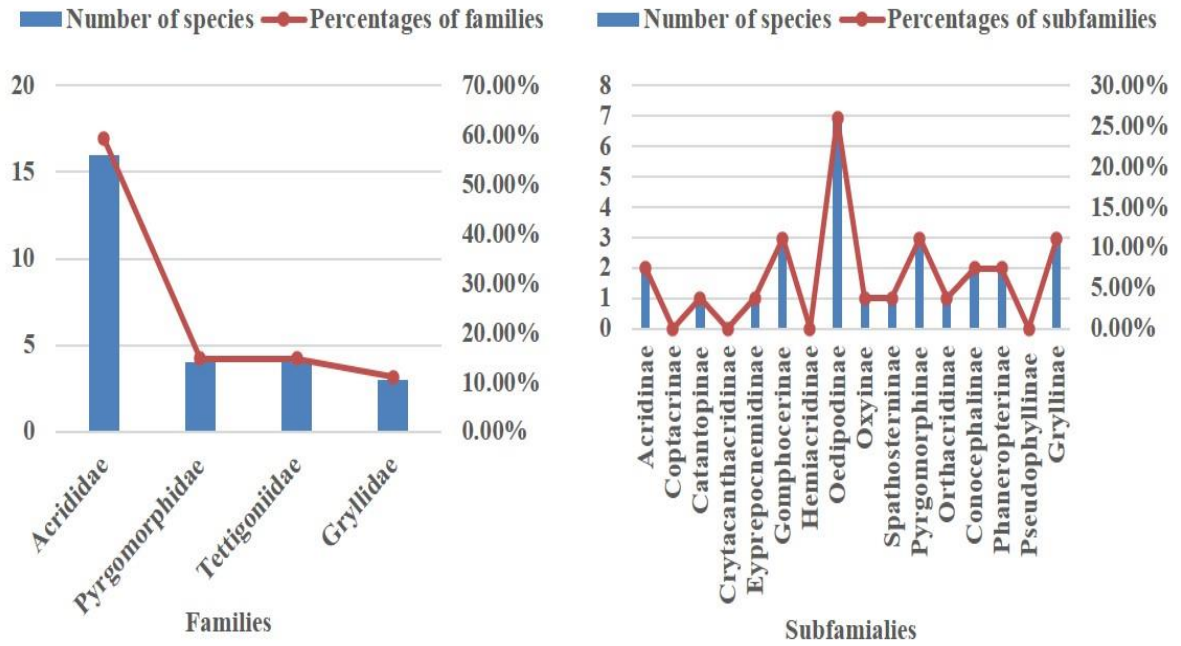


Figure - 12  
Species rich families and subfamilies of Orthopterans in site II

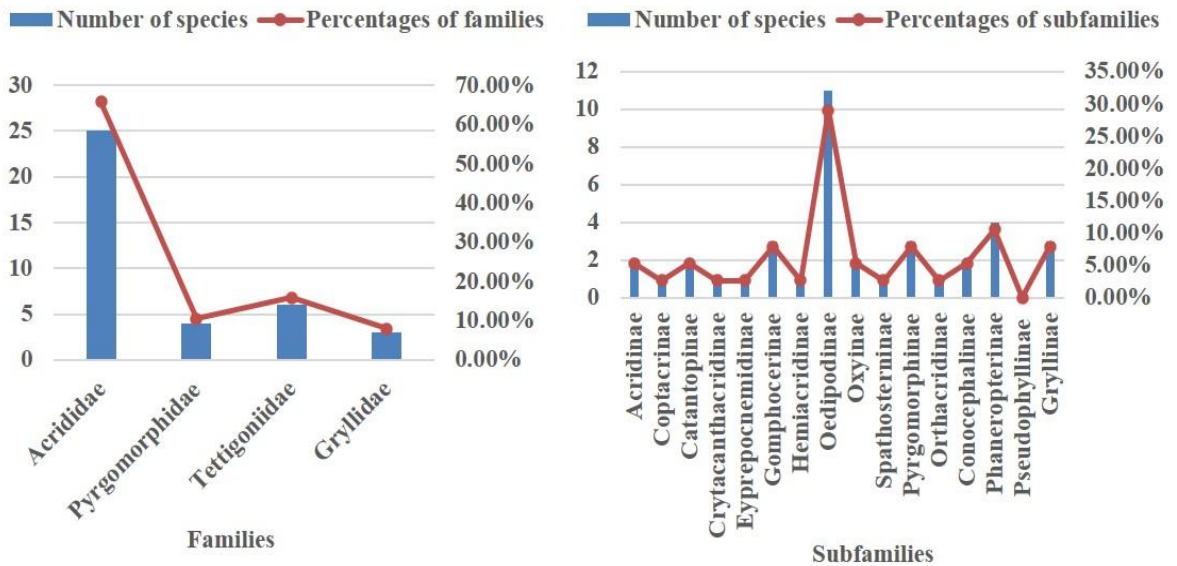


Figure -13  
Species rich families and subfamilies of Orthopterans in site III

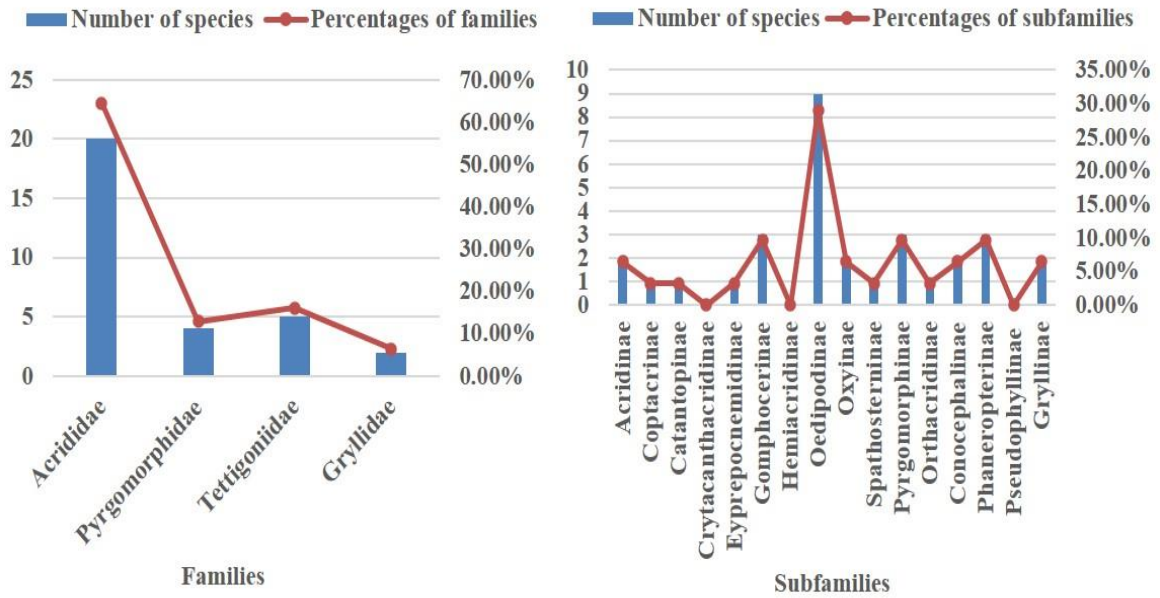


Figure - 14

Species rich families and subfamilies of Orthopterans in site IV

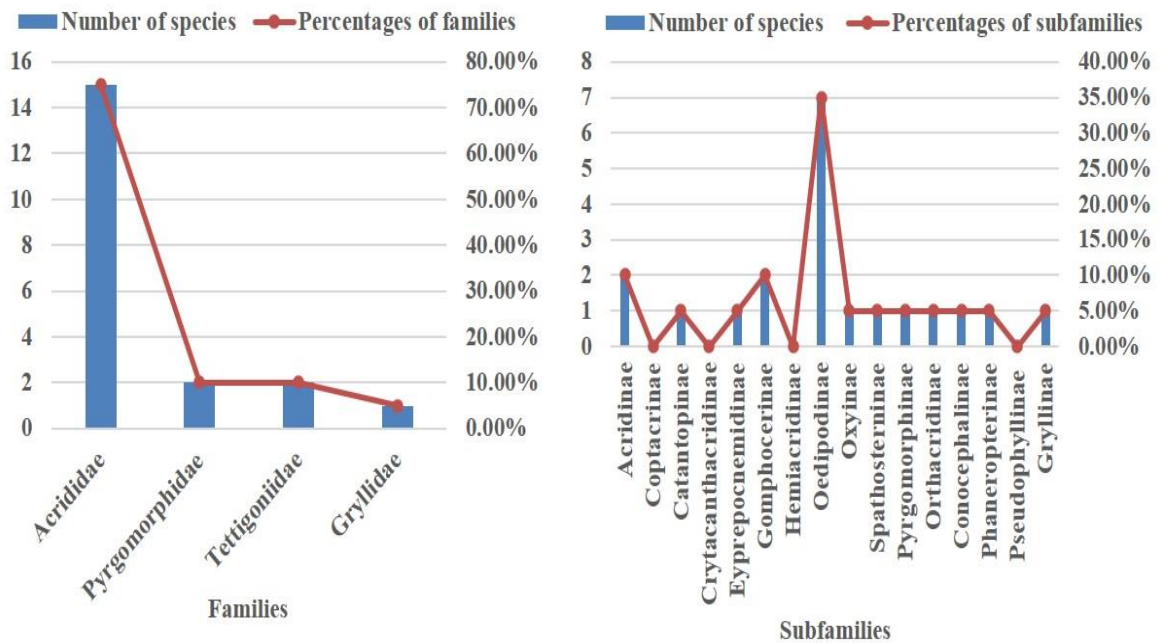
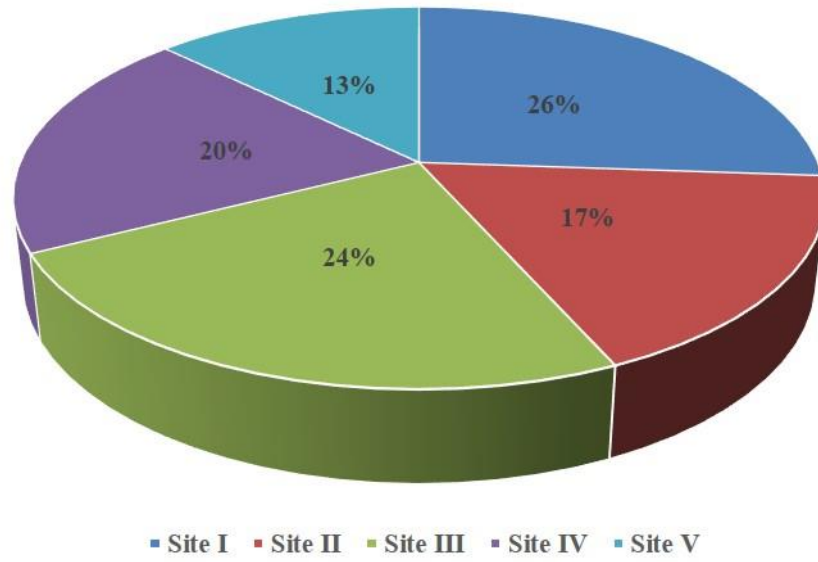
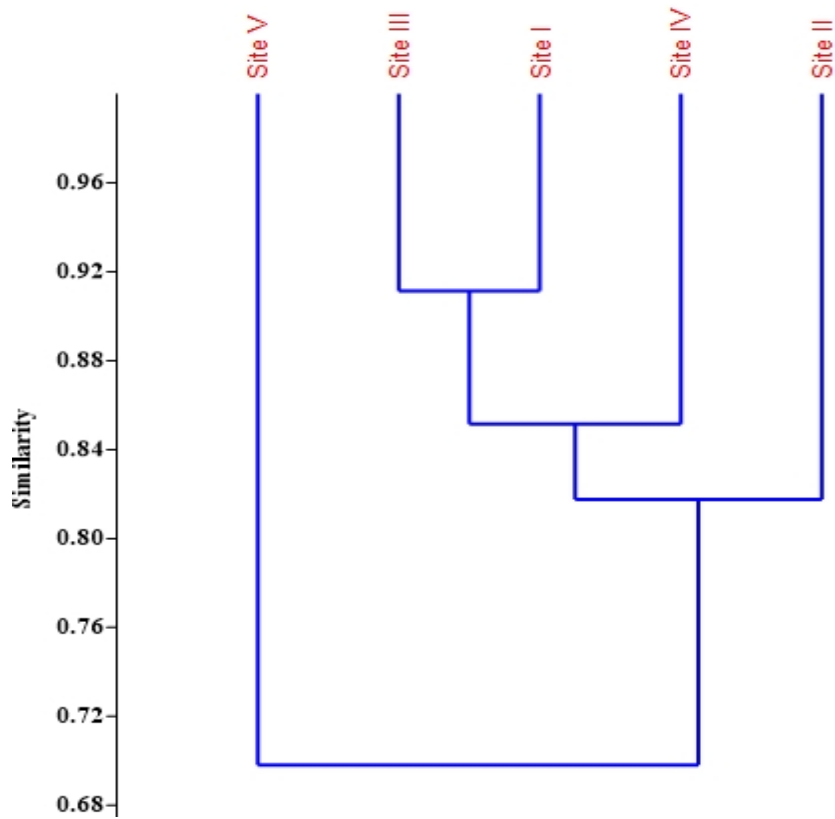


Figure - 15

Species rich families and subfamilies of Orthopterans in site V



**Figure - 16**  
Species rich sites in the study area



**Figure - 17**  
Species similarity in different sites using cluster analysis

**Table - 11**  
**Orthopterans diversity in different sites of Coimbatore**

S. No.	Species	Site I	Site II	Site III	Site IV	Site V
1.	<i>A. exaltata</i>	+	+	+	-	+
2.	<i>A. turrita</i>	-	-	-	+	-
3.	<i>P. infumata</i>	+	+	+	+	+
4.	<i>E. sinetyi</i>	+	-	+	+	-
5.	<i>D. pinguis</i>	+	+	+	+	+
6.	<i>X. humilis</i>	-	-	+	-	-
7.	<i>C. tatarica</i>	+	-	+	-	-
8.	<i>E. alacris</i>	+	+	+	+	+
9.	<i>C. decisa</i>	+	+	+	+	-
10.	<i>A. luteipes</i>	+	+	+	+	+
11.	<i>L. indica</i>	+	+	+	+	+
12.	<i>H. banian</i>	-	-	+	-	-
13.	<i>A. longipes</i>	+	+	+	+	-
14.	<i>A. humberianus</i>	+	-	+	-	-
15.	<i>A. insubricus</i>	+	-	+	-	-
16.	<i>A. patruelis</i>	+	+	+	+	+
17.	<i>A. thalassinus</i>	+	-	+	+	-
18.	<i>D. venusta</i>	+	+	+	+	+
19.	<i>G. africanus</i>	+	+	+	+	+
20.	<i>G. marmoratus</i>	+	-	+	+	-
21.	<i>O. abruptus</i>	+	+	+	+	+
22.	<i>O. infernalis</i>	+	-	-	-	-
23.	<i>M. fasciata</i>	+	+	+	+	+
24.	<i>T. annulata</i>	+	+	+	+	+
25.	<i>S. longipennis</i>	-	-	-	-	+
26.	<i>O. velox</i>	+	-	+	-	-
27.	<i>O. hyla</i>	+	-	-	+	-
28.	<i>O. fuscovittata</i>	+	+	+	+	+
29.	<i>S. prasiniferum</i>	+	+	+	+	+
30.	<i>A. crenulata</i>	+	+	+	+	+
31.	<i>C. oxypterus</i>	+	+	+	+	-
32.	<i>C. trachypterus</i>	+	-	-	-	-
33.	<i>T. indica</i>	+	+	+	+	-
34.	<i>O. maindroni</i>	+	+	+	+	+
35.	<i>C. maculatus</i>	+	+	+	+	+
36.	<i>E. pallidus</i>	+	+	+	+	-
37.	<i>H. spectabilis</i>	+	-	+	+	-
38.	<i>H. kinneari</i>	+	-	-	-	-
39.	<i>H. vidhyavadhiae</i>	+	-	+	+	-
40.	<i>P. gracilis</i>	+	+	+	+	+
41.	<i>T. unicolor</i>	+	+	+	-	-
42.	<i>S. rugosa</i>	+	-	-	-	-
43.	<i>T. mitratus</i>	+	+	+	+	+
44.	<i>G. bimaculatus</i>	+	+	+	-	-
45.	<i>G. sigillatus</i>	+	+	+	+	-
	Total	41	27	38	31	20

### **Orthopterans diversity in different seasons**

The number of collected species greatly varied among different seasons of the study area during the period of study as shown in figure - 18.

#### **Post monsoon season**

Altogether, 25 species of Orthopterans belonging to 24 genera, 17 tribes and 10 subfamilies under four families were collected from post monsoon (Fig - 18). Out of 45 species, 14 acridids species, three pyrgomorphids and three tettigoniids were absent in post monsoon. Family Acrididae with 15 species and subfamily Oedipodinae with eight species were most dominant, which constituted 60% and 32% of the total collected species. Six subfamilies, Coptacrinae, Catantopinae, Cyrtacanthacridinae, Hemicacridinae, Spathosterninae, Orthacridinae and Pseudophyllinae were absent in post monsoon season (Fig -19).

#### **Summer season**

A total of 28 Orthopterans species belonging to 26 genera, 21 tribes and 14 subfamilies under four families were collected from summer (Fig - 18). In summer, nine acridids, three pyrgomorphids, three tettigoniids and two gryllids were absent out of 45 species collected from the study area. Family Acrididae with 20 species and subfamily Oedipodinae with 10 species were most dominant, which contributed 71.43% and 35.71 % of the total collected species. Two subfamilies, Coptacrinae and Eyprepocnemidinae were absent in the summer season (Fig - 20).

#### **Pre-monsoon season**

Totally, 36 Orthopterans belonging to 30 genera, 22 tribes and 13 subfamilies under four families were collected from pre-monsoon (Fig - 18). Four acridids, one pyrgomorphid and one tettigoniid were absent in pre-monsoon season. Family Acrididae with 25 species and subfamily Oedipodinae with 11 species were most dominant, which accounted for 69.44% and 30.56 % of the total collected species. Three subfamilies, Hemicacridinae, Conocephalinae and Pseudophyllinae were absent in the pre-monsoon season (Fig -21).

#### **Monsoon season**

A total of 40 Orthopterans belonging to 32 genera, 24 tribes and 14 subfamilies under four families were collected from the monsoon season (Fig - 18). Five acridids were absent in the monsoon out of the total collected species from the study area. Family Acrididae with 24 species and subfamily Oedipodinae with 10 species were most dominant, which

amounted to 60% and 25% of the collected species. Two subfamilies, Coptacrinae and Cyrtacanthacridinae were absent in the monsoon season (Fig - 22).

The comparison of the abundances in the different seasons revealed that the higher number of species were recorded in monsoon (88.88%) followed by pre-monsoon (80%), post monsoon (62.22%) and summer (55.55%) were illustrated in table - 12 & figure - 23.

During the study period, *A. exaltata*, *P. infumata*, *C. decisa*, *A. luteipes*, *L. indica*, *A. patruelis*, *A. thalassinus*, *D. venusta*, *O. abruptus*, *M. fasciata*, *T. annulata* and *O. fuscovittata* from Acrididae, *T. indica* from Pyrgomorphidae, *T. unicolor* from Tettigoniidae and *G. sigillatus* from Gryllidae were found in all the seasons of the study area. *E. sinetyi*, *S. longipennis* and *O. velox* from Acrididae, *C. trachypterus* from Pyrgomorphida and *H. kinneari* from Tettigoniidae only present in the particular season of the study area (Table - 12).

**Species similarity and dissimilarity among different seasons**

The similarity of species composition among different seasons was performed based on cluster analysis as presented in figure - 24. The similarity matrix from the quantitative data showed that Orthopterans composition between monsoon and pre-monsoon (0.84211); post monsoon and monsoon (0.76923); pre-monsoon and post monsoon (0.72131); pre-monsoon and summer (0.71875); monsoon and summer (0.70588); summer and post monsoon (0.64151) were similar to each other.

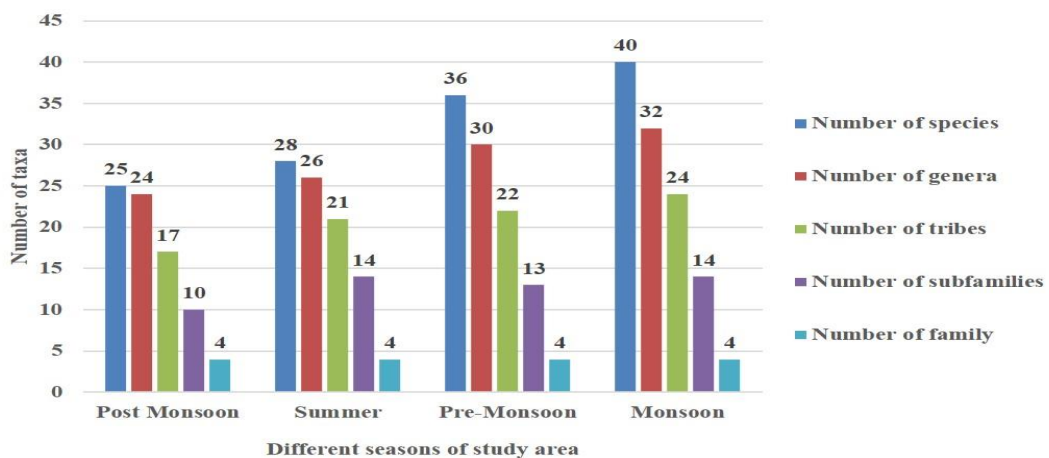
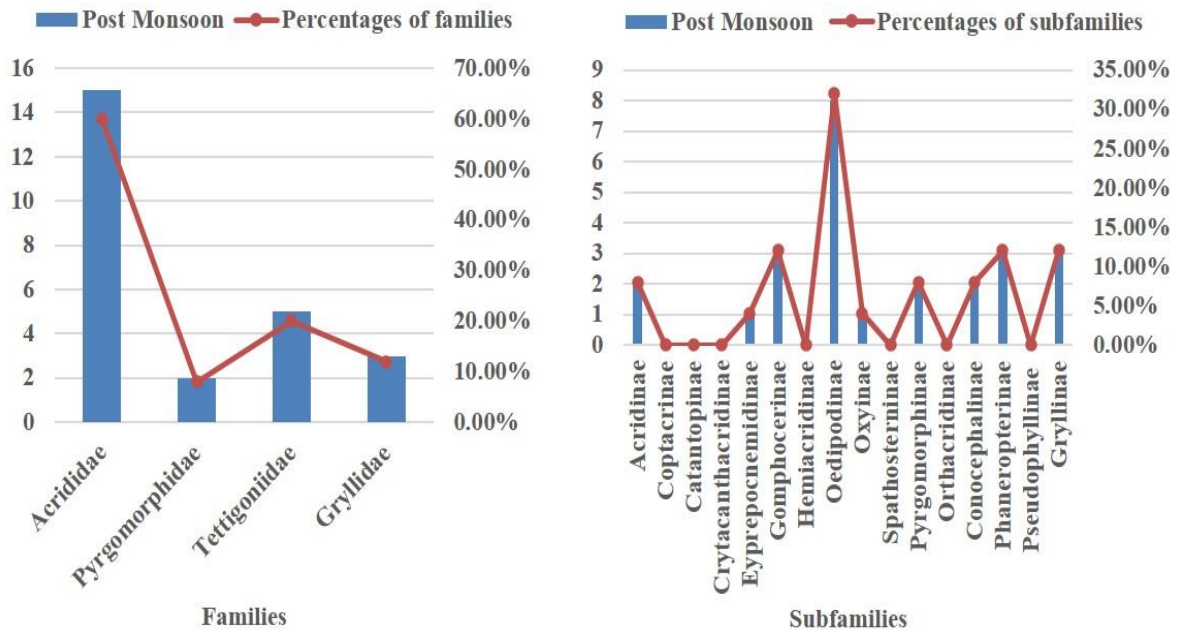
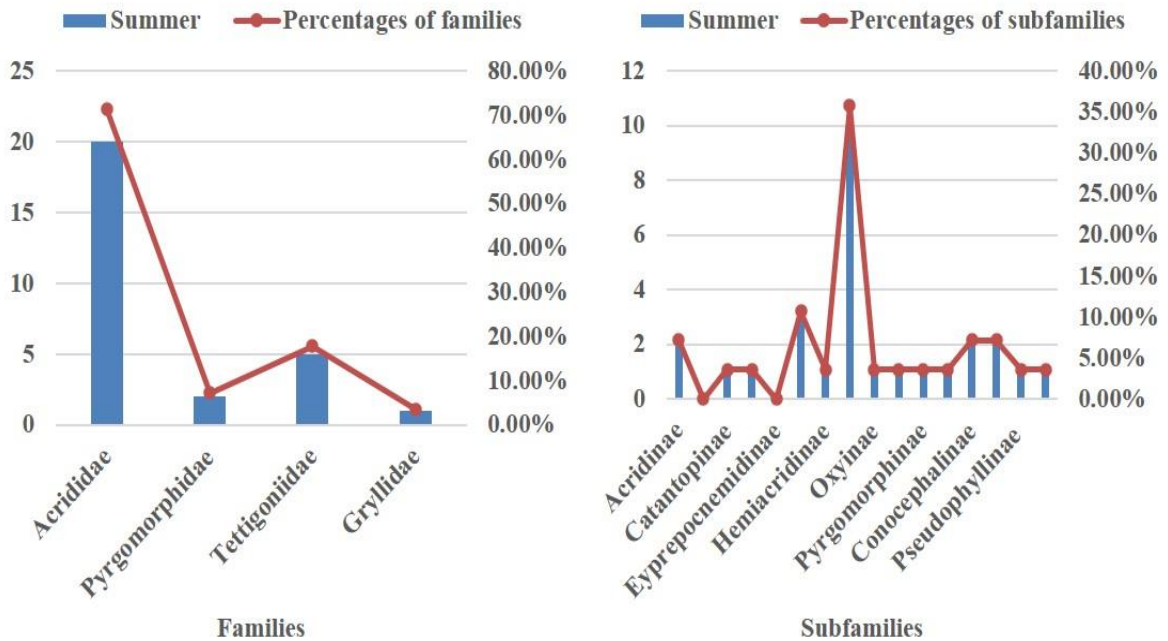


Figure - 18

**Total number of taxa collected from different seasons of the study area**



**Figure - 19**  
Species rich families and subfamilies of Orthopterans in post monsoon



**Figure - 20**  
Species rich families and subfamilies of Orthopterans in summer

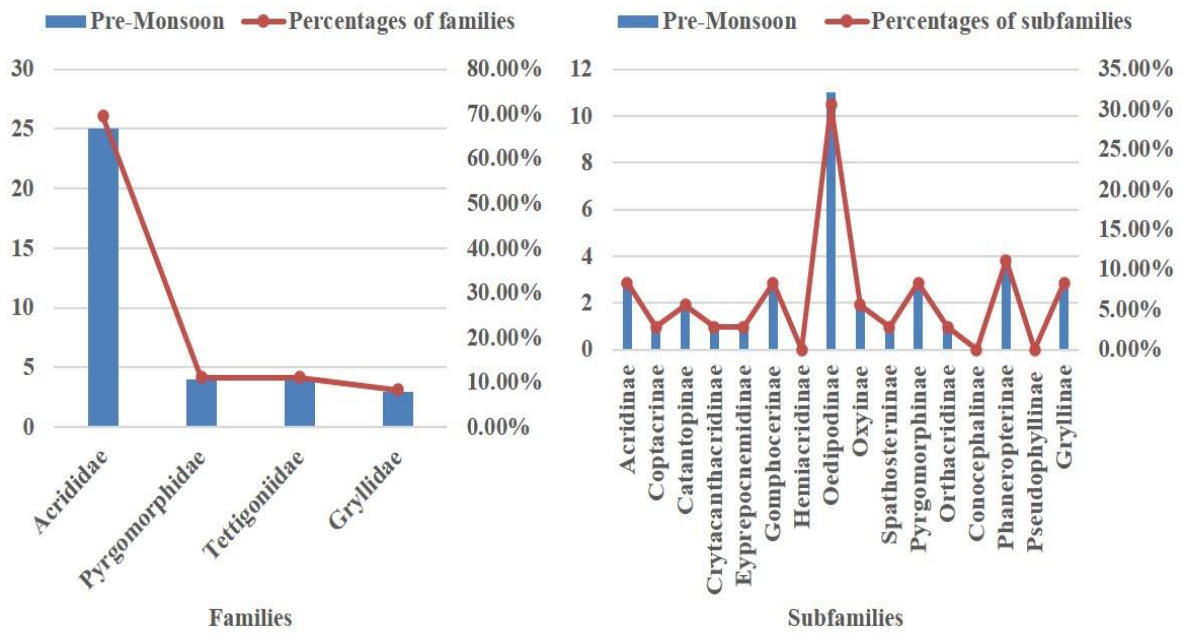


Figure - 21

Species rich families and subfamilies of Orthopterans in pre-monsoon

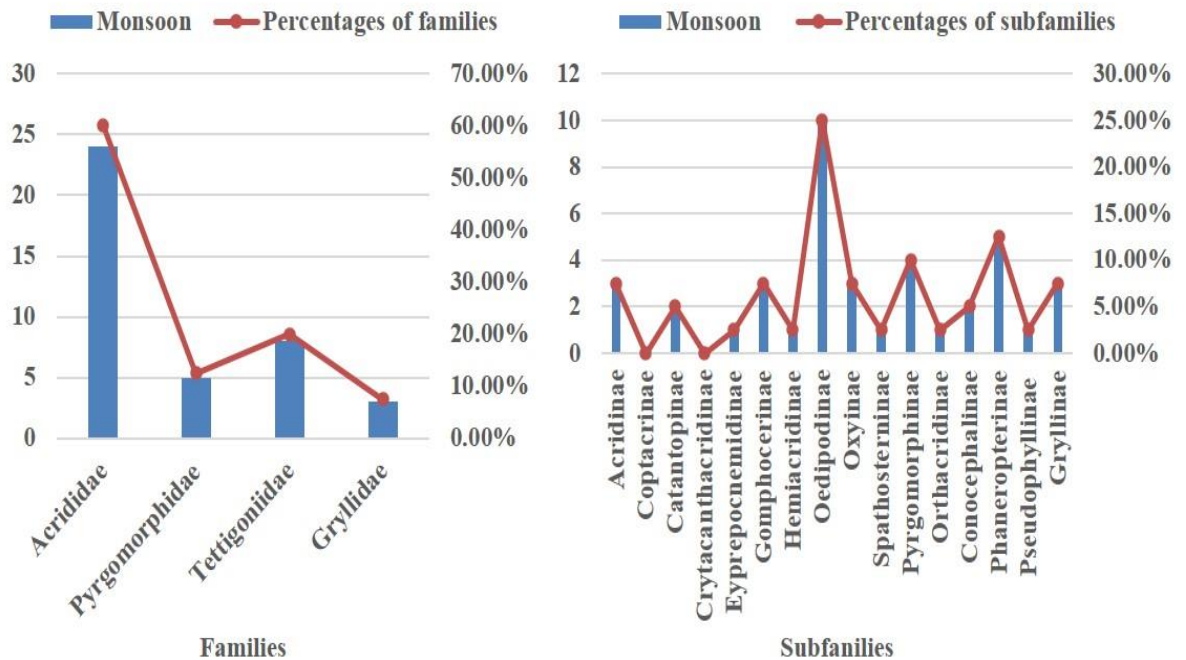
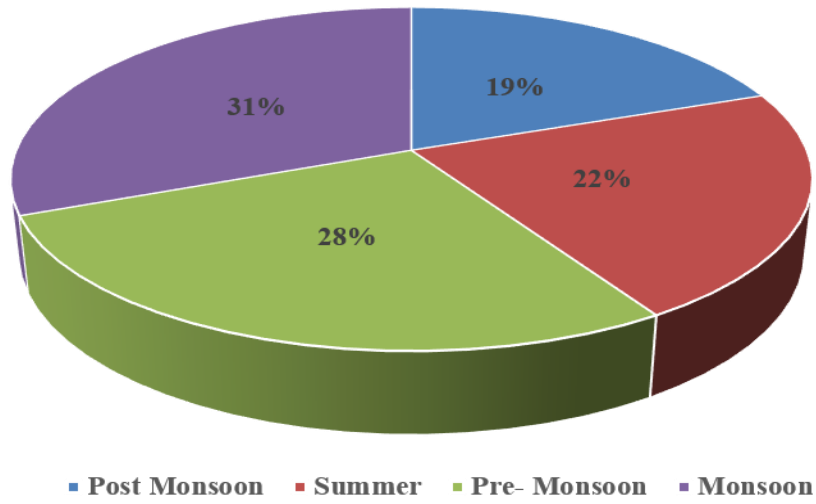
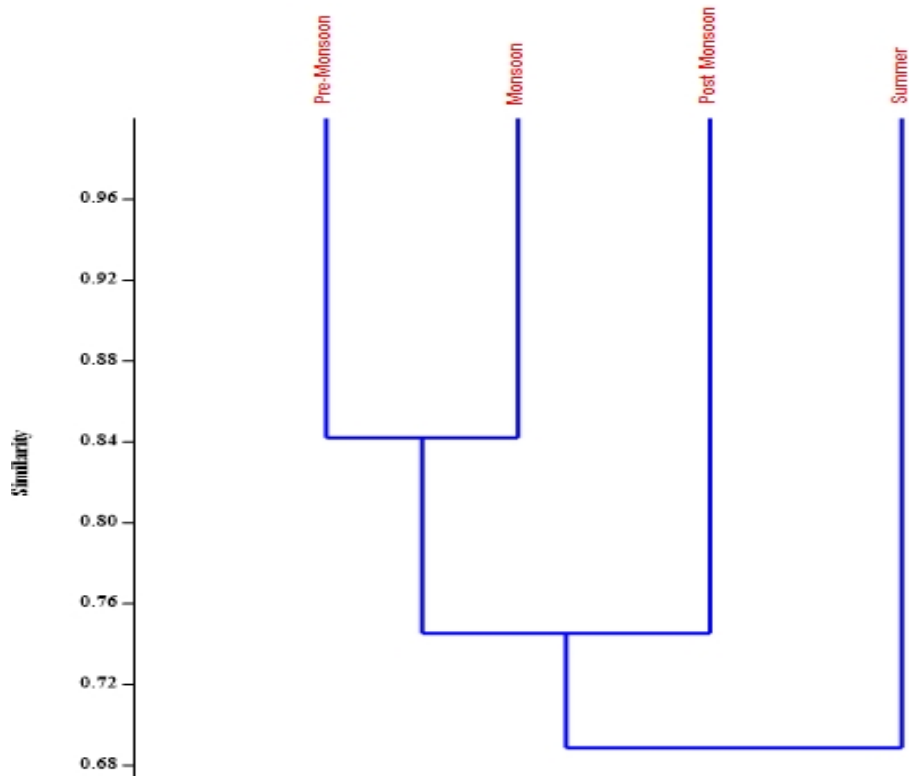


Figure - 22

Species rich families and subfamilies of Orthopterans in monsoon



**Figure -23**  
Species rich seasons in the study area



**Figure - 24**  
Species similarity in different seasons using cluster analysis

Table - 12

## Distribution of Orthopterans in different seasons of Coimbatore

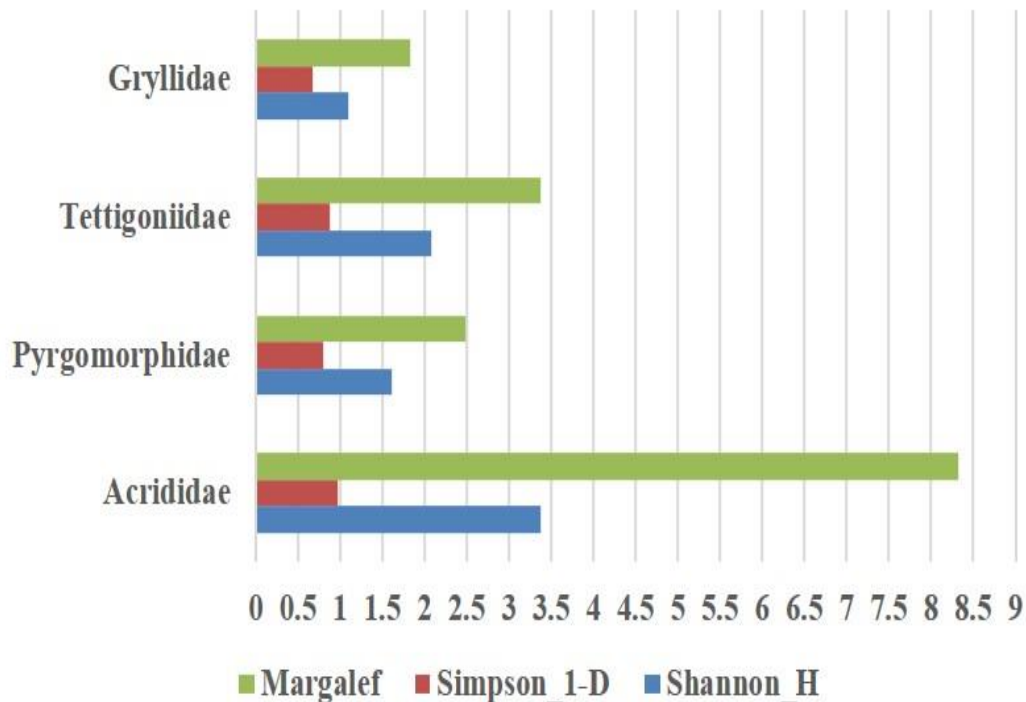
Species	Post monsoon	Summer	Pre- monsoon	Monsoon
<i>A. exaltata</i>	+	+	+	+
<i>A. turrita</i>	-	-	+	+
<i>P. infumata</i>	+	+	+	+
<i>E. sinetyi</i>	-	-	+	-
<i>D. pinguis</i>	-	+	+	+
<i>X. humilis</i>	-	-	+	+
<i>C. tatarica</i>	-	+	+	-
<i>E. alacris</i>	+	-	+	+
<i>C. decisa</i>	+	+	+	+
<i>A. luteipes</i>	+	+	+	+
<i>L. indica</i>	+	+	+	+
<i>H. banian</i>	-	+	-	+
<i>A. longipes</i>	+	-	+	+
<i>A. humbertianus</i>	-	-	+	+
<i>A. insubricus</i>	-	+	+	-
<i>A. patruelis</i>	+	+	+	+
<i>A. thalassinus</i>	+	+	+	+
<i>D. venusta</i>	+	+	+	+
<i>G. africanus</i>	-	+	+	+
<i>G. marmoratus</i>	+	-	-	+
<i>O. abruptus</i>	+	+	+	+
<i>O. infernalis</i>	-	+	+	-
<i>M. fasciata</i>	+	+	+	+
<i>T. annulata</i>	+	+	+	+
<i>S. longipennis</i>	-	+	-	-
<i>O. velox</i>	-	-	-	+
<i>O. hyla</i>	-	-	+	+
<i>O. fuscovittata</i>	+	+	+	+
<i>S. prasiniferum</i>	-	+	+	+
<i>A. crenulata</i>	+	-	+	+
<i>C. oxypterus</i>	-	-	+	+
<i>C. trachypterus</i>	-	-	-	+
<i>T. indica</i>	+	+	+	+
<i>O. maindroni</i>	-	+	+	+
<i>C. maculatus</i>	+	+	-	+
<i>E. pallidus</i>	+	+	-	+
<i>H. spectabilis</i>	+	-	+	+
<i>H. kinneari</i>	-	-	-	+
<i>H. vidhyavadhiaie</i>	+	-	+	+
<i>P. gracilis</i>	-	+	+	+
<i>T. unicolor</i>	+	+	+	+
<i>S. rugosa</i>	-	+	-	+
<i>T. mitratus</i>	+	-	+	+
<i>G. bimaculatus</i>	+	-	+	+
<i>G. sigillatus</i>	+	+	+	+
Total	25	28	36	40

**Diversity indices of Orthopterans among different sites and seasons**

To confirm the highest diversity of Orthopterans among different families, different seasons and different sites in the study area, the data were also subjected to different diversity indices such as Shannon diversity index, Simpson index and Margalef richness.

Diversity indices such as Shannon diversity index, Simpson index and Margalef richness were observed maximum level in the Acrididae family and the minimum species diversity was recorded in the family of Gryllidae. Shannon diversity index fluctuated from 1.099 to 3.367, Simpson index varied from 0.6667 to 0.9655 and Margalef richness varied between 1.82 to 8.315 (Fig - 25).

In the present study, area-wise diversity was carried out to study the suitable sites of Orthopterans species. Among all the observed, diversity indices were observed maximum level in site I and the minimum species diversity was recorded in site V. Shannon diversity index ranged from 2.996 to 3.714, Simpson fluctuated from 0.95 to 0.9756 and Margalef richness varied between 6.342 to 10.77 (Fig - 26).



**Figure - 25**

**Comparison of different diversity index among different families of Orthopterans**

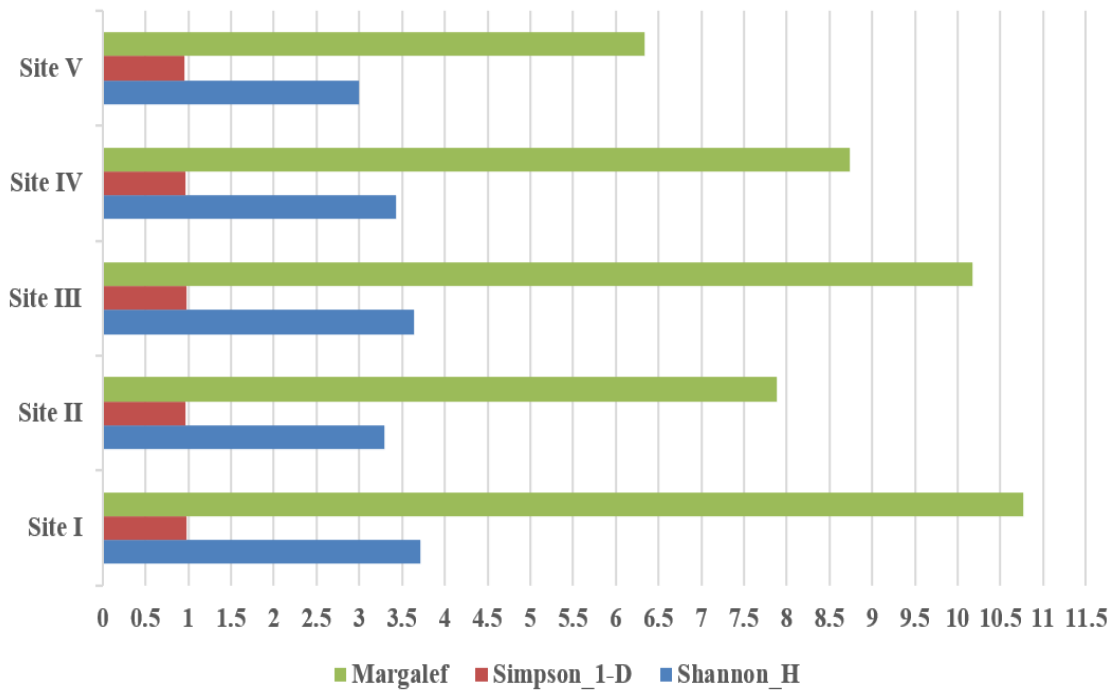


Figure - 26

Comparison of different diversity index among different sites of Orthopterans

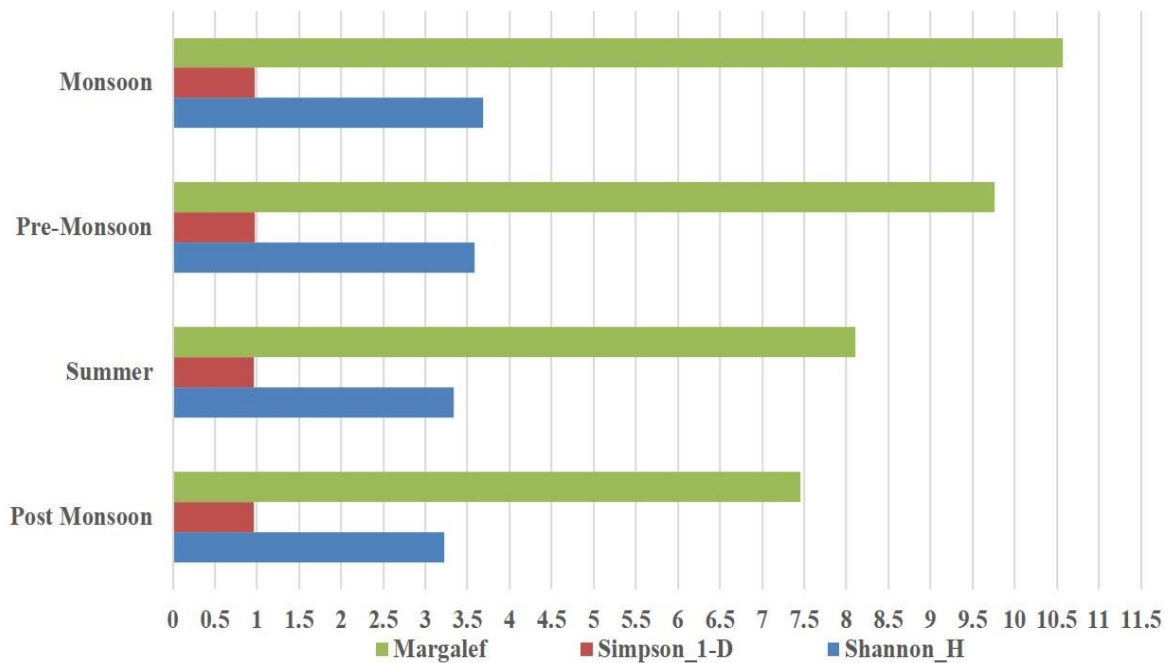


Figure - 27

Comparison of different diversity index among different seasons of Orthopterans

During the study period, seasonal-wise diversity was carried out to study the suitable seasonality of Orthopterans species. Diversity indices such as Shannon diversity index, Simpson index and Margalef richness were observed maximum level during monsoon season and the minimum species diversity was recorded during post monsoon season. Shannon diversity index varied from 3.219 to 3.689, Simpson index ranged from 0.96 to 0.975 and Margalef richness fluctuated between 7.456 to 10.57 (Fig - 27).

## **Discussion**

This study evaluated the species diversity and species richness of Orthopterans species, families and subfamilies in different sites and seasons of Coimbatore, Tamil Nadu, India. Over the study period, 45 species of Orthopterans belonging to four families were recorded from the different sites of Coimbatore. Chitra *et al.* (2000) reported 50 species belonging to six families of Orthopterans were found in rice fields of Coimbatore. Few numbers of Orthopterans species were not found in the study area compared to the previous study. This can be attributed to reduced habitats due to massive development activities, especially the construction of buildings, factories, roads, filling up the wetlands and conversion of agricultural land resulting in the death of plants and other small fauna which has a symbiotic relationship with Orthopterans. Habitat destruction leads to migration, inhibiting their seasonal distribution pattern and changing their breeding season to any favorable condition (Dey and Hazra, 2003; Weiss *et al.*, 2013). Such a wide variation of species may be due to the different conditions of vegetations and other microclimatic factors.

Present findings revealed that family Acrididae was the largest family followed by Tettigoniidae, Pyrgomorphidae and Gryllidae. This perception was in parallel with the observations of Paulraj *et al.* (2009) who also reported that the family Acrididae was the most dominant. Other studies Akhtar *et al.* (2012); Thakkar *et al.*, (2015); Arya *et al.*, (2015); Divya and Senthilkumar (2017); Suganya *et al.* (2020) also found maximum diversity being shown by the family Acrididae. The trend of numerical distribution of different grasshopper families recorded in the present study is similar to the observation of Andersen *et al.*, (2000), who also reported that Acrididae were the largest group followed by Tettigoniidae and Pyrgomorphidae. In addition, Chandra and Gupta, (2013) reported 29 species of acridids presented in Tamil Nadu. Similarly, the present survey revealed the

presence of 29 acridids in collected Orthopterans. Acridids are graminivorous in nature and the grasslands found in the ecosystem provide a wide variety of food and breeding sites for acridids. Growth rate and reproductive efficiency influenced the distribution of dominant species in an ecosystem. Acridids are very easy to grow and its produce high biomass according to their high reproductive ability and survival rate (Haldar *et al.*, 1999).

In the present study, family-wise diversity: Shannon, Simpson and Margalef index values were observed highest in Acrididae. Thakkar *et al.* (2015) also observed family-wise diversity, Shannon-Wiener diversity index and Evenness was elevated for Acrididae followed by Tettigoniidae, Gryllidae and Pyrgomorphidae.

Shishodia *et al.* (2010) recorded seven subfamilies with a maximum number of species in subfamily Oedipodinae. Kumar and Usmani *et al.* (2015) observed that the members of the subfamily Oedipodinae was more diverse and abundant species. Suganya *et al.* (2020) also noted Oedipodinae was an abundant subfamily. The present analysis support previous results that subfamily Oedipodinae showed the highest diversity and more population structure than other subfamilies of Orthopterans in all the sites and seasons

The maximum number of Orthopterans species and populations were recorded in site I. The second largest number of Orthopterans were noted in site III. In site II and V habitat, the Orthopterans species number was very less compared to site I and site III habitat because these habitats were highly disturbed by various anthropogenic activities. Geographical, evolutionary and historical factors play a strong role in determining the composition, diversity and other attributes of its organization (Schluter and Ricklefs, 1993). Statistical analysis shows that most of the rare species studies were closer to the site I (undisturbed site) and the greatest species richness were associated with the undisturbed sites. Similar trends were found by Joshi *et al.* (1999); Parmenter *et al.* (1991); Soliman *et al.* (2017) reported that species diversity, richness and abundance were higher in undisturbed sites than disturbed sites. Saha and Haldar (2009 & 2013) reported that undisturbed habitats had the highest index value while disturbed habitats had the lowest index value.

Higher species richness of Orthopterans was noted during monsoon season, whereas, lower species composition was recorded during post monsoon season in the study area. According to Arya *et al.* (2015) the maximum grasshopper activities were observed during

the rainy season. In addition, Hussain *et al.* (2017) also recorded the greater population abundance during rainy seasons. Thakkar *et al.* (2015) reported that their presence was more prevalent during monsoon seasons, which concedes the optimum growth of all types of vegetation. Higher Orthopteran population structure in this specific season is probably due to a higher amount of vegetation. Rainfall enhances the growth rate of vegetation which ultimately influences the Orthopteran population. In general, the post monsoon season prevalence of the lower temperature with dry season might have adversely affected the biological activity of Orthopterans leading to their little species. Joern (2004) reported that rainfall might also be an important factor playing a positive role in the diversity of grasshoppers. Seasonal fluctuations in species richness and their number throughout the different seasons during the study period might be attributed to the difference in the reproductive period of each species.

A cluster analysis (or classification) is helpful in finding the natural groupings of samples, such that samples within a group are more similar to each other than the samples in different groups. It is also used to define species assemblages and groups of species that tend to occur in a parallel manner across sites (Balakrishnan *et al.*, 2014). In this study, cluster analysis revealed the similarity and dissimilarity of species concentration from various sites and seasons of the study area.

During the study period, acridids namely *T. annulata*, *L. indica*, *A. patruelis*, *O. abruptus*, *P. infumata*, *A. luteipes*, *M. fasciata*, *O. fuscovittata* and *D. venusta* were found in all the seasons as well as all sites of the study area. These nine species of acridids were breeds continuously throughout the year. They have no seasonal differences in hatching between males and females. Further, for the sustenance of their populations, they have probably adopted themselves to change their breeding season to any favorable condition. They are migratory in nature. In addition, migratory individuals are sometimes found in areas unsuitable for their reproduction and distribution (Kristin *et al.*, 2007; Holusa *et al.*, 2013).

Orthopteran diversity index value was observed high in site I and monsoon season. Generally, Shannon diversity index and Simpson diversity index are commonly used to evaluate the diverse richness of organisms present in an area. Typical values of H are usually between 1.5 and 3.5 in most ecological studies and the index is rarely greater than 4

(Shannon and Weiner, 1949). Simpsons's diversity index ( $\lambda$ ) was calculated since it is well accepted that all species are at a site. The value ranges between 0 and 1 (Simpson, 1949). The present study reveals that the greatest species richness was associated with the site I and the monsoon season.

In the present study, the ecological indices used to assess the Orthopterans community structure which revealed variances among different sites and different seasons. According to Miller and Onsager (1991) the dynamic in population structure is closely related to changes in the spatial pattern and vegetation structure. In addition, some grasshopper species are threatened by anthropogenic pressures, such as overgrazing and ploughing (Sergeev, 1998; Latchininsky and Gapparov, 1996). In the present study, it is concluded that site I and monsoon season were better healthy than the other sites and seasons due to higher species diversity and richness. Higher species diversity may be important in maintaining ecosystem functioning (Yachi and Loreau, 1999; Chesson *et al.*, 2001).

## **Phase – II**

### **4.2 Distribution of Orthopterans among Different Host Plants**

Insect diversity and composition are mainly dependent on vegetation and any change in the habitat is likely to have an impact on their distribution and relative abundance. Order Orthopteran are considered one of the most important groups of phytophagous insects. Fluctuation in population of Orthopterans were attributed mainly to the availability of host plant because these plants are potency to enhance the breeding, survival and growth rate of Orthopterans. Higher amount of vegetation structure might have alternate impact of species composition through protecting them against predators, adverse environmental factors and human interference.

In most of the previous studies on Orthoptera fauna and the vegetation of the area were involved, but no specific test seeking for a relationship with plant species diversity has been carried out. Thus, data from the study area was also analysed to see if there was a statistically significant relationship between Orthopterans diversity and plant diversity. Screening of diverse host plants in and around the habitat of Orthopterans was carried out in different ecological sites of Coimbatore region to know the changes in Orthopteran composition according to the composition of host plant species.

A total of 38 host plants of Orthopterans belonging to 37 genera spreading over 16 families of Angiosperms were documented from the study area. The identified host plant list and their scientific name, common name, vernacular name, family, genera and classes were shown in table - 13 and plates VI to IX.

#### **Different class of host plants**

The collected host plants were classified under two classes namely, Dicotyledon and Monocotyledon. Dicotyledon was the most species rich class comprises 13 families of 22 genera with 23 species, which contributed 60.53% of the total recorded species whereas Monocotyledon comprises three families of 15 genera with 15 species, which amounted to 39.47% of total species documented (Fig - 28).

#### **Different families of host plants**

With respect to the total number of species found, family Poaceae (monocot) with 13 species, contributed to 34.21% of the total collected species, which is considered to be the dominant family in the present study. The second dominant family was Asteraceae, which had four species, accounted for 10.53% of the total collected species. The other following families namely Amaranthaceae, Euphorbiaceae and Fabaceae with three species, Apocynaceae with two species and the remaining ten families, had only one species respectively (Fig - 29).

#### **Different habitats of host plants**

The habitat of the host plants species recorded from the study area is broadly classified under four categories namely herbs, shrubs, climbers and creepers. Herbs constitute the major portion with 30 species (79%) followed by shrubs with five species (13%), climbers with two species (5%) and creeper with one species (3%). From this, one can understand that the herbs were dominating and a good source of diet for Orthopterans (Fig - 30).

Table - 13

## List of host plants collected from the study area

S. No	Class	Botanical Name	Family	Common name/Vernacular name	habitat
1.	Dicotyledons	<i>Zaleya decandra</i>	Aizoaceae	Many stamen horse purslane/Charanai	herb
2.		<i>Achyranthes aspera</i>	Amaranthaceae	Prickly chaff flower/Nayuruvi	herb
3.		<i>Alternanthera sessilis</i>	Amaranthaceae	Stalkless joyweed/Ponnanganni	herb
4.		<i>Amaranthus viridis</i>	Amaranthaceae	Green amaranth /Mulaikeerai	herb
5.		<i>Calotropis procera</i>	Apocynaceae	Rubber bush/Vellai erukku	Shrub
6.		<i>Calotropis gigantea</i>	Apocynaceae	Crown flower/Neela erukku	Shrub
7.		<i>Parthenium hysterophorus</i>	Asteraceae	Carrot grass/Malli kizhangu	herb
8.		<i>Tridax procumbens</i>	Asteraceae	Coatbuttons/ Vettukayapundu	herb
9.		<i>Wedelia chinensis</i>	Asteraceae	Chinese Wedelia/Manjalkarilamkanni	herb
10.		<i>Blainvillea acmella</i>	Asteraceae	Para cress/-	herb
11.		<i>Ipomea pes tigridis</i>	Convolvaceae	Tiger foot morning glory/Punaikkirai	Climber
12.		<i>Croton bonplandianum</i>	Euphorbiaceae	Ban Tulsi/ Rail Poнду	herb
13.		<i>Euphorbia hitra</i>	Euphorbiaceae	Asthma plant/ Ammam paccharisi	herb
14.		<i>Ricinus Communis</i>	Euphorbiaceae	Castor bean/ Amanakku	Shrub
15.		<i>Arachis hypogaea</i>	Fabaceae	Groundnut/Nilakkadalai	herb
16.		<i>Clitoria ternatea</i>	Fabaceae	Butterfly pea/Sangu poo	Climber
17.		<i>Tephrosia purpurea</i>	Fabaceae	Tephrosia/Kolunchi	Shrub
18.		<i>Ocimum tenuiflorum</i>	Lamiaceae	Holy basil/Karuntulasi	Shrub
19.		<i>Sida acuta</i>	Malvaceae	Wireweed/Arivalmanaip pundu	herb
20.		<i>Boerhavia erecta</i>	Nyctaginaceae	Erect spideling/Simai Mukkirattai	herb
21.		<i>Oxalis corniculata</i>	Oxalidaceae	Yellow sorrel/Paliakiri	Creeper
22.		<i>Phyllanthus niruri</i>	Phyllanthaceae	Gale of wind/Keelanelli	herb
23.		<i>Tribulus terrestris</i>	Zygophyllaceae	Yellow vine/Nerunci	herb
24.	Monocotyledons	<i>Commelina diffusa</i>	Commelinaceae	Spreading Day flower/Kanavazhai	herb
25.		<i>Cyperus rotundus</i>	Cyperaceae	Nut grass/ Korai kizhangu	herb
26.		<i>Aristida setacea</i>	Poaceae	Needle grass/-	herb
27.		<i>Brachiaria mutica</i>	Poaceae	Buffalo grass/-	herb
28.		<i>Cenchrus ciliaris</i>	Poaceae	Buffel Grass/Kollukattai	herb
29.		<i>Chloris barbata</i>	Poaceae	Wind mill grass/Kodai pillu	herb
30.		<i>Cynodon dactylon</i>	Poaceae	Bermuda grass/Arugampul	herb
31.		<i>Dactyloctenium aegyptium</i>	Poaceae	Crowfoot grass/-	herb
32.		<i>Digitaria sanguinalis</i>	Poaceae	Crabgrass/-	herb
33.		<i>Dinebra retroflexa</i>	Poaceae	Viper grass/-	herb
34.		<i>Oryza sativa</i>	Poaceae	Paddy/Nellu	herb
35.		<i>Panicum maximum</i>	Poaceae	Guinea grass/-	herb
36.		<i>Pennisetum purpureum</i>	Poaceae	Fountain Grasses/Elephant grass	herb
37.		<i>Sorghum bicolor</i>	Poaceae	Great millet /Cholam	herb
38.		<i>Zea mays</i>	Poaceae	Corn/Makkasolam	herb



*Z. decandra*



*A. aspera*



*A. sessilis*



*A. viridis*



*C. procera*



*C. gigantea*



*P. hysterophorus*



*T. procumbens*



*W. chinensis*

**Plate - VI**  
**Orthopteran host plants**



*B. acmella*



*I. tigridis*



*C. bonplandianum*



*E. hitra*



*R. Communis*



*A. hypogaea*



*C. ternatea*



*T. purpurea*



*O. tenuiflorum*

**Plate - VII**

**Orthopterans host plants**



*S. acuta*



*B. erecta*



*O. corniculata*



*P. niruri*



*T. terrestris*



*C. diffusa*



*C. rotundus*



*A. setacea*



*B. mutica*

**Plate - VIII**  
**Orthopterans host plants**



*C. ciliaris*



*C. barbata*



*C. dactylon*



*D. aegyptium*



*D. sanguinalis*



*D. retroflexa*



*O. sativa*



*P. maximum*



*P. purpureum*



*S. bicolor*



*Z. mays*

**Plate - IX**  
**Orthopteran host plants**

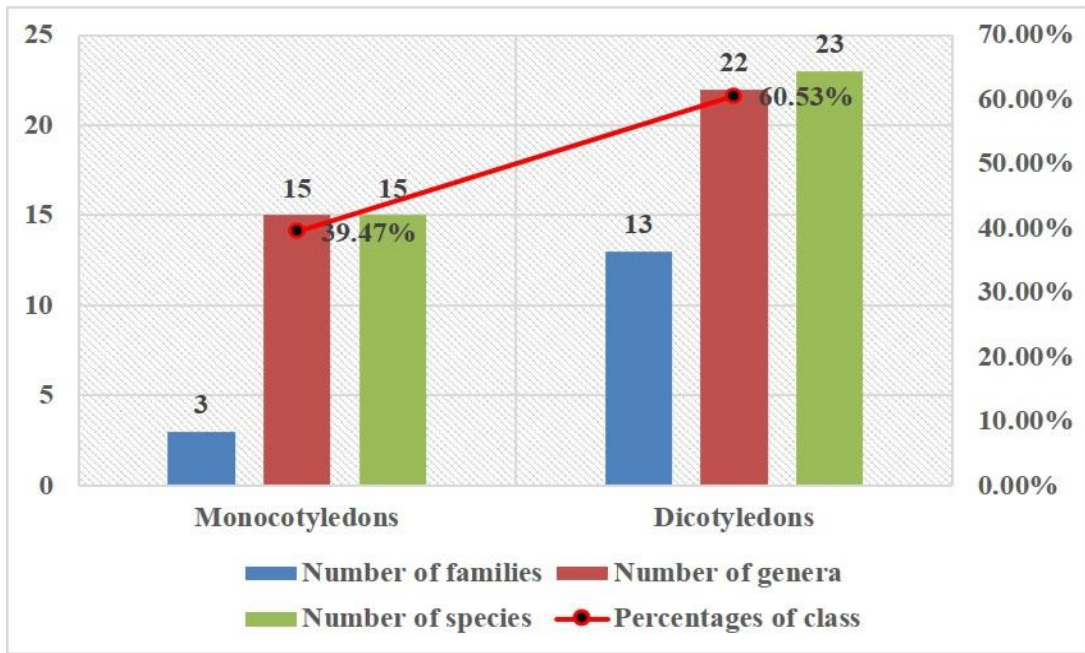


Figure - 28

Numerical representation of the host plants of Orthopterans

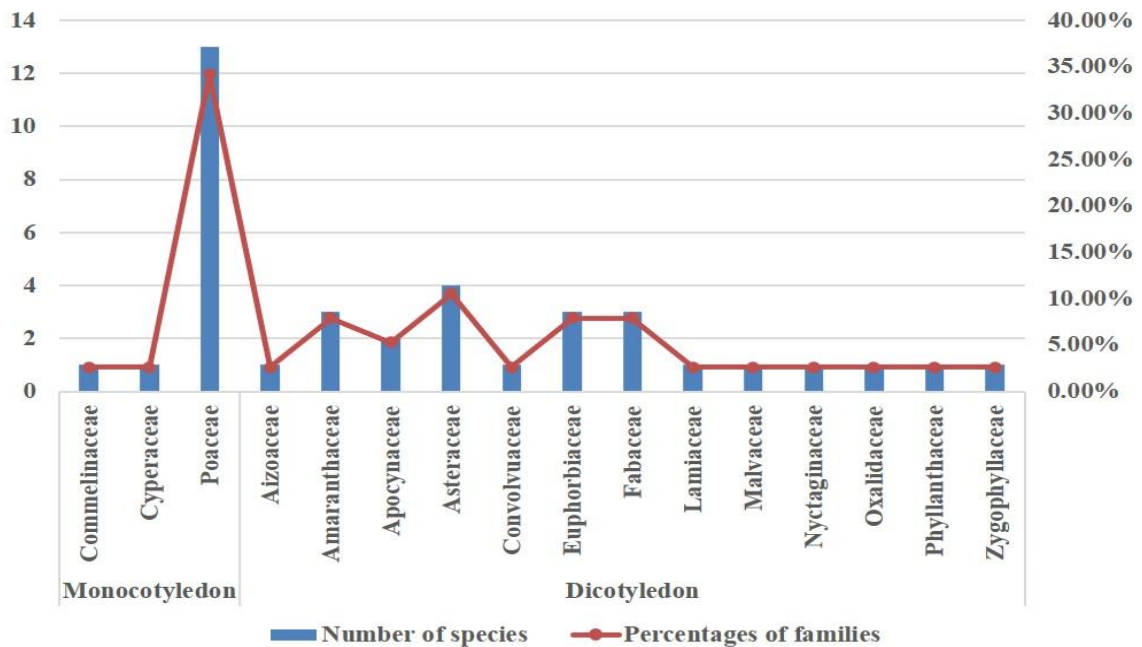
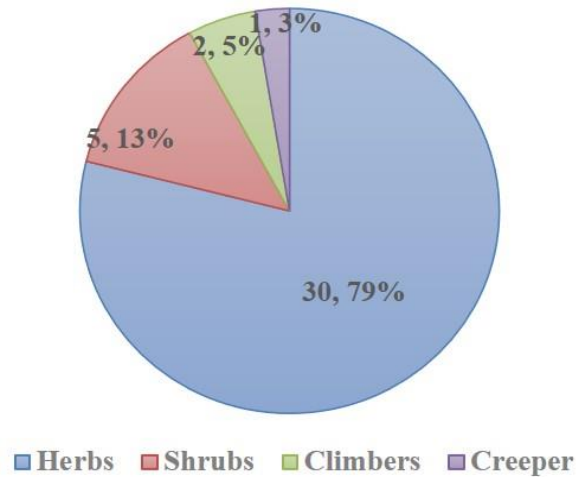


Figure - 29

Dominant monocot and dicot plants families with maximum species occurrence



**Figure - 30**  
**Percentage of host plants habitat**

### Diversity of host plants in different sites

#### Site I: Marudhamalai

Thirty-three host plant species under 16 subfamilies were documented from site I. Among the observed host plants, one species from dicotyledons and four species from monocotyledons were absent in site I. The plants like *C. rotundus*, *A. setacea*, *B. mutica*, *C. ciliaris*, *C. barbata*, *C. dactylon* and *P. maximum* from Monocot and *A. aspera*, *A. sessilis*, *C. gigantea*, *P. hysterothorus*, *T. procumbens*, *T. purpurea* and *B. erecta* from Dicot were occupied the highest region in site I. A total of 23 dominant, 12 moderately dominant and four fewer dominant plants were recorded (Table -14).

#### Site II: Saibaba Colony

Twenty-four host plant species under 12 subfamilies were identified from site II. Among the collected host plants, 10 species from dicotyledons and four species from monocotyledons were absent in site II. The plants, *C. rotundus*, *C. ciliaris*, *C. dactylon* and *P. maximum* from Monocot and *P. hysterothorus*, *T. procumbens* and *B. erecta* from Dicot have inhabited the highest region in site II (Table -14).

#### Site III: Thenkarai

Thirty-three host plant species under 14 subfamilies were investigated from site III. Among the recorded host plants, five species from dicotyledons were absent in site III. The plant species namely *C. rotundus*, *C. dactylon*, *D. retroflexa*, *O. sativa*, *P. maximum*,

*P. purpureum*, *S. bicolor* and *Z. mays* from Monocot and *A. aspera*, *C. gigantea*, *P. hysterophorus*, *T. procumbens*, *A. hypogaea*, *T. purpurea* and *B. erecta* from Dicot have engrossed the highest region in site III (Table - 14).

#### **Site IV: Thudiyalur**

Thirty host plant species under 13 subfamilies were collected from the site IV. Among the documented host plants, eight species from dicotyledons were absent in the site IV. The following plants such as *C. rotundus*, *B. mutica*, *C. dactylon*, *D. aegyptium*, *O. sativa*, *P. maximum*, *P. purpureum*, *S. bicolor* and *Z. mays* from Monocot and *C. gigantea*, *P. hysterophorus*, *T. procumbens*, *A. hypogaea*, *T. purpurea* and *B. erecta* from Dicot have employed the highest region in site IV (Table - 14).

#### **Site V: Singanallur**

Twenty-three host plant species under 11 subfamilies were surveyed from site V. Among the identified host plants, 12 species from dicotyledons and three species from Monocotyledons were absent in the site V. *C. rotundus*, *C. dactylon*, *P. maximum* and *Z. mays* from Monocot and *P. hysterophorus*, *T. procumbens* and *B. erecta* from Dicot were utilized the highest region in site V (Table -14).

Host plants of Orthopterans were observed high in site I (33 species) and site III (33 species) followed by site IV (30 species), site II (24 species) and site V (23 species). In this study area, *C. dactylon*, *D. aegyptium*, *P. hysterophorus*, *T. procumbens*, *C. rotundus*, *C. diffusa*, *E. hitra*, *S. acuta* and *B. erecta* were recorded as dominant species and found in all the sites of Coimbatore (Table - 14).

### **Diversity of host plants in different seasons**

#### **Post monsoon**

Twenty-six host plant species were collected under six subfamilies. Eleven species from dicotyledons and only one species from monocotyledons were absent in post monsoon. The plants like *C. ciliaris* and *C. dactylon* from Monocot and *T. procumbens* from Dicot were moderately presented in post monsoon season compared to other species. In this season plant densities were highly decreased (Table -14).

#### **Summer**

Twenty-nine host plant species were collected under 10 subfamilies. Eight species from dicotyledons and only one species from monocotyledons were absent in the summer

season, whereas 18 species were recorded as lower density and nine species were moderately present in summer. Five species such as *C. dactylon*, *O. sativa*, *S. bicolor* and *Z. mays* from Monocot and one species, *A. hypogaea* from Dicot were recorded the highest density in summer. Summer season also comprised lower diversity of plants (Table - 14).

### **Pre-monsoon**

Thirty-eight host plant species were collected under 16 subfamilies. In this season, four species were recorded as lower density, 10 species were recorded as moderate density and 24 species recorded as higher density (Table -14).

### **Monsoon**

Thirty-eight host plant species were collected under 16 subfamilies. Six species were recorded as moderate density and 31 species were recorded as higher density in monsoon season. Host plants of Orthopterans were observed high in both monsoon and pre-monsoon (33 species) followed by summer (29 species) and post monsoon (26 species) (Table - 14).

Among the 38 species, six species (*Z. decandra*, *W. chinensis*, *I. tigridis*, *R. Communis*, *C. ternatea* and *O. tenuiflorum*) were recorded as moderate density in both monsoon and pre- monsoon season. Five species (*C. procera*, *C. gigantea*, *B. acmella*, *S. bicolor* and *C. diffusa*) were plenty in pre-monsoon season whereas 10 species (*A. viridis*, *C. bonplandianum*, *T. purpurea*, *S. acuta*, *O. corniculate*, *P. niruri*, *T. terrestris*, *C. barbata*, *D. sanguinalis* and *P. purpureum*) were abundant only in monsoon season. Seventeen species (*A. aspera*, *A. sessilis*, *P. hysterothorus*, *T. procumbens*, *E. hitra*, *A. hypogaea*, *B. erecta*, *C. rotundus*, *A. setacea*, *B. mutica*, *C. ciliaris*, *C. dactylon*, *D. aegyptium*, *D. retroflexa*, *O. sativa*, *P. maximum* and *Z. mays*) were recorded high density in both monsoon and pre-monsoon. Pre-monsoon and monsoon season supported the higher number of species in the present study.

In this study, 26 plant species *A. aspera*, *A. sessilis*, *C. gigantea*, *P. hysterothorus*, *W. chinensis*, *E. hitra*, *R. Communis*, *C. ternatea*, *T. purpurea*, *O. tenuiflorum*, *B. erecta*, *P. niruri*, *C. rotundus*, *A. setacea*, *B. mutica*, *C. ciliaris*, *C. barbata*, *C. dactylon*, *D. aegyptium*, *D. sanguinalis*, *D. retroflexa*, *O. sativa*, *P. maximum*, *P. purpureum* and *Z. mays* were found in all the seasons and available throughout the year (Table - 14).

**Table - 14**  
**Distribution of host plants and its densities in different sites and seasons**

Species	Different sites					Different season			
	Site I	Site II	Site III	Site IV	Site V	Post monsoon	Summer	Pre- monsoon	Monsoon
<i>Z. decandra</i>	+	-	+	-	-	-	-	+	++
<i>A. aspera</i>	+++	++	+++	+++	++	+	+	+++	+++
<i>A. sessilis</i>	+++	+	+++	++	+	+	+	+++	+++
<i>A. viridis</i>	+++	+	+++	+	+	-	-	+++	+++
<i>C. procera</i>	++	-	++	-	-	-	-	+++	++
<i>C. gigantea</i>	+++	-	+++	+++	+	+	+	+++	++
<i>P. hysterothorus</i>	+++	+++	+++	+++	+++	++	++	+++	+++
<i>T. procumbens</i>	+++	+++	+++	+++	+++	-	+	+++	+++
<i>W. chinensis</i>	++	-	-	-	-	+	+	++	++
<i>B. acmella</i>	++	+	-	-	-	-	-	+++	++
<i>I. tigridis</i>	+	-	-	-	-	-	-	++	++
<i>C. bonplandianum</i>	++	-	+++	-	-	-	-	+++	+++
<i>E. hitra</i>	+++	++	++	+++	++	+	+	+++	+++
<i>R. Communis</i>	+	-	+	+	-	+	+	++	++
<i>A. hypogaea</i>	-	-	+++	+++	-	-	+++	+++	+++
<i>C. ternatea</i>	+++	+	-	-	-	+	+	++	++
<i>T. purpurea</i>	+++	-	+++	+++	-	+	+	+++	+++
<i>O. tenuiflorum</i>	+	+	+++	++	+	+	+	++	++
<i>S. acuta</i>	+	+	+	+++	+	-	-	+++	+++
<i>B. erecta</i>	+++	+++	+++	+++	+++	+	++	+++	++
<i>O. corniculata</i>	+++	++	+++	+++	++	-	++	+++	+++
<i>P. niruri</i>	+	+	++	+++	-	+	+	++	++
<i>T. terrestris</i>	++	-	-	-	-	-	-	+++	+++
<i>C. diffusa</i>	+++	+	+++	+	+	-	-	++	+++
<i>C. rotundus</i>	+++	+++	+++	+++	+++	+	+	+++	+++
<i>A. setacea</i>	+++	+	++	+	+	+	+	+++	+++
<i>B. mutica</i>	+++	+	++	+++	+	+	+	+++	+++
<i>C. ciliaris</i>	+++	+++	+++	+++	+++	++	++	+++	+++
<i>C. barbata</i>	+++	+++	+++	+++	+++	+	+	+++	+++
<i>C. dactylon</i>	+++	+++	+++	+++	+++	++	++	+++	+++
<i>D. aegyptium</i>	+++	+++	+++	+++	++	+	+	+++	+++
<i>D. sanguinalis</i>	+++	++	+++	+++	++	+	+	+++	+++
<i>D. retroflexa</i>	+++	+++	+++	+++	+++	+	+	+++	+++
<i>O. sativa</i>	-	-	+++	+++	-	+	+++	+++	+++
<i>P. maximum</i>	+++	+++	+++	+++	+++	+	++	+++	+++
<i>P. purpureum</i>	-	-	+++	+++	-	+	++	+++	+++
<i>S. bicolor</i>	-	-	+++	+++	-	+	++	+++	++
<i>Z. mays</i>	-	-	+++	+++	+++	+	++	+++	+++
<b>Total</b>	<b>33</b>	<b>24</b>	<b>33</b>	<b>30</b>	<b>23</b>	<b>26</b>	<b>29</b>	<b>38</b>	<b>38</b>

**Note: - Absent, + Present, ++ Moderately present, +++ Luxuriantly present**

### Different host plants of Orthopterans

Orthopterans host plants such as *C. dactylon*, *O. sativa* and *Z. mays* from Poaceae and *C. rotundus* from Cyperaceae were comprised higher diversity of Orthopterans whereas lower diversity was recorded from the host plants, *I. tigridis* and *C. procera* (Table - 15). In the present study, different diversity indices were carried out to confirm the suitable host of Orthopterans species. The diversity indices were observed at maximum level in *C. dactylon* and the minimum species diversity was recorded in *I. tigridis*. Shannon diversity index varied from 0.69 to 3.33, Simpson index ranged from 0.33 to 0.96 and Margalef richness fluctuated between 1.44 to 8.10 (Table - 16).

Among the different species, *T. annulata* was collected from maximum host plants (20) followed by *A. luteipes* (16), *L. indica* (16), *A. crenulata* (15) and *S. prasiniferum* (14). At the same time, *X. humilis*, *H. banian*, *A. insubricus*, *H. kinneari* and *S. rugosa* were recorded from only two types of host plants (Table - 15). Cluster analysis of shared species Orthopterans abundance among different host plants were shown in figure - 31. The similarity matrix from the quantitative data showed that the host plant selection similarity between *A. thalassinus* and *O. hyla* (0.88%); *X. humilis* and *C. tatarica* (0.8%); *M. fasciata* and *A. exaltata* (0.78%); *O. hyla* and *O. velox* (0.75%); *M. fasciata* and *O. maindroni* (0.75%); *T. indica* and *O. maindroni* (0.69%) and *O. abruptus* and *O. maindroni* (0.69%) respectively. The rest of the species in Orthoptera community showed less than 0.69% similarity, whereas *O. infernalis*, *A. insubricus* and *E. sinetyi* species host preference was many dissimilarities with other species of Orthopterans.

### Distribution of Orthopterans among Dicot and Monocot plants

Twenty species from Acrididae family (*A. exaltata*, *P. infumata*, *E. sinetyi*, *D. pinguis*, *C. tatarica*, *E. alacris*, *C. decisa*, *A. luteipes*, *L. indica*, *A. longipes*, *A. humberianus*, *A. patruelis*, *D. venusta*, *G. africanus*, *O. abruptus*, *O. infernalis*, *M. fasciata*, *T. annulata*, *O. fuscovittata* and *S. prasiniferum*), five species from Pyrgomorphidae (*A. crenulata*, *C. oxypterus*, *C. trachypterus*, *T. indica* and *O. maindroni*), six species from Tettigoniidae (*C. maculatus*, *H. spectabilis*, *H. vidhyavadhiae*, *P. gracilis*, *T. unicolor* and *S. rugosa*) and two species from Gryllidae (*G. bimaculatus* and *G. sigillatus*) were found in both Dicot and Monocot plants. The following eight Orthoptera species namely *A. turrita*, *X. humilis*, *H. banian*, *A. thalassinus*, *G. marmoratus*, *S. longipennis*, *O. velox* and *O. hyla* from Acrididae, *E. pallidus* and *H. kinneari* from Tettigoniidae and *T. mitratus* from Gryllidae were absent in dicot plants whereas *A. insubricus* was the only species not found in Monocotyledons (Fig - 32).

PC analysis clearly showed that the *C. dactylon*, *O. sativa*, *Z. mays* and *C. rotundus* from Monocotyledons; *A. hypogaea*, *B. erecta*, *A. aspera*, *T. procumbens* and *P. hysterothorus* from Dicotyledons were supported the maximum number of Orthopterans. PC analysis also shows that most of the Orthopteran species studied were closer to Monocotyledons plants compared to Dicotyledons. Principal component 1 (variance explained 28.62%; eigenvalue = 1.13) represents the higher abundances of species and component 2 (variance explained = 8.39%; eigenvalue = 0.33) indicates the lower abundance of species (Fig - 33).

#### **Composition of Orthopterans families among host plants**

Acridids were found highest in the host plants, *O. sativa* (20) and *Z. mays* (20) followed by *C. dactylon* (16) and *C. rotundus* (14). Acridids were found almost all types of plants collected from the study area except *C. procera* and *C. gigantea*. Pyrgomorphids were recorded in 23 host plants. Among them, the highest number of pyrgomorphids species were noted from *C. dactylon* (5); however, they were absent in 15 plants. Tettigoniids were recorded highest in *C. rotundus* (4), *C. dactylon* (4) and *P. maximum* (4) and they were not recorded from 14 plants. Gryllids were found maximum number in the host plant *C. dactylon* (3) and *P. maximum* (3) and they were not recorded in 20 plants. Overall, Orthopterans abundance were identified high in the host plants, *C. dactylon* (8%) followed by *O. sativa* (7.71%) and *Z. mays* (7.71%) and *C. rotundus* (6.57%), while only one species was found in *I. tigridis* plant (Table - 17).

#### **Orthopterans distribution in different families of host plants**

Orthopterans, *L. indica* (9), *T. annulata* (8), *A. exaltata* (7), *C. decisa* (7), *A. luteipes* (7), *A. patruelis* (7), *O. abruptus* (7), *A. crenulata* (7) and *O. maindroni* (7) were found in different families of host plant. *X. humilis*, *H. banian*, *A. thalassinus*, *S. longipennis*, *O. velox*, *O. hyla* and *T. mitratus* were found only in the family of Poaceae. Orthopterans diversity was recorded high in the family Poaceae followed by Cyperaceae, Fabaceae, Asteraceae, Amaranthaceae and Nyctaginaceae, while only one species were found in the family of Convolvulaceae. In the Poaceae family, *T. annulata* was collected from the highest number of host plants (12) followed by *S. prasiniferum* (9), *A. crenulata* (8), *G. sigillatus* (8), *A. luteipes* (7), *L. indica* (7), *G. africanus* (7), *O. abruptus* (7) and *M. fasciata* (7) (Table - 18). PC analysis also showed Poaceae supported a maximum number of Orthopterans. Principal component 1 (variance explained 21.20%; eigenvalue = 21.20) represents the higher abundances of species and component 2 (variance explained = 14.16%; eigenvalue = 2.26) constitutes the lower abundance of species (Fig - 34).



Table - 16

## Comparison of different diversity index among different host plants

Plant species	Orthopterans recorded	Shannon H	Simpson 1-D	Margalef
<i>Z. decandra</i>	3	1.09	0.66	1.82
<i>A. aspera</i>	10	2.30	0.9	3.90
<i>A. sessilis</i>	5	1.60	0.8	2.48
<i>A. viridis</i>	5	1.60	0.8	2.48
<i>C. procera</i>	2	0.69	0.5	1.44
<i>C. gigantea</i>	3	1.09	0.66	1.82
<i>P. hysterophorus</i>	8	2.07	0.87	3.36
<i>T. procumbens</i>	9	2.19	0.88	3.64
<i>W. chinensis</i>	4	1.38	0.75	2.16
<i>B. acmella</i>	3	1.09	0.66	1.82
<i>I. tigridis</i>	1	0	0	0
<i>C. bonplandianum</i>	4	1.38	0.75	2.16
<i>E. hitra</i>	4	1.38	0.75	2.16
<i>R. Communis</i>	5	1.60	0.8	2.48
<i>A. hypogaea</i>	13	2.56	0.92	4.67
<i>C. ternatea</i>	3	1.09	0.66	1.82
<i>T. purpurea</i>	6	1.79	0.83	2.79
<i>O. tenuiflorum</i>	3	1.09	0.66	1.82
<i>S. acuta</i>	4	1.38	0.75	2.16
<i>B. erecta</i>	13	2.56	0.92	4.67
<i>O. corniculata</i>	3	1.09	0.66	1.82
<i>P. niruri</i>	3	1.09	0.66	1.82
<i>T. terrestris</i>	6	1.79	0.83	2.79
<i>C. diffusa</i>	5	1.60	0.8	2.48
<i>C. rotundus</i>	23	3.13	0.95	7.01
<i>A. setacea</i>	9	2.19	0.88	3.64
<i>B. mutica</i>	16	2.77	0.93	5.41
<i>C. ciliaris</i>	14	2.63	0.92	4.92
<i>C. barbata</i>	12	2.48	0.91	4.42
<i>C. dactylon</i>	28	3.33	0.96	8.10
<i>D. aegyptium</i>	7	1.94	0.85	3.08
<i>D. sanguinalis</i>	6	1.79	0.83	2.79
<i>D. retroflexa</i>	7	1.94	0.85	3.08
<i>O. sativa</i>	27	3.29	0.96	7.88
<i>P. maximum</i>	21	3.04	0.95	6.56
<i>P. purpureum</i>	11	2.39	0.90	4.17
<i>S. bicolor</i>	17	2.83	0.94	5.64
<i>Z. mays</i>	27	3.29	0.96	7.88

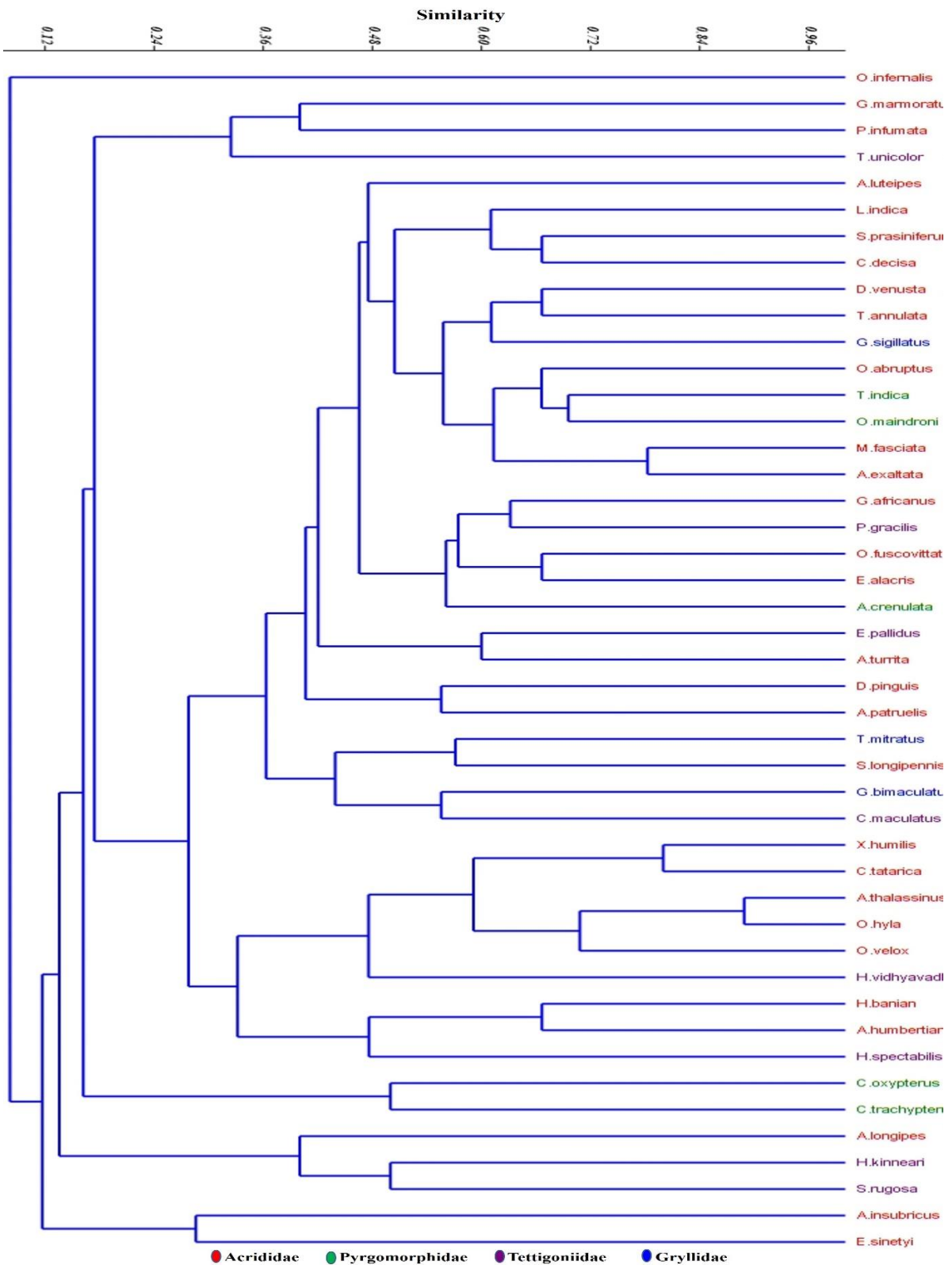


Figure - 31

Species similarity among host plants selection

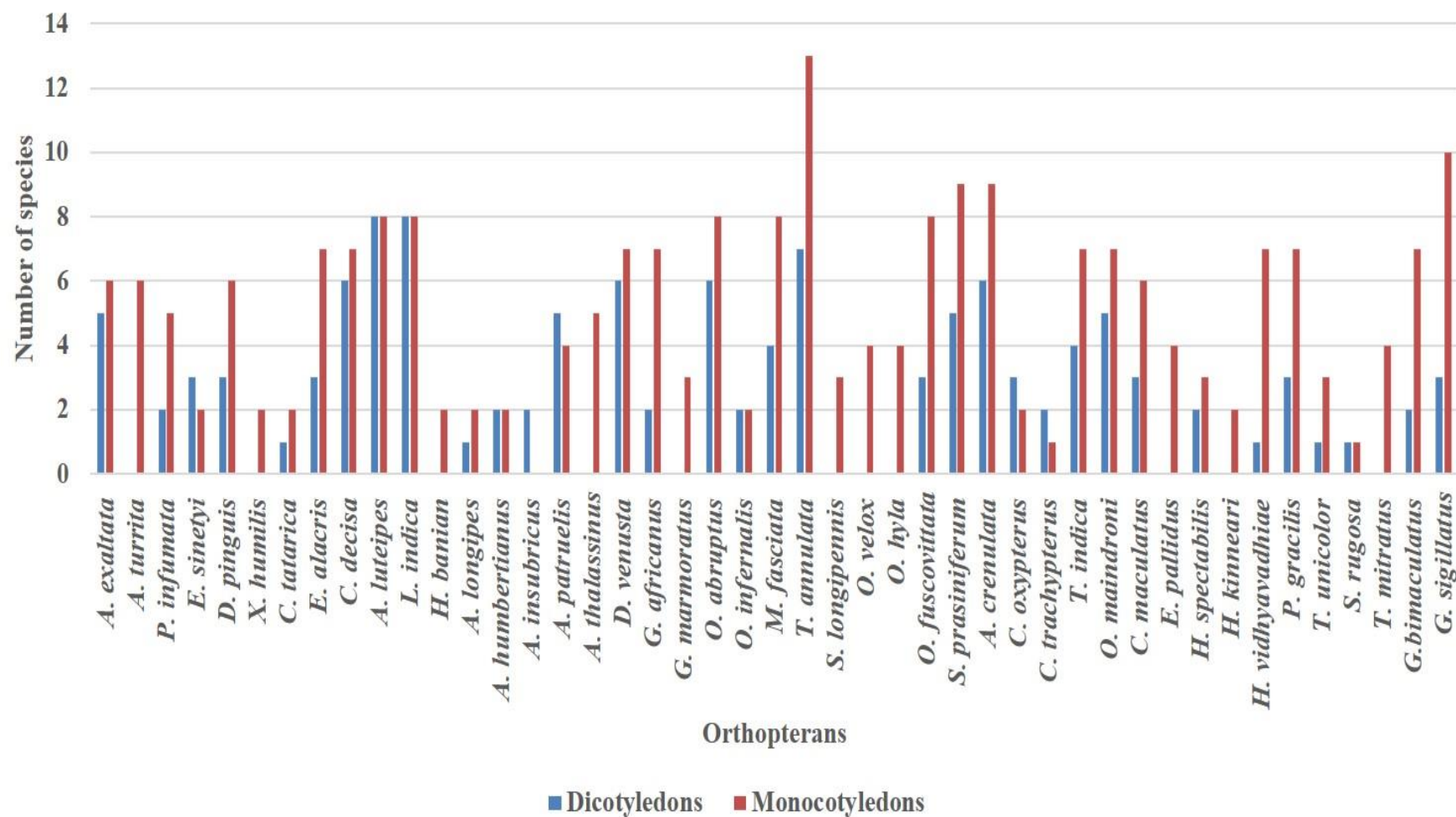


Figure -32  
Total number of Orthopterans among Monocot and Dicot plants



Table - 17

## Comparison of Orthopterans family composition among different host plants

Class	Caelifera		Ensifera		Total	Dominance
	Acrididae	Pyrgomorphidae	Tettigoniidae	Gryllidae		
Species						
<i>Z. decandra</i>	3	0	0	0	3	0.86%
<i>A. aspera</i>	7	3	0	0	10	2.86%
<i>A. sessilis</i>	4	0	1	0	5	1.43%
<i>A. viridis</i>	5	0	0	0	5	1.43%
<i>C. procera</i>	0	2	0	0	2	0.57%
<i>C. gigantea</i>	0	3	0	0	3	0.86%
<i>P. hysterochorus</i>	4	2	1	1	8	2.29%
<i>T. procumbens</i>	7	1	0	1	9	2.57%
<i>W. chinensis</i>	2	0	0	2	4	1.14%
<i>B. acmella</i>	3	0	0	0	3	0.86%
<i>I. tigridis</i>	1	0	0	0	1	0.29%
<i>C. bonplandianum</i>	3	0	1	0	4	1.14%
<i>E. hitra</i>	4	0	0	0	4	1.14%
<i>R. Communis</i>	1	2	2	0	5	1.43%
<i>A. hypogaea</i>	10	1	2	0	13	3.71%
<i>C. ternatea</i>	2	1	0	0	3	0.86%
<i>T. purpurea</i>	4	1	1	0	6	1.71%
<i>O. tenuiflorum</i>	3	0	0	0	3	0.86%
<i>S. acuta</i>	3	0	1	0	4	1.14%
<i>B. erecta</i>	10	1	1	1	13	3.71%
<i>O. corniculata</i>	2	1	0	0	3	0.86%
<i>P. niruri</i>	2	0	1	0	3	0.86%
<i>T. terrestris</i>	4	2	0	0	6	1.71%
<i>C. diffusa</i>	3	0	1	1	5	1.43%
<i>C. rotundus</i>	14	3	4	2	23	6.57%
<i>A. setacea</i>	4	1	2	2	9	2.57%
<i>B. mutica</i>	11	2	2	1	16	4.57%
<i>C. ciliaris</i>	9	2	2	1	14	4.00%
<i>C. barbata</i>	8	0	2	2	12	3.43%
<i>C. dactylon</i>	16	5	4	3	28	8.00%
<i>D. aegyptium</i>	5	0	1	1	7	2.00%
<i>D. sanguinalis</i>	4	0	1	1	6	1.71%
<i>D. retroflexa</i>	4	1	1	1	7	2.00%
<i>O. sativa</i>	20	3	3	1	27	7.71%
<i>P. maximum</i>	11	3	4	3	21	6.00%
<i>P. purpureum</i>	10	3	1	0	11	3.14%
<i>S. bicolor</i>	11	3	2	1	17	4.86%
<i>Z. mays</i>	20	3	3	1	27	7.71%

Table - 18

## Total number of Orthopterans recorded from different families of host plants

Class	Monocots			Dicots													Total Number of subfamilies
	Commelinaceae	Cyperaceae	Poaceae	Aizoaceae	Amaranthaceae	Apocynaceae	Asteraceae	Convolvaceae	Euphorbiaceae	Fabaceae	Lamiaceae	Malvaceae	Nyctaginaceae	Oxalidaceae	Phyllanthaceae	Zygophyllaceae	
Species																	
<i>A. exaltata</i>	0	1	5	0	2	0	1	0	0	1	0	0	1	0	0	0	7
<i>A. turrita</i>	0	1	5	0	0	0	0	0	0	0	0	0	0	0	0	0	2
<i>P. infumata</i>	1	1	3	0	0	0	1	0	0	1	0	0	0	0	0	0	5
<i>E. sinetyi</i>	0	0	2	0	0	0	1	0	0	1	0	0	1	0	0	0	4
<i>D. pinguis</i>	0	1	5	0	0	0	0	0	0	2	0	1	0	0	0	0	4
<i>X. humilis</i>	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	1
<i>C. tatarica</i>	0	0	2	0	0	0	1	0	0	0	0	0	0	0	0	0	2
<i>E. alacris</i>	0	1	6	0	0	0	1	0	1	1	0	0	0	0	0	0	5
<i>C. decisa</i>	0	1	6	0	2	0	1	0	1	1	0	0	0	0	0	1	7
<i>A. luteipes</i>	0	1	7	0	3	0	2	1	0	0	0	1	0	0	0	1	7
<i>L. indica</i>	0	1	7	1	1	0	0	0	1	2	1	0	1	0	1	0	9
<i>H. banian</i>	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	1
<i>A. longipes</i>	0	0	2	0	1	0	0	0	0	0	0	0	0	0	0	0	2
<i>A. humbertianus</i>	0	0	2	0	1	0	0	0	0	0	0	0	1	0	0	0	3
<i>A. insubricus</i>	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	2
<i>A. patruelis</i>	0	1	3	0	0	0	1	0	1	1	0	1	0	0	0	1	7
<i>A. thalassinus</i>	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	1
<i>D. venusta</i>	0	1	6	1	0	0	2	0	1	0	0	0	1	0	0	1	6
<i>G. africanus</i>	0	0	7	0	0	0	0	0	1	1	0	0	0	0	0	0	3
<i>G. marmoratus</i>	1	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	2
<i>O. abruptus</i>	0	1	7	0	1	0	2	0	1	1	0	0	1	0	0	0	7
<i>O. infernalis</i>	0	0	2	0	0	0	1	0	1	0	0	0	0	0	0	0	3
<i>M. fasciata</i>	0	1	7	0	2	0	0	0	0	1	0	0	1	0	0	0	5
<i>T. annulata</i>	0	1	12	1	1	0	2	0	0	1	0	0	1	1	0	0	8
<i>S. longipennis</i>	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	1
<i>O. velox</i>	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	1
<i>O. hyla</i>	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	1
<i>O. fuscovittata</i>	1	1	6	0	0	0	0	0	0	1	1	0	1	0	0	0	6
<i>S. prasiferum</i>	0	0	9	0	2	0	0	0	0	1	0	0	0	1	1	0	5
<i>A. crenulata</i>	0	1	8	0	0	2	1	0	1	1	0	0	0	1	0	0	7
<i>C. oxypterus</i>	0	0	2	0	1	1	0	0	0	0	0	0	0	0	0	1	4
<i>C. trachypterus</i>	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	1	3
<i>T. indica</i>	0	1	6	0	1	0	1	0	1	1	0	0	0	0	0	0	6
<i>O. maindroni</i>	0	1	6	0	1	1	1	0	0	1	0	0	1	0	0	0	7
<i>C. maculatus</i>	0	0	6	0	0	0	1	0	0	2	0	0	0	0	0	0	3
<i>E. pallidus</i>	0	1	3	0	0	0	0	0	0	0	0	0	0	0	0	0	2
<i>H. spectabilis</i>	0	0	3	0	1	0	0	0	0	0	0	0	1	0	0	0	3
<i>H. kinneari</i>	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	2
<i>H. vidhyavadhiae</i>	1	0	6	0	0	0	0	0	1	0	0	0	0	0	0	0	3
<i>P. gracilis</i>	0	1	6	0	0	0	0	0	0	1	0	1	0	0	1	0	5
<i>T. unicolor</i>	0	1	2	0	0	0	0	0	1	0	0	0	0	0	0	0	3
<i>S. rugosa</i>	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	2
<i>T. mitratus</i>	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	1
<i>G. bimaculatus</i>	0	1	6	0	0	0	2	0	0	0	0	0	0	0	0	0	3
<i>G. sigillatus</i>	1	1	8	0	0	0	2	0	0	0	0	0	1	0	0	0	5
<b>Total Number of species</b>	<b>5</b>	<b>23</b>	<b>38</b>	<b>3</b>	<b>14</b>	<b>4</b>	<b>18</b>	<b>1</b>	<b>13</b>	<b>19</b>	<b>3</b>	<b>3</b>	<b>13</b>	<b>3</b>	<b>3</b>	<b>6</b>	<b>-</b>

**Different habitats of Orthopterans**

Orthopterans that were found feeding on host plants were collected from the grasslands, agricultural lands and ground surface. A total of 43 Orthopterans belonging to 33 genera and four families from the grasslands, 36 species belonging to 30 genera and four families from the agricultural lands, whereas 22 species belonging to 19 genera and four families from the ground surface were recorded during the study period. Species, *X. humilis* and *H. banyan* mainly found in agriculture land. *O. infernalis*, *S. longipennis*, *C. oxypterus* *C. trachypterus* and *E. pallidus* were present only in the grasslands. Among the different habitats, grasslands were found to be the most common habitat for Orthopterans occupied 95.55% of the total number of collected individuals. Next to grasslands, a greater number of Orthopterans was collected from the agricultural land and least number of species was recorded from the ground surface were presented in table -19.

**Table - 19**

**Total number of Orthopterans recorded from different habitats**

Family	Species	Grasslands	Agricultural land	Ground surface
Acrididae	<i>A. exaltata</i>	+	+	+
	<i>A. turrita</i>	+	+	-
	<i>P. infumata</i>	+	+	-
	<i>E. sinetyi</i>	+	+	-
	<i>D. pinguis</i>	+	+	+
	<i>X. humilis</i>	-	+	-
	<i>C. tatarica</i>	+	+	-
	<i>E. alacris</i>	+	+	-
	<i>C. decisa</i>	+	+	+
	<i>A. luteipes</i>	+	+	+
	<i>L. indica</i>	+	+	+
	<i>H. banyan</i>	-	+	-
	<i>A. longipes</i>	+	-	+
	<i>A. humbertianus</i>	+	+	+
	<i>A. insubricus</i>	+	-	+
	<i>A. patruelis</i>	+	+	+
	<i>A. thalassinus</i>	+	+	-
	<i>D. venusta</i>	+	+	+
	<i>G. africanus</i>	+	+	-
	<i>G. marmoratus</i>	+	+	-

Contd....

Family	Species	Grasslands	Agricultural land	Ground surface
	<i>O. abruptus</i>	+	+	+
	<i>O. infernalis</i>	+	-	-
	<i>M. fasciata</i>	+	+	+
	<i>T. annulata</i>	+	+	+
	<i>S. longipennis</i>	+	-	-
	<i>O. velox</i>	+	+	-
	<i>O. hyla</i>	+	+	-
	<i>O. fuscovittata</i>	+	+	-
	<i>S. prasiniferum</i>	+	+	+
Pyrgomorphidae	<i>A. crenulata</i>	+	+	+
	<i>C. oxypterus</i>	+	-	-
	<i>C. trachypterus</i>	+	-	-
	<i>T. indica</i>	+	+	+
	<i>O. maindroni</i>	+	+	+
Tettigoniidae	<i>C. maculatus</i>	+	+	-
	<i>E. pallidus</i>	+	-	-
	<i>H. spectabilis</i>	+	+	-
	<i>H. kinneari</i>	+	+	-
	<i>H. vidhyavadhia</i>	+	+	+
	<i>P. gracilis</i>	+	+	-
	<i>T. unicolor</i>	+	-	+
	<i>S. rugosa</i>	+	-	+
Gryllidae	<i>T. mitratus</i>	+	+	-
	<i>G. bimaculatus</i>	+	+	+
	<i>G. sigillatus</i>	+	+	+
Total		43	36	22
Dominance		95.55	80	48.88

### Correlation between plant diversity and Orthopterans diversity

The correlation coefficient of plant species composition and their families richness with Orthoptera species composition from five different sites and four different seasons were calculated (Fig - 35 & 36). The plant species richness showed a significant strong positive correlation with Orthopterans composition in different sites ( $R^2 = 0.90$ ) and season ( $R^2 = 0.94$ ). The plant families richness also showed a strong positive correlation with Orthopterans diversity in different sites ( $R^2 = 0.92$ ) and seasons ( $R^2 = 0.94$ ). This follows from the result that as the number of plant species increased, the number of Orthopterans species increased.

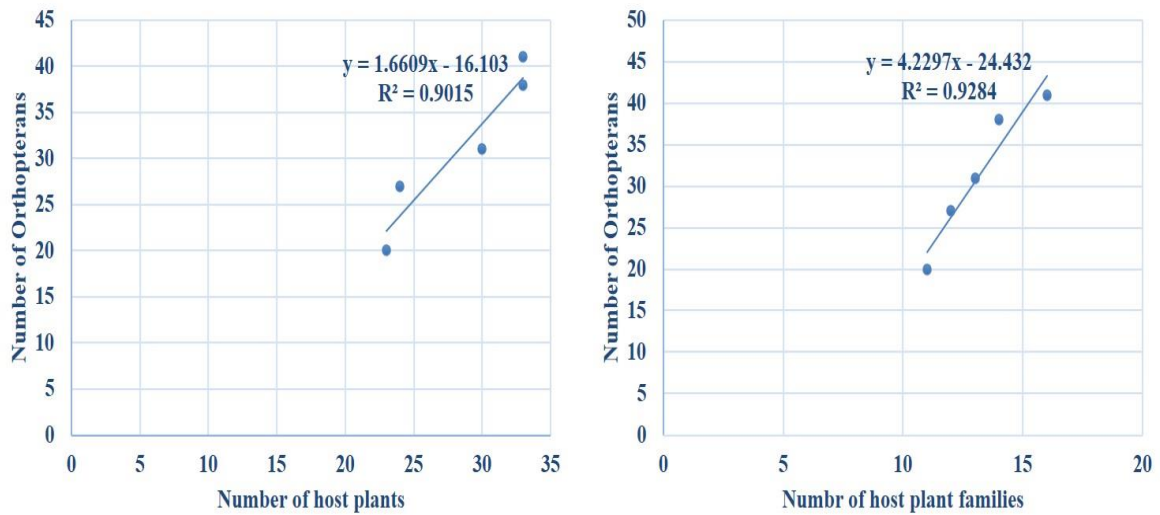


Figure - 35

Correlation coefficient of Orthopterans composition with host plants and its families composition from different sites

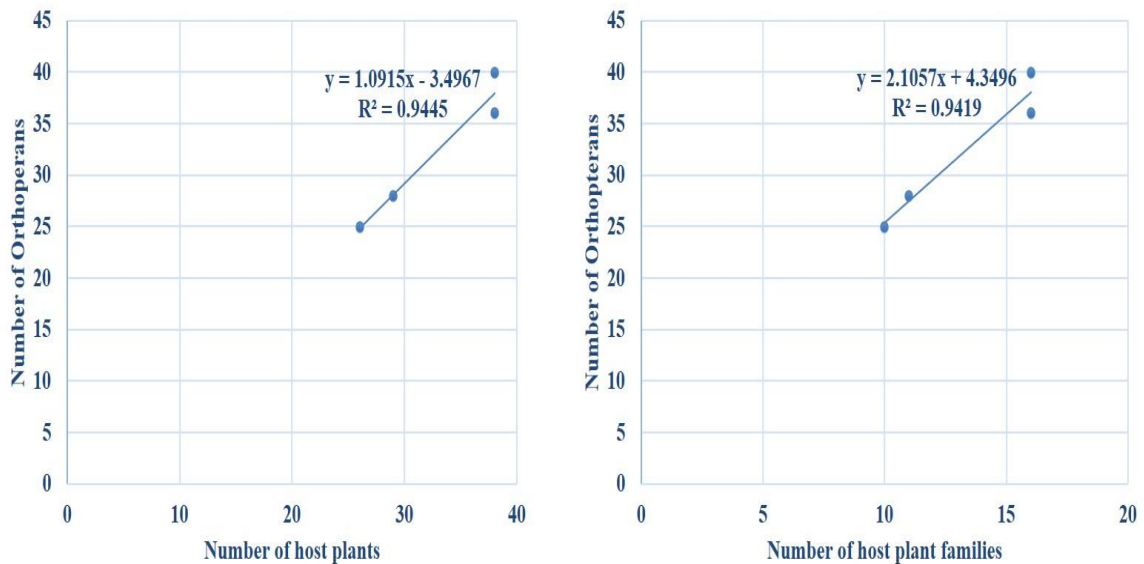


Figure - 36

Correlation coefficient of Orthopterans composition with host plants and its families composition from different seasons

### Discussion

In this attempt, different varieties of host plants were documented in the habitat of Orthopterans. The present study revealed that the plant species diversity and Orthopterans species diversity were recorded high in sites I and III, while the least was recorded in sites

V and II. Due to the less anthropogenic activities, site I and site III gives shelter for the huge number of plants and animal species. The higher number of vegetation provides hideouts for Orthopterans from predators and harsh climatic conditions like high temperature and heavy rainfall, which facilitates survival. It also provides a wide variety of food for Orthopterans which translates to an increase in population and distribution. Species dominance at the specific sites indicated the availability of optimum conditions for its growth and ecological success. Saha and Halder (2013) diversity difference between seasons and habitats can be attributed to the availability of suitable conditions for acridids in the forest ecosystem.

In site V and site II, plant species are decreasing in their number might be due to the anthropogenic impacts (constructions of buildings and extension of roads etc.) and pollution since it is located inside the city, which showed the least diversity of Orthopterans. Number of plant species were uprooted for road construction and highway extension programs. Mostly animals depend on plants for their diet; plants have to be protected at any cost otherwise, animals would have got extinct. Urbanisation affects the natural flora and fauna that imposes to document the existing biodiversity to conserve them from extinction (Dolan *et al.*, 2011). Similar Observation was made by Kariuki *et al.* (2019) that grasshopper diversity was highest in zone II, which comprises small forests, thickets of bamboo and grasslands compared to zone IV, it contains a little region of grasslands. Furthermore, detritus from the dead plants attracts microorganisms like algae, fungi, detritus matter, humus and moss found on the ground, providing nutrient supplements to the Caeliferans. This was lacking in zone IV, which explains the little diversity. According to Morin (1999), habitats with fewer plant species have a relatively lower diversity of insects and other consumers. Diverse plots may have been more structurally complex providing a suitable habitat or greater space for more insects (Southwood *et al.*, 1979; Lawton, 1983; Ritchie and Olf, 1999), independent of the amount of food available.

In this study plant species and plant families richness highly correlated with Orthopteras composition. This supports the results of other studies that have shown a positive relationship between insect species richness and plant diversity (Murdoch *et al.*, 1972; Southwood *et al.*, 1979; Strong *et al.*, 1984). In addition, Evans (1988) reported a positive correlation between vegetation structure and grasshopper species richness. Kemp *et al.* (1990 a & b) observed that the composition of acridid species depends on the availability of host plant species. The positive correlations between the population

density of grasshoppers and plant species diversity can be explained by feeding and sheltering requirements of grasshoppers (Spungis, 2007).

Monsoon and pre-monsoon comprised the highest number of the Orthopterans host plant. During monsoon season rainfall enhances the growth rate of vegetation which ultimately influences Orthopterans population. In general, it was observed that the rainy season was characterized by a higher number of species with better distribution followed by winter and summer seasons. This fact shows that rainfall is the primary factor in this region influencing the community composition and the distribution level as well. According to Saha and Haldar (2013) seasonal fluctuation is conditioned by the environmental factors and even little alterations in such factors may produce a large impact on the biological behavior of the species concerned.

Detailed analysis of the host plants of 45 species of Orthopterans revealed their highly polyphagous nature, thereby exhibiting certain preferences towards specific host plants. On the basis of total collected species, *T. annulata*, *A. luteipes*, *L. indica*, *A. crenulate* and *S. prasiniferum* were found in a higher number of plants and they are well adapted for colonizing different habitats and are capable of feeding and utilizing a wide range of host plants. Paulraj *et al.* (2009) recorded 24 species of Orthopterans from only one type of host plant and suggested that most of the grasshoppers are highly selective to host habitats.

The preference towards the specific host plants also varied between species to species and family to family. But it is well known that the host preference of grasshoppers is influenced by physical and chemical characteristics like nutrition or secondary chemicals (Gangwere, 1972; Chapman and Bernays, 1977; Bernays and Chapman, 1977).

Twenty species from Acrididae, five species from Pyrgomorphidae, six species from Tettigoniidae and two species from Gryllidae were found in both Dicot and Monocot plants. In this study, the Monocotyledons class supported a maximum number of Orthopterans. Among the different families of Orthopterans, Acrididae was found in almost all types of plants. They are able to colonize habitats with both monocot and dicots plants and they are able to colonize a wide range of habitats which explains their wide range of diversity and distribution. Shrinivasan and Muralirangan (1992) have also recorded monocot and dicot plants as hosts for acridids.

In the current exploration, Orthopterans host plants such as *C. dactylon*, *O. sativa*, *Z. mays* and *C. rotundus* were supported the maximum number of Orthopterans. Subhasish *et al.* (2014) examined that the *C. dactylon* is the best food plant for rearing nymphs of *O. hyla hyla*. Das *et al.* (2012) observed that the fecundity, fertility and sex ratio of acridid species increases fed with three different food plants, *D. aegyptium*, *B. mutica* and *C. dactylon* for the annual biomass production. Pitafi *et al.* (2016) reported that the *Z. mays*, *S. officinarum*, *S. bicolor*, *C. dactylon* and *B. oleracea* were highly suitable for *A. humbertianus*.

Family Poaceae comprised the highest number of plants, highest number of Orthopterans and found to be dominant in all the sites and seasons of the study area. Orthopterans, *L. indica*, *T. annulata*, *A. exaltata*, *C. decisa*, *A. luteipes*, *A. patruelis*, *O. abruptus*, *A. crenulata* and *O. maindroni* were found in different families of host plants. *X. humilis*, *H. banian*, *A. thalassinus*, *S. longipennis*, *O. velox*, *O. hyla* and *T. mitratus* were found only in the family of Poaceae. Most of the dominant species in the studied sites are members of the Poaceae family, which produces a large number of seeds for sexual reproduction and possesses different means for vegetative reproduction (Ismail and ELawad, 2015). The members of Poaceae were known to be resistant against disturbance. The fecundity of acridids increased that were fed on plants of the Poaceae family (Uvarov, 1966). This plant family was mostly preferred by acridids (Haldar *et al.*, 1995). Therefore, it is suggested that the phytochemicals of *C. dactylon* have the potency to enhance the survival and growth of Orthopterans.

Among the three habitats, grasslands supported more Orthopterans than agriculture fields and ground surface. Grasslands found in the ecological zones provide a wide variety of food as well as breeding grounds for Orthopterans. This perception was in parallel with the observation of Bhusnar *et al.* (2015) in Maharashtra, Paulraj *et al.* (2009) in Tamil Nadu and Suganya *et al.* (2020) in Coimbatore, Tamil Nadu stated that species diversity and richness were higher in a grassland ecosystem. Shelton and Rogers (1978) have reported that some grasshoppers feed on algae, fungi, detritus matter, humus and moss found on ground. Braker (1989) has reported that most of the grasshoppers, particularly the members of the superfamily Acridoidea lay eggs in soil. Hence, the grasshopper collected from the ground surface in the present study. The present findings indicated that the preferable host plants like grasses in and around the field supported a large number of Orthopterans.

---

**Phase - III**
**4.3 Population Dynamics of Acridids**

Population dynamics of species are needed to identify the dominant and rare species from an ecosystem. Understanding the abundance of acridids species among different seasons and geographical regions will pave the way for appropriate strategies for conserving grasshopper in an ecosystem. Among the 45 species of Orthopterans, nine acridids namely, *T. annulata*, *A. luteipes*, *L. indica*, *O. abruptus*, *D. venusta*, *O. fuscovittata*, *P. infumata*, *A. patruelis* and *M. fasciata* were found all the sites and seasons of the study area. Hence, the present study an attempt has been made to assess whether environmental factors such as maximum and minimum temperature, humidity and rainfall have any impact on the population dynamics of selected nine acridids species.

During the study period, 3939 individuals belonging to nine species of acridids were classified under four subfamilies namely, Acridinae, Gomphocerinae, Oedipodinae and Oxyinae were collected from five different localities of Coimbatore. Overall analysis, *T. annulata* was the most dominant species (22.26%) followed by *A. luteipes* (16.22%), *L. indica* (15.79%), *O. abruptus* (13.30%), *D. venusta* (6.60%), *O. fuscovittata* (8.15%), *P. infumata* (7.24%), *A. patruelis* (5.38%) and *M. fasciata* (5.05%) were represented in table - 20.

**Population dynamics in different sites**

Among the different sites of the study area, the maximum number of acridids abundance were observed in site I (25.34%) followed by site III (24.93%), site IV (19.65%), site II (17.34%) and site V (12.74%) (Table - 20). PC analysis also shows that most of the species studied were closer to site I followed by site III, site IV, site II and site V. Acridids, *A. luteipes*, *O. abruptus*, *D. venusta*, *O. fuscovittata* and *M. fasciata* were specific to site I whereas *T. annulata*, *L. indica* and *A. patruelis* were specific to site III and *P. infumata*, was the only species highest in site IV. Principal component 1 (variance explained 60.49%; eigenvalue = 5.44) represents the higher abundance of species. Principal component 2 (variance explained = 19.29%; eigenvalue = 1.73) illustrates the lower abundance of species (Fig - 37).

The similarity matrix from the quantitative data showed that acridids composition between site I and site III formed a first cluster, sharing 0.88% similarity in species. In

contrast, site II and site IV formed a second cluster, sharing 0.84% similarity. Site V was formed as single cluster and species composition had much dissimilarity with other sites of the study area. Site I shared similarities with site II, site IV and site V were 0.81%, 0.81% and 0.66%. Site II shared similarities with site III and site V were 0.80% and 0.80%. Site III shared similarities with site IV and site V were 0.85% and 0.67%. Site IV shared similarities with site V was 0.77%. The similarities of acridids population varied from one region to another region (Fig - 38).

Table - 20

Population dynamics of acridids in different sites of the study area

Species	Site I	Site II	Site III	Site IV	Site V	Total	Percentage
<i>T. annulata</i>	211	180	274	127	85	877	22.26%
<i>A. luteipes</i>	207	85	152	124	71	639	16.22%
<i>L. indica</i>	161	91	164	137	69	622	15.79%
<i>O. abruptus</i>	129	107	108	108	72	524	13.30%
<i>D. venusta</i>	68	39	57	43	53	260	6.60%
<i>O. fuscovittata</i>	84	61	63	68	45	321	8.15%
<i>P. infumata</i>	42	33	73	92	45	285	7.24%
<i>A. patruelis</i>	45	39	56	39	33	212	5.38%
<i>M. fasciata</i>	51	48	35	36	29	199	5.05%
<b>Total</b>	<b>998</b>	<b>683</b>	<b>982</b>	<b>774</b>	<b>502</b>	<b>3939</b>	<b>100</b>
<b>Percentage</b>	<b>25.34%</b>	<b>17.34%</b>	<b>24.93%</b>	<b>19.65%</b>	<b>12.74%</b>	<b>100</b>	<b>-</b>

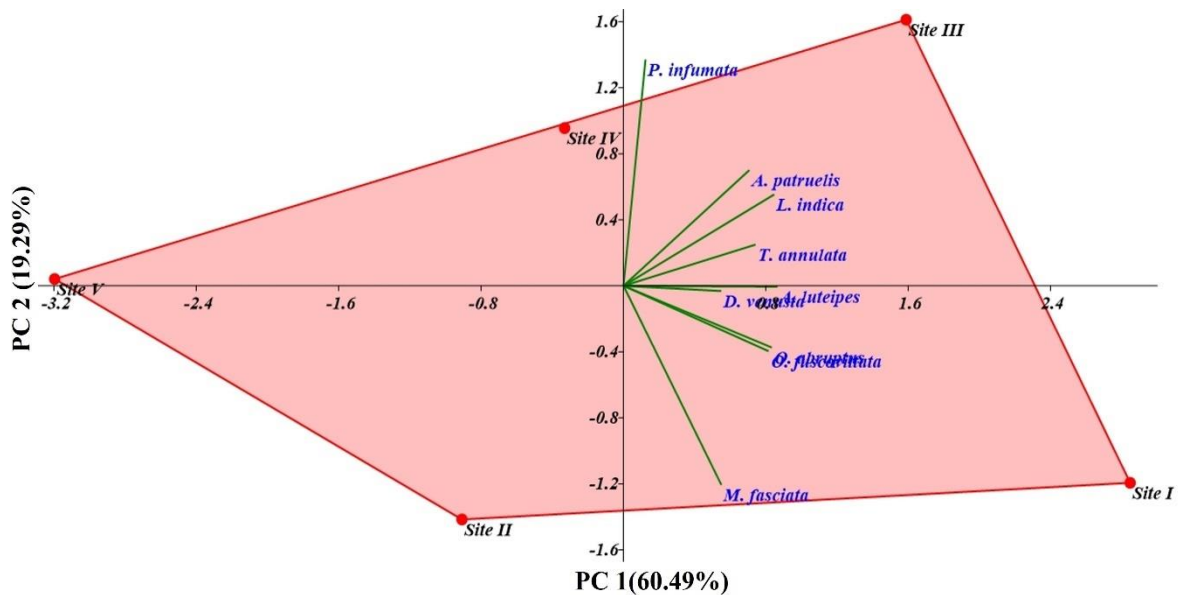


Figure - 37

Bi-plot of the first two axes of the principal component analysis of acridids among different sites

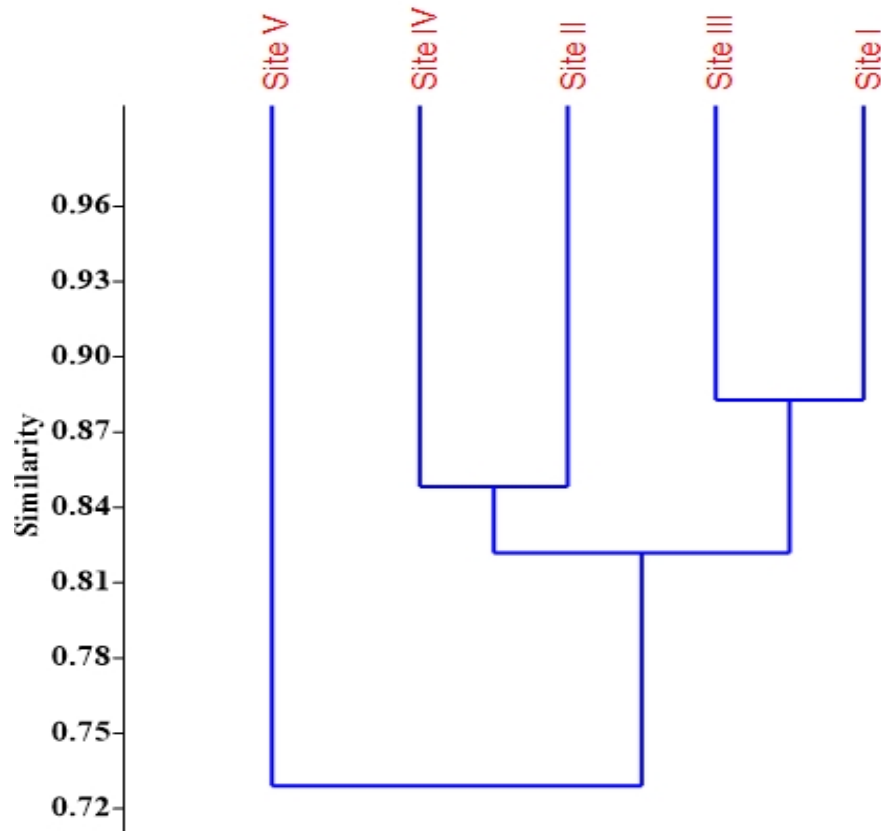


Figure - 38

### Similarity and dissimilarity of acridids composition among different sites

#### Site I: Marudhamalai

A total of 998 acridids individuals were collected from site I. Among the acridids, *T. annulata* (D = 21.1) and *A. luteipes* (D = 20.7) were found to be a predominant species. Acridids *P. infumata* (D = 4.21) and *A. patruelis* (D = 4.51) were the least dominant species in Site I. The maximum and minimum abundance of acridids during post monsoon, summer, pre-monsoon and monsoon were *A. luteipes* (D = 24.82) and *D. venusta* (D = 3.65), *L. indica* (D = 26.28) and *A. patruelis* (D = 2.19), *T. annulata* (D = 24.10) and *M. fasciata* (D = 3.05), *T. annulata* (D = 23.14) and *P. infumata* (D = 3.31) respectively. Over all, population of *T. annulata* (87), *L. indica* (64), *P. infumata* (14) and *A. patruelis* (20) were observed highest during pre-monsoon season while, *A. luteipes* (76), *O. abruptus* (51), *D. venusta* (33), *O. fuscovittata* (31) and *M. fasciata* (23) were recorded highest during monsoon season. In site I, the maximum number of acridids were recorded during monsoon season (363) and pre-monsoon season (361) (Table - 21).

Table - 21

## Population dynamics of acridids in site I

Species	Post monsoon	Dominance	Summer	Dominance	Pre-monsoon	Dominance	Monsoon	Dominance	Over all	Dominance
<i>T. annulata</i>	18	13.14	22	16.06	87	24.10	84	23.14	211	21.1
<i>A. luteipes</i>	34	24.82	29	21.17	68	18.84	76	20.94	207	20.7
<i>L. indica</i>	22	16.06	36	26.28	64	17.73	39	10.74	161	16.1
<i>O. abruptus</i>	21	15.33	12	8.76	45	12.47	51	14.05	129	12.9
<i>D. venusta</i>	5	3.65	5	3.65	25	6.93	33	9.09	68	6.81
<i>O. fuscovittata</i>	11	8.03	15	10.95	27	7.48	31	8.54	84	8.42
<i>P. infumata</i>	9	6.57	7	5.11	14	3.88	12	3.31	42	4.21
<i>A. patruelis</i>	8	5.84	3	2.19	20	5.54	14	3.86	45	4.51
<i>M. fasciata</i>	9	6.57	8	5.84	11	3.05	23	6.34	51	5.11
<b>Total</b>	<b>137</b>	<b>100</b>	<b>137</b>	<b>100</b>	<b>361</b>	<b>100</b>	<b>363</b>	<b>100</b>	<b>998</b>	<b>100</b>

## Site II: Saibaba Colony

Totally, 683 acridids population were collected from site II. Acridids species, *T. annulata* (D = 26.35) and *O. abruptus* (D = 15.67) were the dominant species and *P. infumata* (D = 4.83), *D. venusta* (5.71) and *A. patruelis* (D = 5.71) were the least dominant species in site II. The maximum and minimum abundance of acridids during post monsoon, summer, pre-monsoon and monsoon were *L. indica* (D = 24.68) and *M. fasciata* (D = 2.60), *O. abruptus* (D = 21.36) and both *P. infumata* and *A. patruelis* (D = 4.85), *T. annulata* (D = 30.31) and *P. infumata* (D = 4.33), *T. annulata* (D = 26.51) and *M. fasciata* (D = 5.22) respectively. Overall population of *T. annulata* (77), *O. abruptus* (34), *A. patruelis* (16) and *M. fasciata* (22) were observed higher during pre- monsoon season while, *A. luteipes* (31), *L. indica* (26), *D. venusta* (16), *O. fuscovittata* (26) and *P. infumata* (14) were recorded higher during monsoon season. Maximum number of acridids were recorded during pre-monsoon season (254) compared to another season (Table - 22).

## Site III: Thenkarai

Overall, 982 number of acridids were collected from site III. The most abundant species in site III were *T. annulata* (D = 27.90) and *L. indica* (D = 16.70). Acridids, *M. fasciata* (D = 3.56) and *A. patruelis* (D = 5.70) were the least dominant species in site III. The maximum and minimum abundance of acridids during post monsoon, summer,

pre-monsoon and monsoon were *L. indica* (D = 21.24) and *M. fasciata* (D = 3.54), *T. annulata* (D = 28.38) and *M. fasciata* (D = 2.03), *T. annulata* (D = 27.16) and *M. fasciata* (D = 3.40), *T. annulata* (D = 30.48) and both *D. venusta* and *M. fasciata* (D = 4.28) respectively. Overall population of *D. venusta* (25) and *O. fuscovittata* (22) were observed higher during pre-monsoon season while *T. annulata* (121), *A. luteipes* (72), *L. indica* (D = 69), *O. abruptus* (28), *P. infumata* (29), *A. patruelis* (25) and *M. fasciata* (17) were recorded higher during monsoon season. Maximum number of acridids were recorded during monsoon season (397) and pre-monsoon season (324) (Table - 23).

**Table - 22**  
**Population dynamics of acridids in site II**

Species	Post monsoon	Dominance	Summer	Dominance	Pre-monsoon	Dominance	Monsoon	Dominance	Over all	Dominance
<i>T. annulata</i>	16	20.78	21	20.39	77	30.31	66	26.51	180	26.35
<i>A. luteipes</i>	16	20.78	13	12.62	25	9.84	31	12.45	85	12.45
<i>L. indica</i>	19	24.68	9	8.74	37	14.57	26	10.44	91	13.32
<i>O. abruptus</i>	9	11.69	22	21.36	34	13.39	42	16.87	107	15.67
<i>D. venusta</i>	3	3.90	6	5.83	14	5.51	16	6.43	39	5.71
<i>O. fuscovittata</i>	6	7.79	11	10.68	18	7.09	26	10.44	61	8.93
<i>P. infumata</i>	3	3.90	5	4.85	11	4.33	14	5.62	33	4.83
<i>A. patruelis</i>	3	3.90	5	4.85	16	6.30	15	6.02	39	5.71
<i>M. fasciata</i>	2	2.60	11	10.68	22	8.66	13	5.22	48	7.03
<b>Total</b>	<b>77</b>	<b>100</b>	<b>103</b>	<b>100</b>	<b>254</b>	<b>100</b>	<b>249</b>	<b>100</b>	<b>683</b>	<b>100</b>

**Table - 23**  
**Population dynamics of acridids in site III**

Species	Post monsoon	Dominance	Summer	Dominance	Pre-monsoon	Dominance	Monsoon	Dominance	Over all	Dominance
<i>T. annulata</i>	23	20.35	42	28.38	88	27.16	121	30.48	274	27.90
<i>A. luteipes</i>	11	9.73	24	16.22	45	13.89	72	18.14	152	15.48
<i>L. indica</i>	24	21.24	18	12.16	53	16.36	69	17.38	164	16.70
<i>O. abruptus</i>	11	9.73	27	18.24	42	12.96	28	7.05	108	11.00
<i>D. venusta</i>	9	7.96	6	4.05	25	7.72	17	4.28	57	5.80
<i>O. fuscovittata</i>	10	8.85	12	8.11	22	6.79	19	4.79	63	6.42
<i>P. infumata</i>	12	10.62	9	6.08	23	7.10	29	7.30	73	7.43
<i>A. patruelis</i>	9	7.96	7	4.73	15	4.63	25	6.30	56	5.70
<i>M. fasciata</i>	4	3.54	3	2.03	11	3.40	17	4.28	35	3.56
<b>Total</b>	<b>113</b>	<b>100</b>	<b>148</b>	<b>100</b>	<b>324</b>	<b>100</b>	<b>397</b>	<b>100</b>	<b>982</b>	<b>100</b>

**Site IV: Thudiyalur**

In site IV, 774 number of acridids population were recorded. Among the nine species of acridids in site IV, *L. indica* (D = 17.70) and *T. annulata* (D = 16.41) were the most dominant species. *M. fasciata* (D = 4.65) and *A. patruelis* (D = 5.04) were the least dominant species in site IV. The maximum and minimum abundance of acridids during post monsoon, summer, pre-monsoon and monsoon were *L. indica* (D = 23.42) and both *D. venusta* and *A. patruelis* (D = 2.70), *L. indica* (D = 23.01) and both *D. venusta* and *A. patruelis* (D = 1.77), *A. luteipes* (D = 17.93) and *M. fasciata* (D = 3.59), *A. luteipes* (D = 19.06) and both *D. venusta* and *A. patruelis* (D = 4.01) respectively. In overall population, *D. venusta* (26) was the only species observed higher during pre-monsoon season. *T. annulata* (52), *A. luteipes* (57), *L. indica* (45), *O. abruptus* (39), *O. fuscovittata* (28), *P. infumata* (33), *A. patruelis* (21) and *M. fasciata* (12) were recorded higher during monsoon season. Maximum number of acridids were recorded during monsoon season (299) and pre-monsoon season (251) (Table - 24).

**Table - 24****Population dynamics of acridids in site IV**

Species	Post monsoon	Dominance	Summer	Dominance	Pre-monsoon	Dominance	Monsoon	Dominance	Over all	Dominance
<i>T. annulata</i>	22	19.82	19	16.81	34	13.55	52	17.39	127	16.41
<i>A. luteipes</i>	13	11.71	9	7.96	45	17.93	57	19.06	124	16.02
<i>L. indica</i>	26	23.42	26	23.01	40	15.94	45	15.05	137	17.70
<i>O. abruptus</i>	14	12.61	22	19.47	33	13.15	39	13.04	108	13.95
<i>D. venusta</i>	3	2.70	2	1.77	26	10.36	12	4.01	43	5.56
<i>O. fuscovittata</i>	6	5.41	8	7.08	26	10.36	28	9.36	68	8.79
<i>P. infumata</i>	17	15.32	17	15.04	25	9.96	33	11.04	92	11.89
<i>A. patruelis</i>	3	2.70	2	1.77	13	5.18	21	7.02	39	5.04
<i>M. fasciata</i>	7	6.31	8	7.08	9	3.59	12	4.01	36	4.65
<b>Total</b>	<b>111</b>	<b>100</b>	<b>113</b>	<b>100</b>	<b>251</b>	<b>100</b>	<b>299</b>	<b>100</b>	<b>998</b>	<b>100</b>

**Site V: Singanallur**

In total, 502 number of acridids were collected from site V. Among the nine species of acridids, *T. annulata* (D = 16.93) and *O. abruptus* (D = 14.34) was found to be a predominant species in site I. *M. fasciata* (D = 5.78) and *A. patruelis* (D = 6.57) were the least dominant species in site V. The maximum and minimum abundance of acridids during post monsoon, summer, pre-monsoon and monsoon were *A. luteipes* (D = 21.21) and

*A. patruelis* (D = 3.03), *L. indica* (D = 18.39) and *A. patruelis* (D = 3.45), *T. annulata* (D = 18.45) and both *D. venusta* and *M. fasciata* (D = 6.55), *T. annulata* (D = 17.68) and *M. fasciata* (D = 3.87) respectively. Over all, population of *L. indica* (26), *P. infumata* (22) and *M. fasciata* (11) were observed higher during pre-monsoon season while *T. annulata* (32), *A. luteipes* (24), *O. abruptus* (28), *D. venusta* (23), *O. fuscovittata* (21) and *A. patruelis* (16) were recorded higher during monsoon season. Maximum number of acridids were recorded during monsoon season (181) compared to other seasons of the study area (Table - 25).

Table - 25

Population dynamics of acridids in site V

Species	Post monsoon	Dominance	Summer	Dominance	Pre-monsoon	Dominance	Monsoon	Dominance	Over all	Dominance
<i>T. annulata</i>	9	13.64	13	14.94	31	18.45	32	17.68	85	16.93
<i>A. luteipes</i>	14	21.21	11	12.64	22	13.10	24	13.26	71	14.14
<i>L. indica</i>	6	9.09	16	18.39	26	15.48	21	11.60	69	13.75
<i>O. abruptus</i>	12	18.18	12	13.79	20	11.90	28	15.47	72	14.34
<i>D. venusta</i>	9	13.64	10	11.49	11	6.55	23	12.71	53	10.56
<i>O. fuscovittata</i>	4	6.06	7	8.05	13	7.74	21	11.60	45	8.96
<i>P. infumata</i>	5	7.58	9	10.34	22	13.10	9	4.97	45	8.96
<i>A. patruelis</i>	2	3.03	3	3.45	12	7.14	16	8.84	33	6.57
<i>M. fasciata</i>	5	7.58	6	6.90	11	6.55	7	3.87	29	5.78
<b>Total</b>	<b>66</b>	<b>100</b>	<b>87</b>	<b>100</b>	<b>168</b>	<b>100</b>	<b>181</b>	<b>100</b>	<b>502</b>	<b>100</b>

Population dynamics in different seasons

Among the different seasons of study area, the maximum number of grasshopper abundances were observed in monsoon season (D = 37.95) followed by pre-monsoon (D = 34.32), summer (D= 14.93) and post monsoon (D = 12.80) (Table - 26). PC analysis also shows that most of the species studied were closer to monsoon season. Acridids namely *T. annulata*, *A. luteipes*, *O. abruptus*, *O. fuscovittata*, *P. infumata*, *A. patruelis* and *M. fasciata* were specific to the monsoon season and *L. indica* was specific to the pre-monsoon season. *D. venusta* was the only species specific to both monsoon and pre-monsoon season. Principal component 1 (variance explained 97.76%; eigen value = 8.79) represents the higher abundance of species. Principal component 2 (variance explained = 1.57%; eigen value = 0.66) represents the lower abundance of species (Figure - 39).

The similarity matrix from the quantitative data showed that acridids composition between monsoon and pre-monsoon formed a first cluster, sharing 0.93572 similarities in species, whereas post monsoon and summer formed a second cluster, sharing 0.91026 similarity. Post monsoon sharing similarity with pre-monsoon and monsoon is 0.5431 and 0.50425 respectively. Summer sharing similarity with pre-monsoon and monsoon is 0.60619 and 0.564572 respectively. Moreover, significant differences were found between the seasons of the study area. Less similarity was observed between post monsoon and monsoon season (0.50425) (Figure - 40).

Table - 26

Population fluctuation in different season of the study area

Species	Post monsoon	Summer	Pre monsoon	Monsoon
<i>T. annulata</i>	88	117	317	355
<i>A. luteipes</i>	88	86	205	260
<i>L. indica</i>	97	105	220	200
<i>O. abruptus</i>	67	95	174	188
<i>D. venusta</i>	29	29	101	101
<i>O. fuscovittata</i>	37	53	100	131
<i>P. infumata</i>	46	47	95	97
<i>A. patruelis</i>	25	20	76	91
<i>M. fasciata</i>	27	36	64	72
<b>Total</b>	<b>504</b>	<b>588</b>	<b>1352</b>	<b>1495</b>
<b>Percentage</b>	<b>12.80</b>	<b>14.93</b>	<b>34.32</b>	<b>37.95</b>

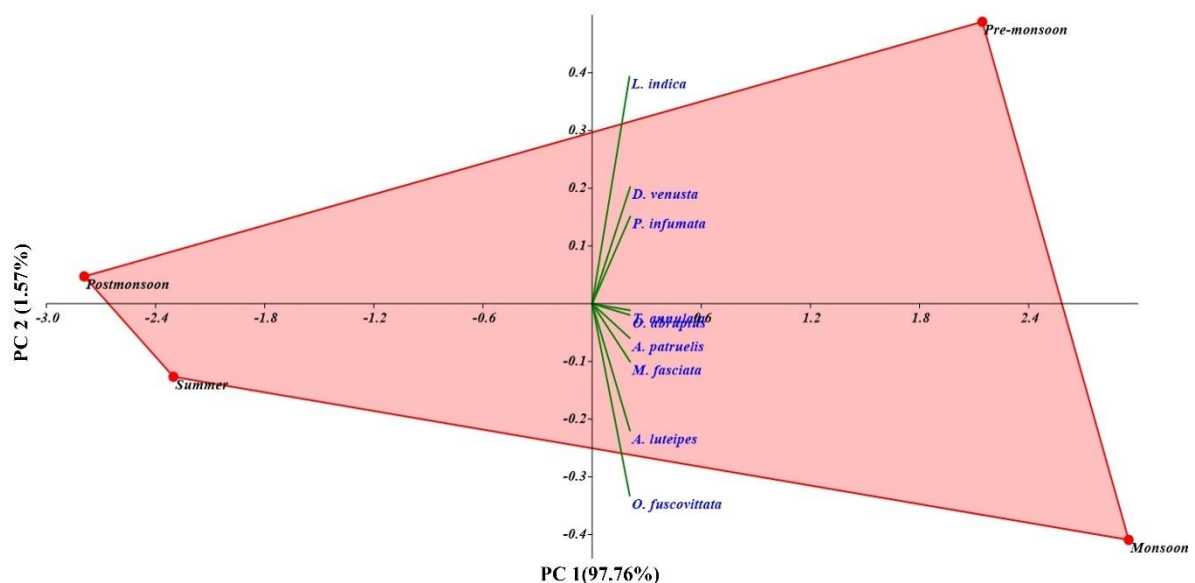


Figure - 39  
Bi-plot of the first two axes of the principal component analysis of acridids among different seasons

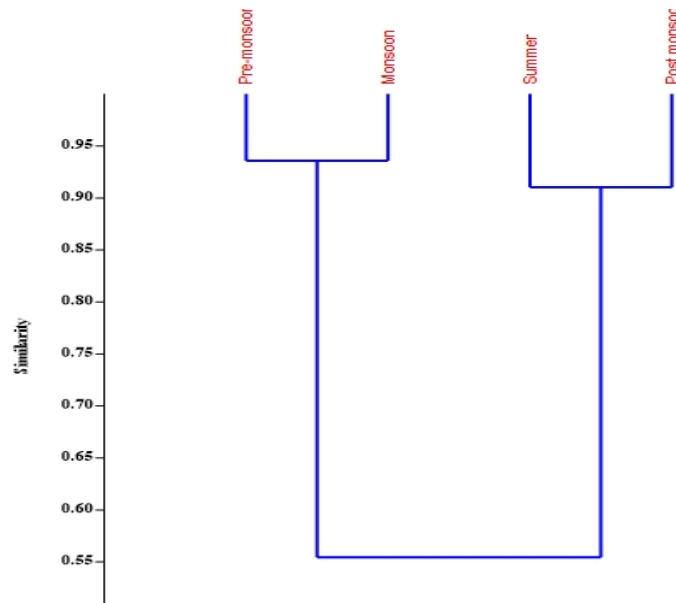


Figure - 40

### Similarity and dissimilarity of acridids composition among different seasons

#### Post monsoon season

A total of 504 acridids were collected from post monsoon season. *L. indica* ( $D = 19.25$ ) *T. annulata* ( $D = 17.46$ ) and *A. luteipes* ( $D = 17.46$ ) were found to be a dominant species in post monsoon season whereas *A. patruelis* ( $D = 4.96$ ) and *M. fasciata* ( $D = 5.36$ ) were the least dominant species. *A. luteipes* (34), *O. abruptus* (21), *O. fuscovittata* (11) and *M. fasciata* (9) were observed high in site I. *T. annulata* (23), *D. venusta* (9) and *A. patruelis* (9) were recorded high in site III. *L. indica* (26) and *P. infumata* (17) were observed high in site IV. The maximum number of acridids were recorded in site I (137) during post monsoon season (Table - 27).

#### Summer season

Totally, 588 acridids were collected from the summer season. Among the nine species of acridids, *T. annulata* ( $D = 19.90$ ) and *L. indica* ( $D = 17.86$ ) were found to be a predominant species in the summer season while *A. patruelis* ( $D = 3.40$ ) and *D. venusta* ( $D = 4.93$ ) were the least dominant species. *A. luteipes* (29), *L. indica* (36) and *O. fuscovittata* (15) were observed high in site I. *M. fasciata* (11) was highest in site II. *T. annulata* (42), *O. abruptus* (27) and *A. patruelis* (7) were highest in site III. *P. infumata* (17) was highest in site IV. *D. venusta* (10) was observed high in site V. Maximum number of acridids were recorded in site III (148) during summer season (Table - 28).

**Pre-monsoon season**

In total, 1352 acridids were collected from pre-monsoon season. Among the nine species of acridids, *T. annulata* (D = 23.45) and *L. indica* (D = 15.16) were found to be a predominant species in pre-monsoon season whereas *M. fasciata* (D = 4.73) and *A. patruelis* (D = 5.62) were the least dominant. *A. luteipes* (68), *L. indica* (64), *O. abruptus* (45) and *A. patruelis* (20) were observed high in site I. *M. fasciata* (22) was highest in site II, *T. annulata* (88) was highest in site III. *D. venusta* (26), *O. fuscovittata* (26) and *P. infumata* (25) were observed high in site IV. The maximum number of acridids were recorded in site I (355) during pre-monsoon season (Table - 29).

**Monsoon season**

Overall, 1495 acridids were collected from monsoon season. Among the nine species of acridids, *T. annulata* (D = 23.75) and *A. luteipes* (D = 17.39) were found to be a predominant species in monsoon season while *M. fasciata* (D = 4.82) and *A. patruelis* (D = 6.09) were the least dominant species. *A. luteipes* (76), *O. abruptus* (51), *D. venusta* (33), *O. fuscovittata* (37) and *M. fasciata* (23) were observed high in site I. *T. annulata* (121), *L. indica* (69) and *A. patruelis* (25) were higher in site III while *P. infumata* (33) was highest in site IV. The maximum number of acridids were recorded in site I (369) during monsoon season (Table - 30).

**Table - 27****Population dynamics of acridids in post monsoon season**

Species	Site I	Dominance	Site II	Dominance	Site III	Dominance	Site IV	Dominance	Site V	Dominance	Over all	Dominance
<i>T. annulata</i>	18	13.14	16	20.78	23	20.35	22	19.82	9	13.64	88	17.46
<i>A. luteipes</i>	34	24.82	16	20.78	11	9.73	13	11.71	14	21.21	88	17.46
<i>L. indica</i>	22	16.06	19	24.68	24	21.24	26	23.42	6	9.09	97	19.25
<i>O. abruptus</i>	21	15.33	9	11.69	11	9.73	14	12.61	12	18.18	67	13.29
<i>D. venusta</i>	5	3.65	3	3.90	9	7.96	3	2.70	9	13.64	29	5.75
<i>O. fuscovittata</i>	11	8.03	6	7.79	10	8.85	6	5.41	4	6.06	37	7.34
<i>P. infumata</i>	9	6.57	3	3.90	12	10.62	17	15.32	5	7.58	46	9.13
<i>A. patruelis</i>	8	5.84	3	3.90	9	7.96	3	2.70	2	3.03	25	4.96
<i>M. fasciata</i>	9	6.57	2	2.60	4	3.54	7	6.31	5	7.58	27	5.36
<b>Total</b>	137	100	77	100	113	100	111	100	66	100	504	100

Table - 28

## Population dynamics of acridids in summer season

Species	Site I	Dominance	Site II	Dominance	Site III	Dominance	Site IV	Dominance	Site V	Dominance	Over all	Dominance
<i>T. annulata</i>	22	16.06	21	20.39	42	28.38	19	16.81	13	14.94	117	19.90
<i>A. luteipes</i>	29	21.17	13	12.62	24	16.22	9	7.96	11	12.64	86	14.63
<i>L. indica</i>	36	26.28	9	8.74	18	12.16	26	23.01	16	18.39	105	17.86
<i>O. abruptus</i>	12	8.76	22	21.36	27	18.24	22	19.47	12	13.79	95	16.16
<i>D. venusta</i>	5	3.65	6	5.83	6	4.05	2	1.77	10	11.49	29	4.93
<i>O. fuscovittata</i>	15	10.95	11	10.68	12	8.11	8	7.08	7	8.05	53	9.01
<i>P. infumata</i>	7	5.11	5	4.85	9	6.08	17	15.04	9	10.34	47	7.99
<i>A. patruelis</i>	3	2.19	5	4.85	7	4.73	2	1.77	3	3.45	20	3.40
<i>M. fasciata</i>	8	5.84	11	10.68	3	2.03	8	7.08	6	6.90	36	6.12
<b>Total</b>	<b>137</b>	<b>100</b>	<b>103</b>	<b>100</b>	<b>148</b>	<b>100</b>	<b>113</b>	<b>100</b>	<b>87</b>	<b>100</b>	<b>588</b>	<b>100</b>

Table - 29

## Population dynamics of acridids in pre-monsoon season

Species	Site I	Dominance	Site II	Dominance	Site III	Dominance	Site IV	Dominance	Site V	Dominance	Over all	Dominance
<i>T. annulata</i>	87	24.51	77	30.31	88	27.16	34	13.55	31	18.45	317	23.45
<i>A. luteipes</i>	68	19.15	25	9.84	45	13.89	45	17.93	22	13.10	205	15.16
<i>L. indica</i>	64	18.03	37	14.57	53	16.36	40	15.94	26	15.48	220	16.27
<i>O. abruptus</i>	45	12.68	34	13.39	42	12.96	33	13.15	20	11.90	174	12.87
<i>D. venusta</i>	25	7.04	14	5.51	25	7.72	26	10.36	11	6.55	101	7.47
<i>O. fuscovittata</i>	21	5.92	18	7.09	22	6.79	26	10.36	13	7.74	100	7.40
<i>P. infumata</i>	14	3.94	11	4.33	23	7.10	25	9.96	22	13.10	95	7.03
<i>A. patruelis</i>	20	5.63	16	6.30	15	4.63	13	5.18	12	7.14	76	5.62
<i>M. fasciata</i>	11	3.10	22	8.66	11	3.40	9	3.59	11	6.55	64	4.73
<b>Total</b>	<b>355</b>	<b>100</b>	<b>254</b>	<b>100</b>	<b>324</b>	<b>100</b>	<b>251</b>	<b>100</b>	<b>168</b>	<b>100</b>	<b>1352</b>	<b>100</b>

Table - 30

## Population dynamics of acridids in monsoon season

Species	Site I	Dominance	Site II	Dominance	Site III	Dominance	Site IV	Dominance	Site V	Dominance	Over all	Dominance
<i>T. annulata</i>	84	22.76	66	26.51	121	30.48	52	17.39	32	17.68	355	23.75
<i>A. luteipes</i>	76	20.60	31	12.45	72	18.14	57	19.06	24	13.26	260	17.39
<i>L. indica</i>	39	10.57	26	10.44	69	17.38	45	15.05	21	11.60	200	13.38
<i>O. abruptus</i>	51	13.82	42	16.87	28	7.05	39	13.04	28	15.47	188	12.58
<i>D. venusta</i>	33	8.94	16	6.43	17	4.28	12	4.01	23	12.71	101	6.76
<i>O. fuscovittata</i>	37	10.03	26	10.44	19	4.79	28	9.36	21	11.60	131	8.76
<i>P. infumata</i>	12	3.25	14	5.62	29	7.30	33	11.04	9	4.97	97	6.49
<i>A. patruelis</i>	14	3.79	15	6.02	25	6.30	21	7.02	16	8.84	91	6.09
<i>M. fasciata</i>	23	6.23	13	5.22	17	4.28	12	4.01	7	3.87	72	4.82
<b>Total</b>	<b>369</b>	<b>100</b>	<b>249</b>	<b>100</b>	<b>397</b>	<b>100</b>	<b>299</b>	<b>100</b>	<b>181</b>	<b>100</b>	<b>1495</b>	<b>100</b>

### Percentage and variation of acridids among sites and seasons

The composition of *T. annulata* population was varied from 1.02 to 13.7. The minimum species diversity was recorded in site V during post monsoon and the maximum level was observed in site III during monsoon season. *A. luteipes* was ranged from 1.41 to 11.89. The minimum species diversity was noted in site IV during summer and the maximum level was recorded in site I during monsoon season. *L. indica* was differed from 0.96 to 11.09. The minimum species diversity was observed in site V during post monsoon and the maximum level was noticed in site III during monsoon season. *O. abruptus* was changed from 1.72 to 9.73. The minimum species diversity was recorded in site II during post monsoon and the maximum level was accounted in site I during monsoon season. *D. venusta* was fluctuated from 0.77 to 12.69. The minimum species diversity was noted in site IV during summer and the maximum level was observed in site I during monsoon season. *O. fuscovittata* was varied from 1.25 to 11.53. The minimum species diversity was identified in site V during post monsoon and the maximum level was recorded in site I during monsoon season. *P. infumata* was ranged from 1.05 to 11.58. The minimum species diversity was recorded in site II during post monsoon and the maximum level was observed in site IV during monsoon season. *A. patruelis* was differed from 0.94 to 11.79. The minimum species diversity was noticed in site V during post monsoon and site IV during summer and the maximum level was recorded in site III during monsoon season. *M. fasciata* was varied from 1.01 to 11.56. The minimum species diversity was recorded in site II during post monsoon and site IV during summer, the maximum level was noticed in site I during monsoon season (Table - 31).

### Impact of meteorological parameters on acridids population

Patterns of population density and growth rates from January to December varied among the nine most common acridids species in the study area. Overall, the highest Acridids population were collected from November month (678) followed by October (588) and August (578) and the lowest acridids were recorded from February (106). *T. annulata* (164), *A. luteipes* (128), *D. venusta* (47), *O. fuscovittata* (60), *P. infumata* (50) and *M. fasciata* (36) were observed high in the month of November. *L. indica* (93) and *A. patruelis* (42) were observed high in October month. *O. abruptus* (79) were observed high in September month. Among the nine species of acridids, six species namely, *T. annulata* (22), *L. indica* (18), *O. abruptus* (11), *D. venusta* (3), *P. infumata* (9) and *A. patruelis* (2)

were recorded lowest in month of February while *A. luteipes* (16) was observed lowest in month of June, *O. fuscovittata* (7) was lowest in January month and *M. fasciata* (3) was observed lowest in month of April (3) (Fig - 41).

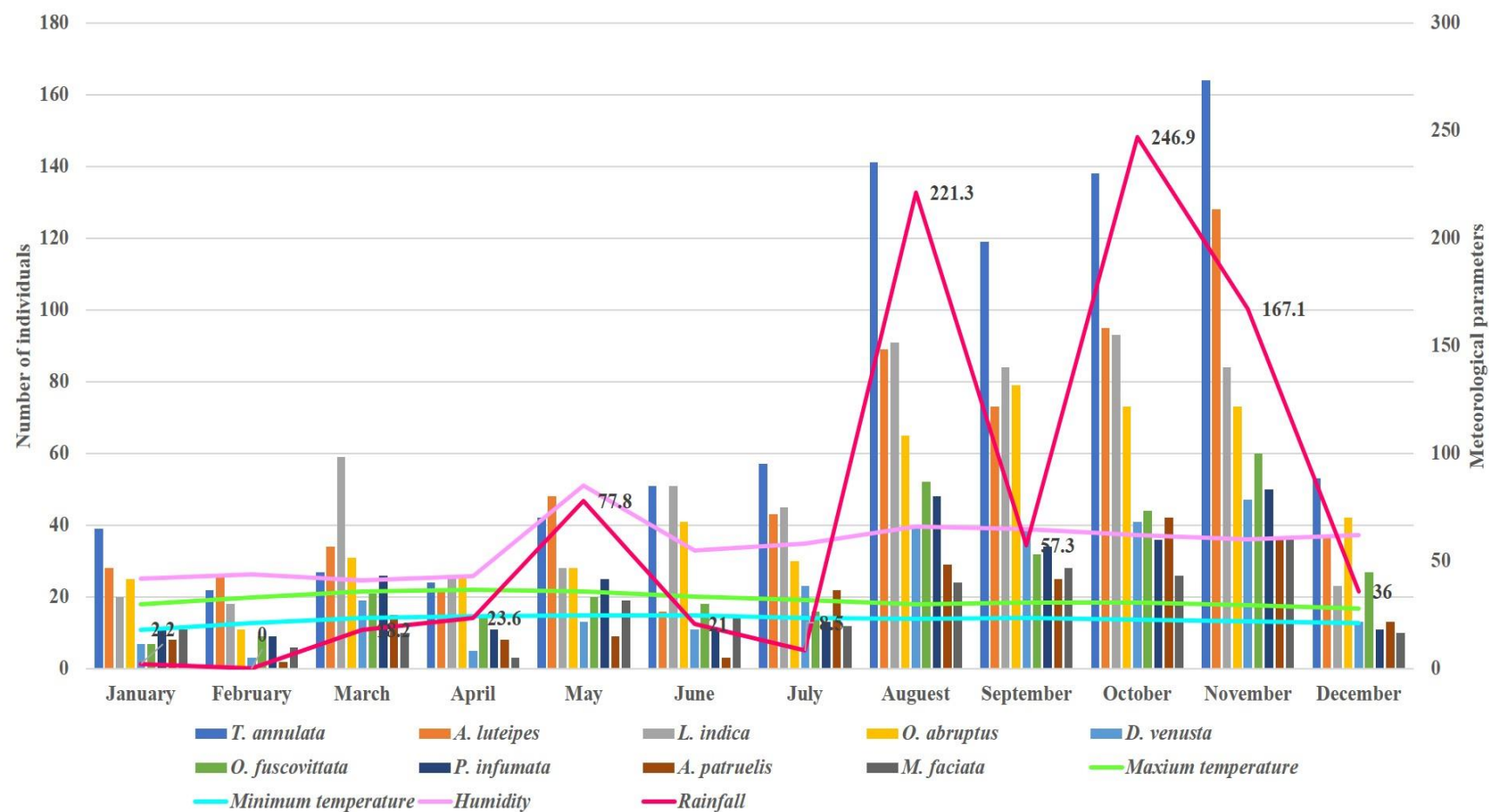
During the study period, maximum and minimum temperatures were inversely related to the population numbers in general. With high average temperature, particularly in the months of April and February, the population decreased. The acridids population density was increased between August to November, when average temperatures were low compared to April and high than December and January. The population of acridids increase during pre-monsoon season (July to September) after summer (May to June) and the population of acridids was highest during monsoon season (October to December). As for the influence of rainfall, it usually supported a high population in monsoon (October and November). Acridids composition were increased where the rainfall increased. November, October, August and September months population were recorded high and rainfall also observed high during the study period.

The correlation of meteorological parameters with acridids population varied among nine species of the present study. Correlation coefficient data show that the maximum and minimum temperature had a significant negative correlation with acridids population. Relative humidity also had a negative correlation coefficient with acridids population. Rainfall had a significant positive correlation with the population of acridids, *T. annulata* ( $R^2 = 0.7334$ ), *A. luteipes* ( $R^2 = 0.7209$ ), *L. indica* ( $R^2 = 0.6181$ ), *O. abruptus* ( $R^2 = 0.5711$ ), *D. venusta* ( $R^2 = 0.6345$ ), *O. fuscovittata* ( $R^2 = 0.7725$ ), *P. infumata* ( $R^2 = 0.709$ ), *A. patruelis* ( $R^2 = 0.6982$ ) and *M. fasciata* ( $R^2 = 0.5634$ ) respectively (Fig - 42 to 50).

**Table - 31**  
**Percentages of acridids composition in different sites and seasons**

Sites	Seasons	<i>T. annulata</i>	<i>A. luteipes</i>	<i>L. indica</i>	<i>O. abruptus</i>	<i>D. venusta</i>	<i>O. fuscovittata</i>	<i>P. infumata</i>	<i>A. patruelis</i>	<i>M. fasciata</i>
I	Post monsoon	18 (2.05)	34 (5.32)	22 (3.54)	21 (4.01)	5 (1.92)	11 (3.43)	9 (3.16)	8 (3.77)	9 (4.52)
		16 (1.82)	16 (2.50)	19 (3.05)	9 (1.72)	3 (1.15)	6 (1.87)	3 (1.05)	3 (1.42)	2 (1.01)
		23 (2.62)	11 (1.72)	24 (3.86)	11 (2.10)	9 (3.46)	10 (3.12)	12 (4.21)	9 (4.25)	4 (2.01)
		22 (2.51)	13 (2.03)	26 (4.18)	14 (2.67)	3 (1.15)	6 (1.87)	17 (5.96)	3 (1.42)	7 (3.52)
		9 (1.03)	14 (2.19)	6 (0.96)	12 (2.29)	9 (3.46)	4 (1.25)	5 (1.75)	2 (0.94)	5 (2.51)
II	Summer	22 (2.51)	29 (4.54)	36 (5.79)	12 (2.29)	5 (1.92)	15 (4.67)	7 (2.46)	3 (1.42)	8 (4.02)
		21 (2.39)	13 (2.03)	9 (1.45)	22 (4.20)	6 (2.31)	11 (3.43)	5 (1.75)	5 (2.36)	11 (5.53)
		42 (4.79)	24 (3.76)	18 (2.89)	27 (5.15)	6 (2.31)	12 (3.74)	9 (3.16)	7 (3.30)	3 (1.51)
		19 (2.17)	9 (1.41)	26 (4.18)	22 (4.20)	2 (0.77)	8 (2.49)	17 (5.96)	2 (0.94)	8 (4.02)
		13 (1.48)	11 (1.72)	16 (2.57)	12 (2.29)	10 (3.85)	7 (2.18)	9 (3.16)	3 (1.42)	6 (3.02)
III	Pre-monsoon	87 (9.92)	68 (10.64)	64 (10.29)	45 (8.59)	25 (9.62)	21 (6.54)	14 (4.91)	20 (9.43)	11 (5.53)
		77 (8.78)	25 (3.91)	37 (5.95)	34 (6.49)	14 (5.38)	18 (5.61)	11 (3.86)	16 (7.55)	22 (11.06)
		88 (10.03)	45 (7.04)	53 (8.52)	42 (8.02)	25 (9.62)	22 (6.85)	23 (8.07)	15 (7.08)	11 (5.53)
		34 (3.88)	45 (7.04)	40 (6.43)	33 (6.30)	26 (10.00)	26 (8.10)	25 (8.77)	13 (6.13)	9 (4.52)
		31 (3.53)	22 (3.44)	26 (4.18)	20 (3.82)	11 (4.23)	13 (4.05)	22 (7.72)	12 (5.66)	11 (5.53)
IV	Monsoon	84 (9.58)	76 (11.89)	39 (6.27)	51 (9.73)	33 (12.69)	37 (11.53)	12 (4.21)	14 (6.60)	23 (11.56)
		66 (7.53)	31 (4.85)	26 (4.18)	42 (8.02)	16 (6.15)	26 (8.10)	14 (4.91)	15 (7.08)	13 (6.53)
		121 (13.80)	72 (11.27)	69 (11.09)	28 (5.34)	17 (6.54)	19 (5.92)	29 (10.18)	25 (11.79)	17 (8.54)
		52 (5.93)	57 (8.92)	45 (7.23)	39 (7.44)	12 (4.62)	28 (8.72)	33 (11.58)	21 (9.91)	12 (6.03)
		32 (3.65)	24 (3.76)	21 (3.38)	28 (5.34)	23 (8.85)	21 (6.54)	9 (3.16)	16 (7.55)	7 (3.52)

Note: The values in parenthesis indicates the % of acridids



**Figure – 41**  
**Population dynamics of acridids in monthly wise in relation to meteorological parameters**

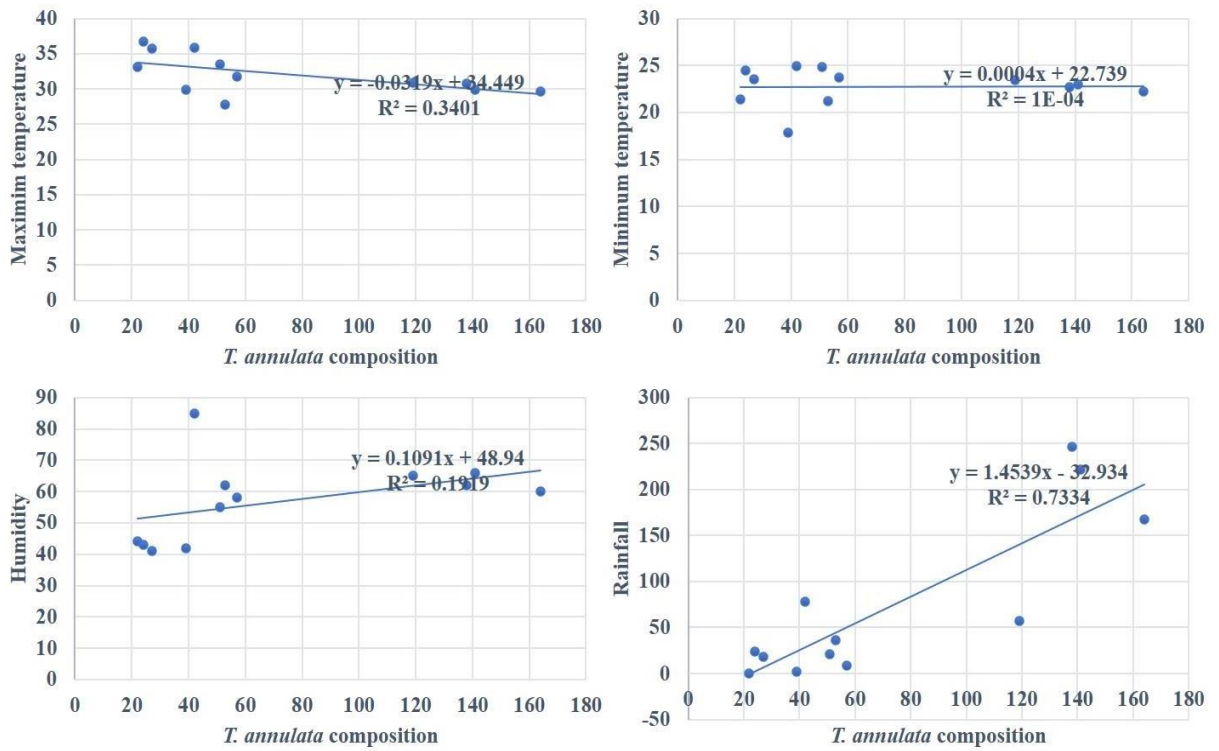


Figure - 42

Correlation coefficient between *T. annulata* and meteorological parameters

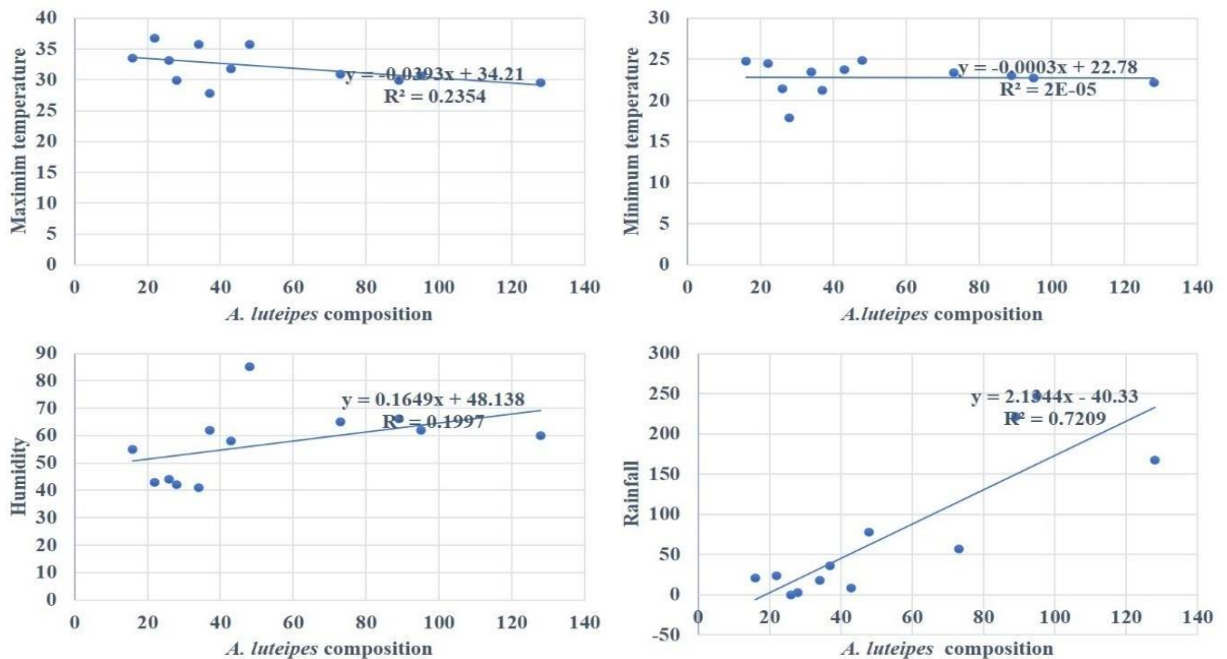


Figure - 43

Correlation coefficient between *A. luteipes* and meteorological parameters

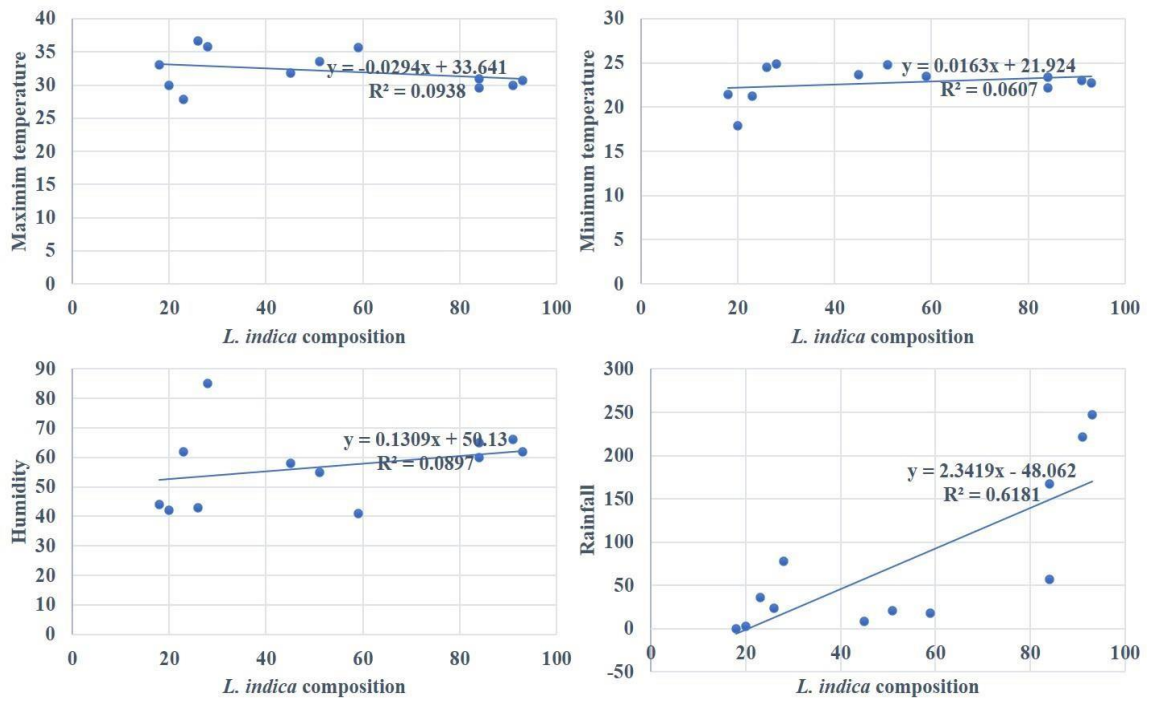


Figure - 44

Correlation coefficient between *L. indica* and meteorological parameters

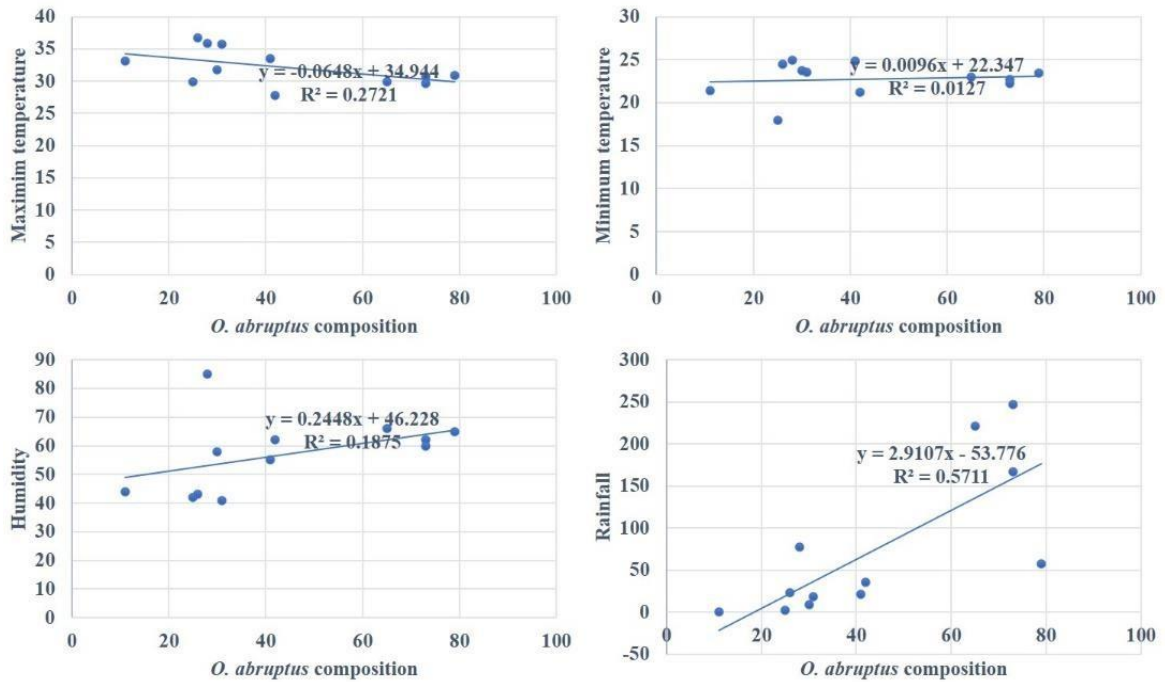


Figure - 45

Correlation coefficient between *O. abruptus* and meteorological parameters

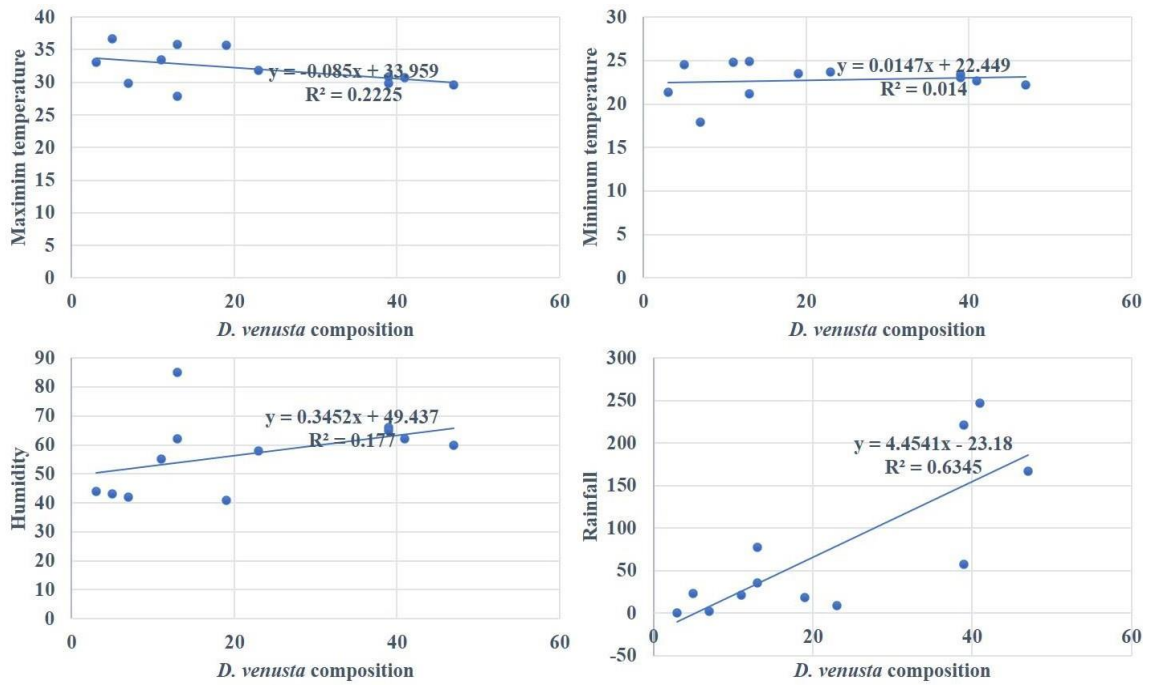


Figure - 46

Correlation coefficient between *D. venusta* and meteorological parameters

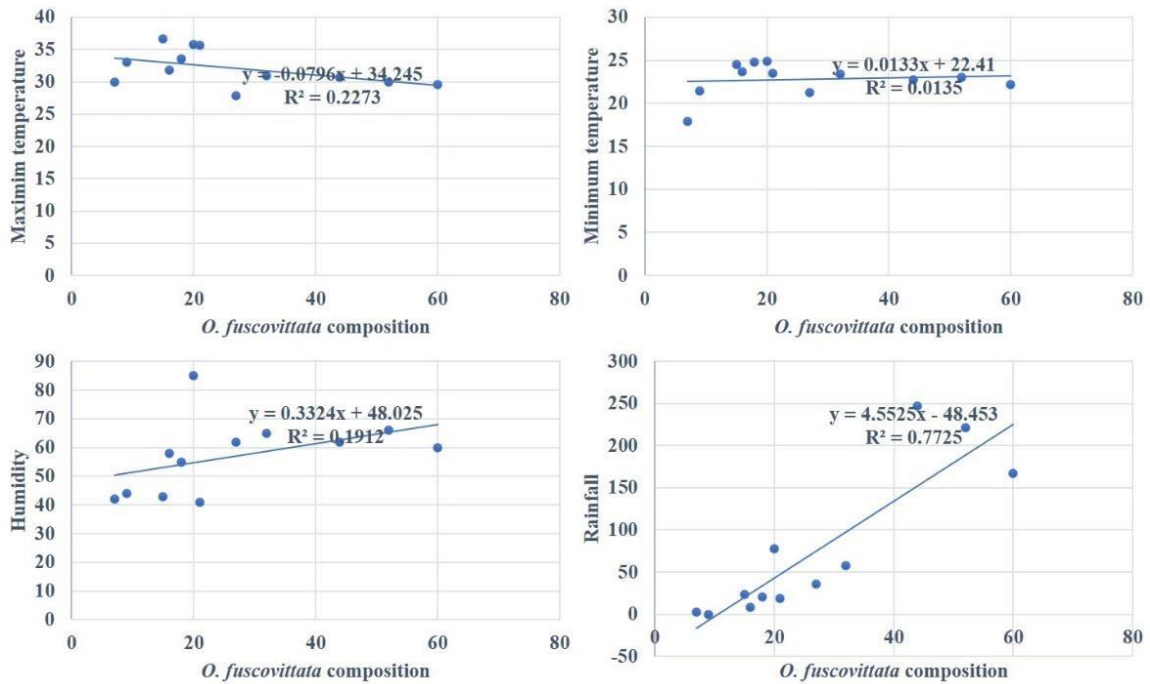


Figure - 47

Correlation coefficient between *O. fuscovittata* and meteorological parameters

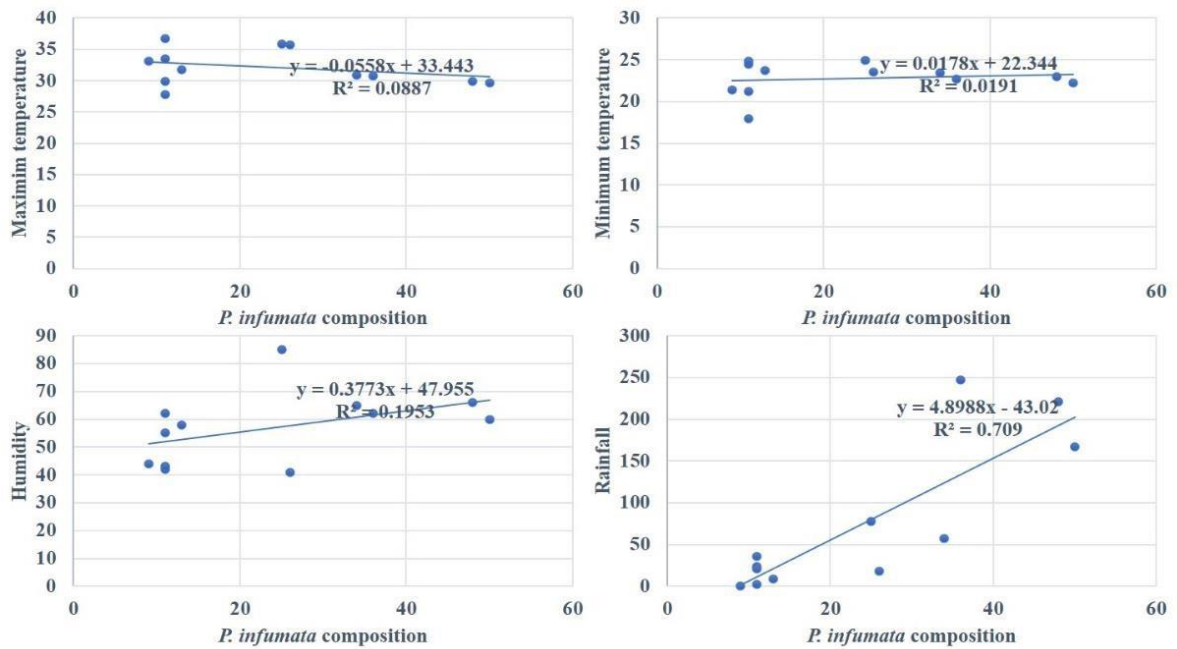


Figure - 48

Correlation coefficient between *P. infumata* and meteorological parameters

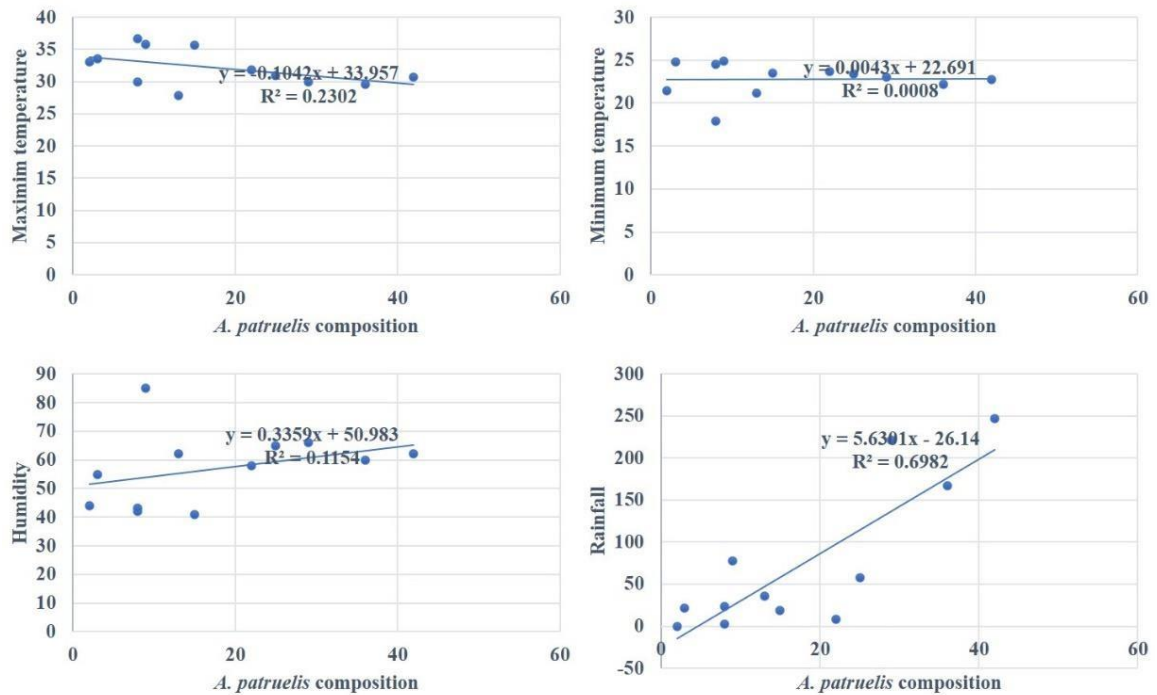


Figure - 49

Correlation coefficient between *A. patruelis* and meteorological parameters

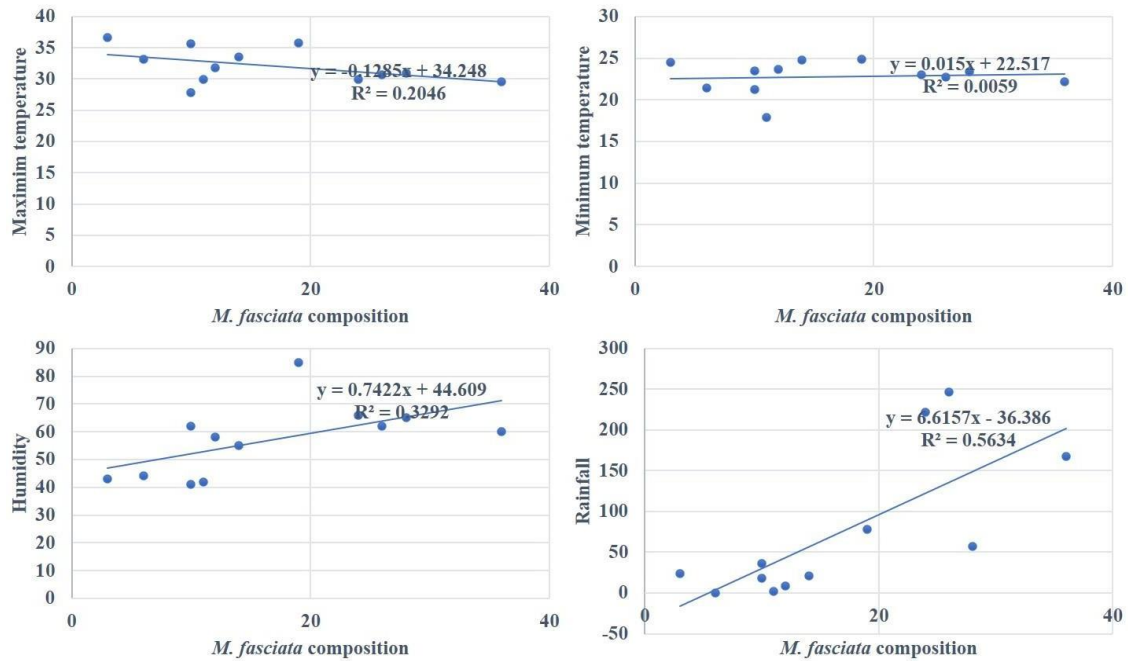


Figure - 50

Correlation coefficient between *M. fasciata* and meteorological parameters

Discussion

The evaluation and comparison of acridids populations were studied in the same way in all regions and seasons of the study area. Acridids are indeed recognized as abundant in open environments, which may explain the highest composition in this work. The population of acridids greatly varied among all the sites as well as all the seasons of the study area. The differences in the composition of acridids may be due to the changes in surrounding conditions and anthropogenic activities around the sites.

The observed a reduction in the abundance of acridids at site II and site IV progressively closer to the sources of the industrial pollution. The separation of the composition of acridids between sites and seasons indicated an effect of geographical variation and an impact of meteorological parameters. A scatter plot generated from a principal component analysis (PCA) of acridids composition showed a clear grouping of the study sites and seasons, segregation supported by cluster analysis. The highest similarity was recorded between site I and site III, may be attributed to the fact that the two sites were characterized by similar geography characteristics and relatively close elevation and also these two regions were located at hill regions. In fact, ecosystem changes strongly affect

behavior, especially of poikilotherms such as grasshoppers that feed on plant materials (Bronwyn, 2013). The similarity between monsoon and pre-monsoon season may be attributed to the fact that the two seasons were characterized by similar climatic conditions.

Among the nine species of acridids, *T. annulata* was found to be the dominant species and *M. fasciata* was recorded least number. According to Bhandari *et al.* (1999), any species in a community plays a specific role and there is a definite quantitative relationship between abundant and rare species. The structure, biology and ecology of the acridids communities are logically expected to be different in the five different environmental sites of the study area.

The relationship between grasshopper population dynamics and the biotic and abiotic factors is so complex that a holistic understanding of this relationship is still lacking. Grasshopper distribution depends upon abiotic factors like temperature, rainfall and relative humidity, as well as biotic factors such as availability of food, mates and the density of predators and parasites, influence the biology of grasshoppers, which in turn affects the overall population (Karpakakunjaram *et al.*, 2002).

In this study, the monsoon season supported the highest abundance of grasshoppers. This is because dark green vegetation increases during the rainy season, which encourages the rapid growth of acridids population. However, during the post monsoon (January to march) eggs undergo diapauses due to unsuitable conditions, as a result very small number of the first instar is hatched out. When suitable conditions occur (especially during summer), first instars emerge and the population gradually increases. During the monsoon season, it reaches a peak when the study area is enriched with vegetation. During post monsoon, temperature and rainfall were recorded low and drought was observed high. It is true that temperature difference affects the life cycle of poikilothermic organisms like grasshopper.

Similar observations have been made in previous reports (Andersen *et al.*, 2001; Nath *et al.*, 2010). Frequently during the rainy season, the sky is cloudy throughout the day and weather is moist, causing a lower temperature. These conditions are suitable for mating, breeding and hatching of acridids. During early showers of rain, egg hatches and nymph emerge and start feeding. Therefore, this study assumes that the behavior of grasshoppers in response to environmental disturbance is influenced by climate change.

Riegert (1972) suggested that the correlation between climatic conditions and population changes is often weak and non-existent. However, Gage and Mukerji (1977) observed that warm weather favors growth, survival and reproduction. Favorable effect of rainfall was noted by Reddy and Alfred (1977), who reported a highly positive correlation between the total monthly rainfall and the abundance of different groups of chewing and mining insects in Asian forest ecosystems. These results contrast with those of Capinera (1987) reported a positive correlation between grasshopper abundance and hot dry weather in temperate latitudes at high elevations and with seasonal rainfall in tropical and arid regions. Studies by Ali (1982) observed the rate of hatching and development of grasshopper depend on temperatures and humidity. As was discussed by Jonas *et al.* (2015) lagged effects of temperature and precipitation most likely act on population growth rates by altering host plant nutritional quality available to the parental generation of grasshoppers.

Weather has been historically considered a major driver of insect population dynamics, including grasshopper (Andrewartha and Birch, 1954; Dempster, 1963). Moreover, in this observation, the range of population dynamics differed significantly from one species to another species. In this study, the correlation coefficient tests revealed significant effects of abiotic factors on the acridids population dynamics in the study area. All the species examined in this study showed a negative relationship with maximum temperature, minimum temperature and humidity; a positive relationship with rainfall. Overall, weather variables contributed significantly to patterns of variation in densities of acridids. This study concludes that the availability of food is a significant quality threshold determines the final densities of populations and the amount of food available is determined by weather conditions during the growing season.

The study area, Coimbatore with a typical subtropical climate, is an ideal region for the successful survival of *T. annulata*, *L. indica*, *A. patruelis*, *O. abruptus*, *P. infumata*, *A. luteipes*, *M. fasciata*, *O. fuscovittata* and *D. venusta*. These nine species appeared to have greater ecological plasticity as they can reproduce and increase their population in different ecological sites and different seasons of the study area.

---

**Phase - IV**
**4.4 Geometric Morphometrics Analysis**

Body size is one of the most important traits of organisms and allows predictions of an individual's morphology, physiology, behavior and life history. Morphometrics analysis of acridids is an essential criterion for taxonomical studies. Therefore, the present investigation is an attempt to study the morphology of acridids in the study area. In order to perform the morphometric analyses, commonly available nine species were selected randomly from the populations of Orthopterans. In order to discriminate taxa at the interspecific and intraspecific level, only male population of acridids were calculated to avoid the effect of sexual dimorphism.

**Morphometric parameters of acridid species**

A total of 180 individuals of acridids from nine species, *T. annulata* (20), *A. luteipes* (20), *L. indica* (20), *O. abruptus* (20), *D. venusta* (20), *O. fuscovittata* (20), *P. infumata* (20), *A. patruelis* (20) and *M. fasciata* (20) were selected for morphometric analysis. The minimum and maximum body length, antenna length, head length, pronotum length, forewing length and hind femur length of *T. annulata* varied from 14.01 to 18.59, 5.55 to 7.75, 1.7 to 3.49, 2.23 to 3.99, 10.34 to 12.95 and 6.96 to 8.94 respectively, *A. luteipes* ranged from 12.39 to 18.17, 4.5 to 8.01, 1.78 to 2.7, 2.06 to 3.19, 8.67 to 12.01 and 6.11 to 8.96 respectively, *L. indica* differed from 12.24 to 17.02, 4.02 to 6.22, 0.75 to 2.24, 0.97 to 2.5, 7.32 to 11.82 and 5.1 to 7.25 respectively, *O. abruptus* changed from 13.83 to 16.89, 4.11 to 7.46, 1.67 to 3, 2.13 to 3.53, 9.34 to 12.79 and 4.05 to 8.32 respectively, *D. venusta* fluctuated from 16.53 to 18.36, 7.87 to 8.75, 2.25 to 3.25, 2.91 to 3.96, 15.52 to 17 and 10.74 to 11.66 respectively, *O. fuscovittata* varied from 14.91 to 20.15, 5.33 to 8.84, 2.22 to 3.67, 2.74 to 4.18, 14.36 to 17.12 and 9.32 to 13.43 respectively, *P. infumata* ranged from 20.1 to 24.65, 7.39 to 9.11, 2.72 to 4.4, 3.2 to 4.97, 17.55 to 20.97 and 12.01 to 16.05 respectively, *A. patruelis* differed from 14.21 to 18.46, 5.39 to 7.67, 2.13 to 3.4, 2.53 to 3.93, 12.99 to 17.01 and 9 to 11.21 respectively and *M. fasciata* fluctuated from 16.5 to 18.29, 7.43 to 8.91, 2.46 to 2.98, 3.06 to 3.63, 16.48 to 17.33 and 10.38 to 11.79 respectively. The analysed parameters length was higher in *P. infumata* and lower in *L. indica* compared than other acridids (Table - 32).

### Mean length of different morphological parameters among acridids

The value of mean  $\pm$  SD in length of body, antenna, head, pronotum, forewing and hind femur of nine acridid species were presented in table - 33. The minimum mean  $\pm$  SD values of body length ( $14.46 \pm 1.44$ ), antenna length ( $5.16 \pm 0.7$ ), head length ( $1.46 \pm 0.48$ ), pronotum length ( $1.74 \pm 0.51$ ), fore wing length ( $9.53 \pm 1.38$ ) and hind femur length ( $6.01 \pm 0.63$ ) were observed in *L. indica*. Maximum mean  $\pm$  SD values of body length ( $22.32 \pm 1.32$ ), antenna length ( $8.4 \pm 0.49$ ), head length ( $3.78 \pm 0.42$ ), pronotum length ( $4.26 \pm 0.44$ ), fore wing length ( $19.75 \pm 0.99$ ) and hind femur length ( $14.29 \pm 1.51$ ) were detected in *P. infumata*. The mean data of analysed parameters were also subjected to One way Analysis of Variance (ANOVA). Studied parameters were statistically different from each other.

### Percentages of variation among acridids

Variation of six morphometrics parameters in each individual of acridids were shown in table - 34. Among the nine species, mean body length (3.25%), antenna length (1.54%), head length (0.30%) and pronotum length (0.29%) variances were observed high in *O. fuscovittata* while fore wing length variance was noted maximum in *L. indica* (1.90%) and hind femur length (2.30%) were analysed higher in *P. infumata*. Mean body length (0.27%), antenna length (0.06%) and hind femur length (0.05%) variances were detected lesser in *D. venusta* whereas head length (0.02%), pronotum length (0.02%) and fore wing length (0.06%) variances was noticed minimum in *M. fasciata*.

Among the six parameters, body length showed highest percentage of variation in *T. annulata* (1.43%), *A. luteipes* (2.99%), *L. indica* (2.08%), *D. venusta* (0.27%), *O. fuscovittata* (3.25%) and *A. patruelis* (1.81%); antenna length showed maximum variation in *M. fasciata* (0.33%) while hind femur length showed highest variation in *O. abruptus* (1.79%) and *P. infumata* (2.30%). Head length and pronotum length showed less percentages of variation in all the studied acridids (Table - 34).

Table - 32

## Different morphometric parameters of acridids

<b>1. <i>T. annulata</i></b>						
<b>Specimen</b>	<b>BL</b>	<b>AL</b>	<b>HL</b>	<b>PL</b>	<b>FWL</b>	<b>HFL</b>
<i>Ta 1</i>	17.45	6.89	2.68	3.24	12.22	8.11
<i>Ta 2</i>	18.01	7.11	3.22	3.72	12.53	8.28
<i>Ta 3</i>	16.17	6.07	2.51	2.98	11.69	7.89
<i>Ta 4</i>	15.67	6.01	2.21	2.75	11.15	7.14
<i>Ta 5</i>	18.42	7.66	3.43	3.99	12.86	8.89
<i>Ta 6</i>	15.34	5.89	1.84	2.42	11.01	7.23
<i>Ta 7</i>	16.23	6.17	2.54	3	11.86	7.56
<i>Ta 8</i>	15.78	6.11	2.34	2.86	11.22	7.22
<i>Ta 9</i>	14.01	5.55	1.7	2.23	10.34	6.96
<i>Ta 10</i>	17.22	6.68	2.56	3.13	12.09	8.04
<i>Ta 11</i>	18.59	7.75	3.49	3.84	12.95	8.94
<i>Ta 12</i>	17.43	6.83	2.6	3.21	12.21	8.08
<i>Ta 13</i>	15.97	6.22	2.32	2.99	11.29	7.28
<i>Ta 14</i>	16.78	6.3	2.58	3.12	12.06	7.61
<i>Ta 15</i>	16.17	6.06	2.49	2.98	11.16	7.15
<i>Ta 16</i>	18.41	7.66	3.32	3.93	12.89	8.92
<i>Ta 17</i>	16.11	5.98	2.36	2.95	11.15	7.82
<i>Ta 18</i>	16.91	6.39	2.59	3.17	12.12	7.74
<i>Ta 19</i>	17.49	6.89	2.7	3.27	12.24	8.1
<i>Ta 20</i>	17.96	7.03	2.79	3.34	12.72	8.21
<b>2. <i>A. luteipes</i></b>						
<b>Specimen</b>	<b>BL</b>	<b>AL</b>	<b>HL</b>	<b>PL</b>	<b>FWL</b>	<b>HFL</b>
<i>Al 1</i>	17.11	7.11	2.67	2.93	11.53	8.21
<i>Al 2</i>	15.13	6	2.21	2.51	10.45	7.43
<i>Al 3</i>	12.39	4.5	1.78	2.06	8.67	6.11
<i>Al 4</i>	14.41	5.14	2.24	2.41	10.1	6.23
<i>Al 5</i>	13.72	4.92	2.16	2.31	9.98	7.24
<i>Al 6</i>	16.78	6.92	2.39	2.66	11.12	8.01
<i>Al 7</i>	13.28	5.11	2.18	2.37	10.21	6.78
<i>Al 8</i>	15.61	6.89	2.25	2.59	10.98	7.34
<i>Al 9</i>	14.75	5.89	2.24	2.44	10.89	6.19
<i>Al 10</i>	15.68	6.65	2.32	2.58	10.96	7.22
<i>Al 11</i>	15.69	6.83	2.25	2.53	10.99	7.38
<i>Al 12</i>	17.98	7.59	2.69	2.88	11.76	8.96
<i>Al 13</i>	18.17	8.01	2.29	3.19	12.01	8.86
<i>Al 14</i>	12.61	4.79	1.87	2.08	8.73	6.24
<i>Al 15</i>	13.54	5.01	2.12	2.29	9.68	6.81
<i>Al 16</i>	15.57	6.09	2.21	2.51	10.86	7.23
<i>Al 17</i>	15.43	6.01	2.22	2.44	10.76	7.18
<i>Al 18</i>	16.31	6.98	2.34	2.61	11.02	7.95
<i>Al 19</i>	13.42	4.91	2.1	2.29	10.34	6.86
<i>Al 20</i>	17.44	7.54	2.7	2.91	11.62	8.34

<b>3. <i>L. indica</i></b>						
<b>Specimen</b>	<b>BL</b>	<b>AL</b>	<b>HL</b>	<b>PL</b>	<b>FWL</b>	<b>HFL</b>
<i>Li 1</i>	14.69	5.11	1.25	1.53	9.99	6.08
<i>Li 2</i>	15.34	5.67	1.81	2.11	11.17	6.23
<i>Li 3</i>	16.12	6	2	2.39	11.01	6.88
<i>Li 4</i>	12.61	4.22	0.98	1.2	7.73	5.23
<i>Li 5</i>	13.54	4.85	1.07	1.32	8.68	5.71
<i>Li 6</i>	14.57	5.08	1.22	1.51	9.86	5.99
<i>Li 7</i>	15.43	5.85	1.87	2.14	10.11	6.28
<i>Li 8</i>	16.31	6.18	2.12	2.41	11.14	7.04
<i>Li 9</i>	13.42	4.8	2.1	2.39	8.51	5.62
<i>Li 10</i>	17.02	6.22	2.24	2.5	11.82	7.25
<i>Li 11</i>	15.29	5.41	1.74	1.98	10.11	6.18
<i>Li 12</i>	14.34	5	1.15	1.42	9.62	5.92
<i>Li 13</i>	12.34	4.11	0.87	1.14	7.44	5.14
<i>Li 14</i>	16.04	6	1.94	2.28	10.93	6.84
<i>Li 15</i>	15.24	5.61	1.71	2	10.09	6.17
<i>Li 16</i>	15.09	5.38	1.45	1.76	9.86	6.11
<i>Li 17</i>	12.29	4.09	0.76	0.97	7.32	5.11
<i>Li 18</i>	13.38	4.68	1.02	1.32	8.51	5.59
<i>Li 19</i>	12.24	4.02	0.75	1.02	7.34	5.1
<i>Li 20</i>	13.98	5.01	1.27	1.53	9.36	5.81
<b>4. <i>O. abruptus</i></b>						
<b>Specimen</b>	<b>BL</b>	<b>AL</b>	<b>HL</b>	<b>PL</b>	<b>FWL</b>	<b>HFL</b>
<i>Oa 1</i>	16.45	7.17	2.91	3.4	12.7	8.2
<i>Oa 2</i>	15.01	5.6	2.22	2.75	12.4	6.98
<i>Oa 3</i>	16.2	7	2.8	3.3	12.5	8
<i>Oa 4</i>	15.5	6.1	2.41	2.85	11.89	7.48
<i>Oa 5</i>	15.71	6.56	2.49	2.92	11.97	7.52
<i>Oa 6</i>	14.82	5.3	2.04	2.54	11.1	5.2
<i>Oa 7</i>	15.92	6.66	2.53	3.05	11.99	7.56
<i>Oa 8</i>	13.83	4.11	1.78	2.23	9.34	4.05
<i>Oa 9</i>	14.44	5.23	1.98	2.45	10.89	7.43
<i>Oa 10</i>	14.2	5.11	1.67	2.13	10.51	7.22
<i>Oa 11</i>	15.9	6.61	2.51	3.15	11.95	7.51
<i>Oa 12</i>	16.89	7.46	2.99	3.53	11.79	8.3
<i>Oa 13</i>	16.3	7.01	2.93	3.44	11.63	8.14
<i>Oa 14</i>	14.86	5.33	2.11	2.59	11.18	5.31
<i>Oa 15</i>	16.46	7.17	2.93	3.46	12.71	8.24
<i>Oa 16</i>	15.73	6.19	2.41	2.92	11.93	7.47
<i>Oa 17</i>	13.92	4.22	1.91	2.43	9.41	4.12
<i>Oa 18</i>	16.88	7.41	3	3.51	12.79	8.32
<i>Oa 19</i>	15.93	6.64	2.51	3.15	11.96	7.56
<i>Oa 20</i>	16.22	7.1	2.83	3.22	12.51	7.89

<b>5. <i>D. venusta</i></b>						
Specimen	BL	AL	HL	PL	FWL	HFL
<i>Dv 1</i>	17.22	8.21	2.6	3.3	16.07	11.15
<i>Dv 2</i>	18.01	8.59	2.98	3.52	16.69	11.46
<i>Dv 3</i>	18.22	8.68	3.1	3.65	16.85	11.53
<i>Dv 4</i>	17.37	8.29	2.75	3.44	16.15	11.26
<i>Dv 5</i>	17.23	8.22	2.6	3.32	16.09	11.15
<i>Dv 6</i>	17.49	8.34	2.89	3.61	16.28	11.32
<i>Dv 7</i>	17.69	8.41	2.93	3.62	16.46	11.38
<i>Dv 8</i>	17.11	8.18	2.54	3.42	16.01	11.11
<i>Dv 9</i>	17.28	8.22	2.68	3.36	16.09	11.2
<i>Dv 10</i>	18.21	8.67	3.14	3.66	16.87	11.54
<i>Dv 11</i>	17.11	8.19	2.56	3.43	16	11.11
<i>Dv 12</i>	17.38	8.28	2.75	3.45	16.15	11.26
<i>Dv 13</i>	16.79	8.02	2.35	3.08	15.61	10.95
<i>Dv 14</i>	16.55	7.87	2.27	2.92	15.52	10.74
<i>Dv 15</i>	16.53	7.87	2.25	2.91	15.52	10.74
<i>Dv 16</i>	17.36	8.28	2.75	3.44	16.13	11.22
<i>Dv 17</i>	18.03	8.59	2.98	3.53	16.64	11.43
<i>Dv 18</i>	17.13	8.15	2.52	3.41	16	11.13
<i>Dv 19</i>	17.28	8.21	2.64	3.35	16.09	11.18
<i>Dv 20</i>	18.36	8.75	3.25	3.96	17	11.66
<b>6. <i>O. fuscovittata</i></b>						
Specimen	BL	AL	HL	PL	FWL	HFL
<i>Of 1</i>	17.83	7.3	2.29	2.75	15.91	10.8
<i>Of 2</i>	20.15	8.84	3.67	4.18	17.12	13.43
<i>Of 3</i>	18.91	8.01	3.51	3.95	16.81	12.43
<i>Of 4</i>	17.89	7.23	3.25	3.74	15.99	12.18
<i>Of 5</i>	18.99	8.1	3.59	4.09	16.89	12.45
<i>Of 6</i>	18.79	8.01	3.29	3.78	16.93	12.11
<i>Of 7</i>	15.02	5.79	2.67	3.11	14.73	9.69
<i>Of 8</i>	16.74	5.99	2.97	3.51	15.68	10.92
<i>Of 9</i>	15.89	5.92	2.78	3.22	14.94	9.93
<i>Of 10</i>	16.98	6.39	2.22	2.74	15.59	10.18
<i>Of 11</i>	17.92	7.34	2.34	2.85	15.95	10.95
<i>Of 12</i>	14.91	5.33	2.23	2.79	14.45	9.32
<i>Of 13</i>	18.88	8.11	3.57	4.03	16.78	12.11
<i>Of 14</i>	18.89	8.13	3.53	4.06	16.81	13.09
<i>Of 15</i>	18.45	8.03	3.23	3.75	16.69	12
<i>Of 16</i>	19.78	8.76	3.54	4.03	17.03	13.22
<i>Of 17</i>	15.23	5.83	2.69	3.14	14.78	9.86
<i>Of 18</i>	14.93	5.33	2.31	2.88	14.36	9.39
<i>Of 19</i>	20.11	8.83	3.64	4.13	17.06	13.38
<i>Of 20</i>	19.85	8.81	3.56	4.07	17.07	13.23

<b>7. <i>P. infumata</i></b>						
<b>Specimen</b>	<b>BL</b>	<b>AL</b>	<b>HL</b>	<b>PL</b>	<b>FWL</b>	<b>HFL</b>
<i>Pi 1</i>	24.65	9.11	4.4	4.97	20.97	16.05
<i>Pi 2</i>	22.08	8.38	3.82	4.32	19.98	14.29
<i>Pi 3</i>	20.89	7.89	3.5	3.92	18.55	12.05
<i>Pi 4</i>	21.9	8.13	3.67	4.12	19.34	13.15
<i>Pi 5</i>	22	8.37	3.71	4.29	19.95	14.23
<i>Pi 6</i>	22.1	8.42	3.86	4.33	19.98	14.32
<i>Pi 7</i>	21	8.03	3.61	4.1	19.26	13.14
<i>Pi 8</i>	20.1	7.41	2.86	3.2	17.55	12.05
<i>Pi 9</i>	23.14	8.76	3.93	4.43	20.46	15.89
<i>Pi 10</i>	24.32	9	4.39	4.83	20.86	16.01
<i>Pi 11</i>	20.85	7.84	3.48	3.9	18.52	12.01
<i>Pi 12</i>	22.1	8.43	3.86	4.36	19.98	13.15
<i>Pi 13</i>	23.22	8.8	4.1	4.5	20.52	15.93
<i>Pi 14</i>	23.1	8.68	3.94	4.41	20.45	15.85
<i>Pi 15</i>	24.1	8.95	4.26	4.78	20.4	15.98
<i>Pi 16</i>	23.89	8.89	3.81	4.31	20.76	15.98
<i>Pi 17</i>	20.18	7.39	2.72	3.29	17.61	12.11
<i>Pi 18</i>	22.1	8.41	3.86	4.31	19.95	14.33
<i>Pi 19</i>	22.78	8.74	4	4.56	20.01	15.01
<i>Pi 20</i>	22.08	8.4	3.83	4.35	19.98	14.3
<b>8. <i>A. patruelis</i></b>						
<b>Specimen</b>	<b>BL</b>	<b>AL</b>	<b>HL</b>	<b>PL</b>	<b>FWL</b>	<b>HFL</b>
<i>Ap 1</i>	14.63	5.84	2.21	2.75	15.02	9.13
<i>Ap 2</i>	17.22	7.21	2.97	3.46	16.11	10.93
<i>Ap 3</i>	14.67	5.84	2.22	2.78	12.99	9.12
<i>Ap 4</i>	18.08	7.56	3.23	3.72	16.76	11.03
<i>Ap 5</i>	14.21	5.39	2.13	2.53	13	9
<i>Ap 6</i>	16.87	7.02	2.54	3.13	15.66	10.34
<i>Ap 7</i>	17.98	7.34	3.01	3.58	16.67	10.83
<i>Ap 8</i>	16.34	6.78	2.33	2.81	15.45	10.16
<i>Ap 9</i>	18.23	7.59	3.38	3.84	16.83	11.21
<i>Ap 10</i>	18.24	7.59	3.38	3.84	16.85	11.21
<i>Ap 11</i>	17.24	7.21	2.98	3.46	16.12	10.93
<i>Ap 12</i>	17.24	7.22	2.96	3.22	16.12	10.91
<i>Ap 13</i>	15.29	6.01	2.28	2.79	13.34	9.31
<i>Ap 14</i>	17.83	7.28	3.01	3.57	16.45	10.57
<i>Ap 15</i>	18.05	7.51	3.2	3.75	16.71	10.98
<i>Ap 16</i>	16.34	6.77	2.33	2.82	15.61	10.8
<i>Ap 17</i>	18.24	7.56	3.35	3.84	16.83	11.2
<i>Ap 18</i>	17.29	7.24	2.97	3.41	16.23	10.98
<i>Ap 19</i>	18.46	7.67	3.4	3.93	17.01	11
<i>Ap 20</i>	17.98	7.34	3.06	3.5	16.65	10.76

<b>9. <i>M. fasciata</i></b>						
Specimen	BL	AL	HL	PL	FWL	HFL
<i>Mf 1</i>	17.43	8.7	2.72	3.41	17.1	11.5
<i>Mf 2</i>	18.22	8.88	2.96	3.6	17.32	11.78
<i>Mf 3</i>	17.41	8.72	2.71	3.41	17.09	11.53
<i>Mf 4</i>	17.56	8.79	2.78	3.45	17.14	11.61
<i>Mf 5</i>	16.87	7.56	2.61	3.22	16.7	10.5
<i>Mf 6</i>	17.06	7.87	2.65	3.28	16.86	10.68
<i>Mf 7</i>	16.85	7.56	2.6	3.2	16.7	10.48
<i>Mf 8</i>	18.29	8.91	2.98	3.62	17.32	11.79
<i>Mf 9</i>	18.02	8.85	2.88	3.48	17.18	11.71
<i>Mf 10</i>	18.24	8.88	2.95	3.63	17.33	11.78
<i>Mf 11</i>	17.09	7.87	2.66	3.29	16.87	10.68
<i>Mf 12</i>	17.41	8.73	2.71	3.42	17.11	11.52
<i>Mf 13</i>	16.82	7.55	2.58	3.19	16.68	10.47
<i>Mf 14</i>	17.11	8.46	2.62	3.25	16.86	11.34
<i>Mf 15</i>	17.16	8.48	2.64	3.26	16.89	11.35
<i>Mf 16</i>	17.85	8.81	2.88	3.5	17.15	11.69
<i>Mf 17</i>	17.12	8.46	2.62	3.26	16.86	11.34
<i>Mf 18</i>	16.85	7.56	2.59	3.21	16.69	10.49
<i>Mf 19</i>	16.81	7.53	2.55	3.2	16.65	10.46
<i>Mf 20</i>	16.5	7.43	2.46	3.06	16.48	10.38

Table - 33

## Comparison of mean±SD length of different morphometric parameters of acridids

Species	BL	AL	HL	PL	FWL	HFL
<i>T. annulata</i>	16.8±1.19 <sup>bcd</sup>	6.56±0.64 <sup>bc</sup>	2.61±0.47 <sup>bc</sup>	3.15±0.45 <sup>bc</sup>	11.88±0.73 <sup>c</sup>	7.85±0.6 <sup>c</sup>
<i>A. luteipes</i>	15.25±1.73 <sup>cd</sup>	6.14±1.07 <sup>bc</sup>	2.26±0.23 <sup>bc</sup>	2.52±0.28 <sup>c</sup>	10.63±0.89 <sup>cd</sup>	7.32±0.84 <sup>cd</sup>
<i>L. indica</i>	14.46±1.44 <sup>d</sup>	5.16±0.7 <sup>c</sup>	1.46±0.48 <sup>d</sup>	1.74±0.51 <sup>d</sup>	9.53±1.38 <sup>d</sup>	6.01±0.63 <sup>d</sup>
<i>O. abruptus</i>	15.55±0.94 <sup>bcd</sup>	6.07±1.02 <sup>bc</sup>	2.41±0.42 <sup>bc</sup>	2.9±0.44 <sup>bc</sup>	11.6±0.99 <sup>c</sup>	7.12±1.34 <sup>cd</sup>
<i>D. venusta</i>	17.41±0.52 <sup>bc</sup>	8.3±0.25 <sup>a</sup>	2.72±0.28 <sup>bc</sup>	3.41±0.24 <sup>b</sup>	16.21±0.42 <sup>b</sup>	11.22±0.24 <sup>b</sup>
<i>O. fuscovittata</i>	17.8±1.8 <sup>b</sup>	7.3±1.24 <sup>ab</sup>	3.04±0.54 <sup>b</sup>	3.54±0.54 <sup>b</sup>	16.07±0.97 <sup>b</sup>	11.53±1.44 <sup>b</sup>
<i>P. infumata</i>	22.32±1.32 <sup>a</sup>	8.4±0.49 <sup>a</sup>	3.78±0.42 <sup>a</sup>	4.26±0.44 <sup>a</sup>	19.75±0.99 <sup>a</sup>	14.29±1.51 <sup>a</sup>
<i>A. patruelis</i>	17.02±1.34 <sup>bc</sup>	6.99±0.68 <sup>ab</sup>	2.84±0.44 <sup>bc</sup>	3.33±0.44 <sup>b</sup>	15.82±1.28 <sup>b</sup>	10.52±0.75 <sup>b</sup>
<i>M. fasciata</i>	17.33±0.53 <sup>bc</sup>	8.28±0.57 <sup>a</sup>	2.7±0.14 <sup>bc</sup>	3.34±0.16 <sup>b</sup>	16.94±0.25 <sup>b</sup>	11.15±0.55 <sup>b</sup>

Note: Mean values within the same row sharing different superscript are significantly different (P< 0.05) (one way ANOVA and subsequently post hoc multiple comparison with DMRT)

Table - 34

## Percentage of variance among acridids

Species	BL	AL	HL	PL	FWL	HFL
<i>T. annulata</i>	1.43%	0.41%	0.22%	0.20%	0.54%	0.36%
<i>A. luteipes</i>	2.99%	1.16%	0.05%	0.08%	0.80%	0.72%
<i>L. indica</i>	2.08%	0.50%	0.23%	0.26%	1.90%	0.40%
<i>O. abruptus</i>	0.89%	1.05%	0.18%	0.19%	0.99%	1.79%
<i>D. venusta</i>	0.27%	0.06%	0.07%	0.06%	0.18%	0.05%
<i>O. fuscovittata</i>	3.25%	1.54%	0.30%	0.29%	0.95%	2.07%
<i>P. infumata</i>	1.75%	0.24%	0.17%	0.19%	0.99%	2.30%
<i>A. patruelis</i>	1.81%	0.46%	0.20%	0.20%	1.65%	0.57%
<i>M. fasciata</i>	0.28%	0.33%	0.02%	0.02%	0.06%	0.30%

Based on the PCA results, percentage of variance and eigen values were explained by six PCs. First two PCA (97.1%) showed highest variance and eigen value; other PCs had progressively less variances and eigen value. PC1 explained 92.85% of the variation in the parameters with eigenvalue of 25.59. PC2 explained 4.25% of the variation in the parameters with eigen value of 1.17 (Fig - 51). Morphometric parameters of *T. annulata*, *A. luteipes*, *L. indica* and *O. abruptus* convex hulls formed left of the scatter plots, *P. infumata*, *D. venusta* and *M. fasciata* formed right of the scatter plot whereas *O. fuscovittata* and *A. patruelis* formed centre of the scatter plots. This result indicates significant variance occurred between and within population of acridid species.

Among the nine species of acridids, fore wing length showed highest variation followed by hind femur length and body length whereas length of head, pronotum and antenna length showed less variance (Fig - 51). To confirm this pattern of grouping, the data were also given as input to box plot. The plot revealed that the pattern of variation recognized in the PCA were evident. The results of box plot also revealed that the mean body length and forewing length bears the largest centroid size (Fig - 52). Morphometric similarity of acridids were depicted in figure -53. The higher similarity was found between *D. venusta* and *M. fasciata* (0.99); *O. abruptus* and *A. luteipes* (0.98).

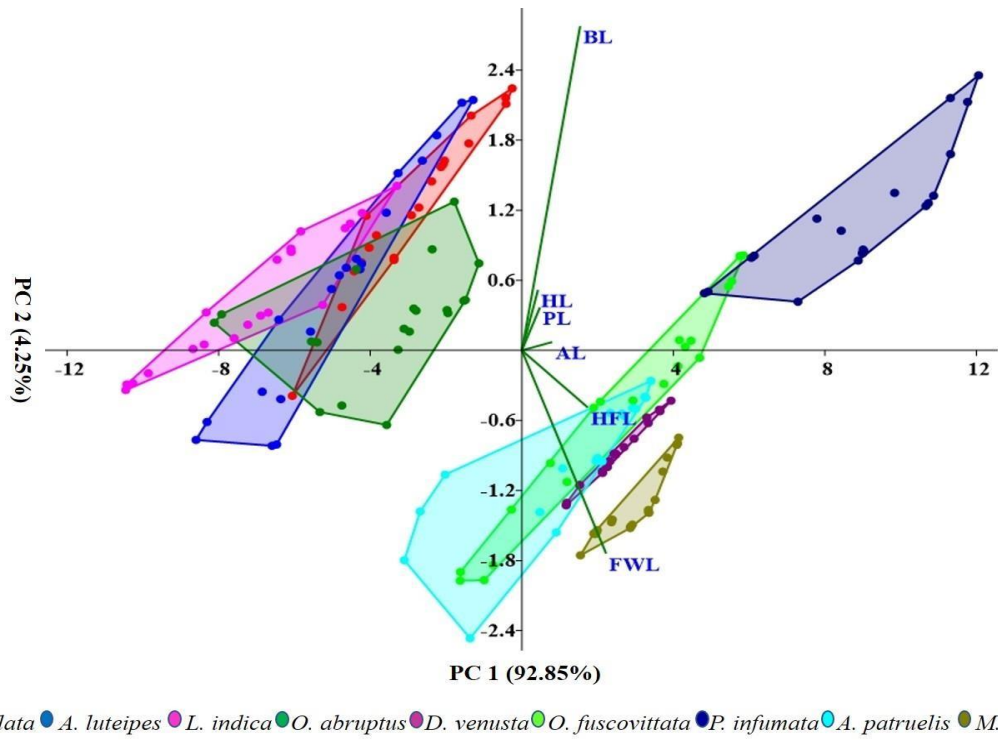


Figure - 51

PCA biplot scatter diagram of various morphological parameters among acridids

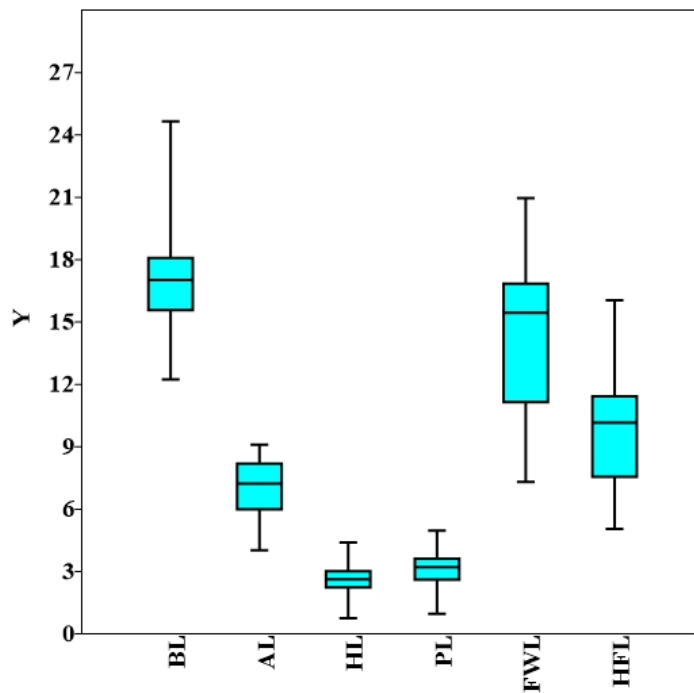


Figure - 52

Box plot showing variances among acridids morphology

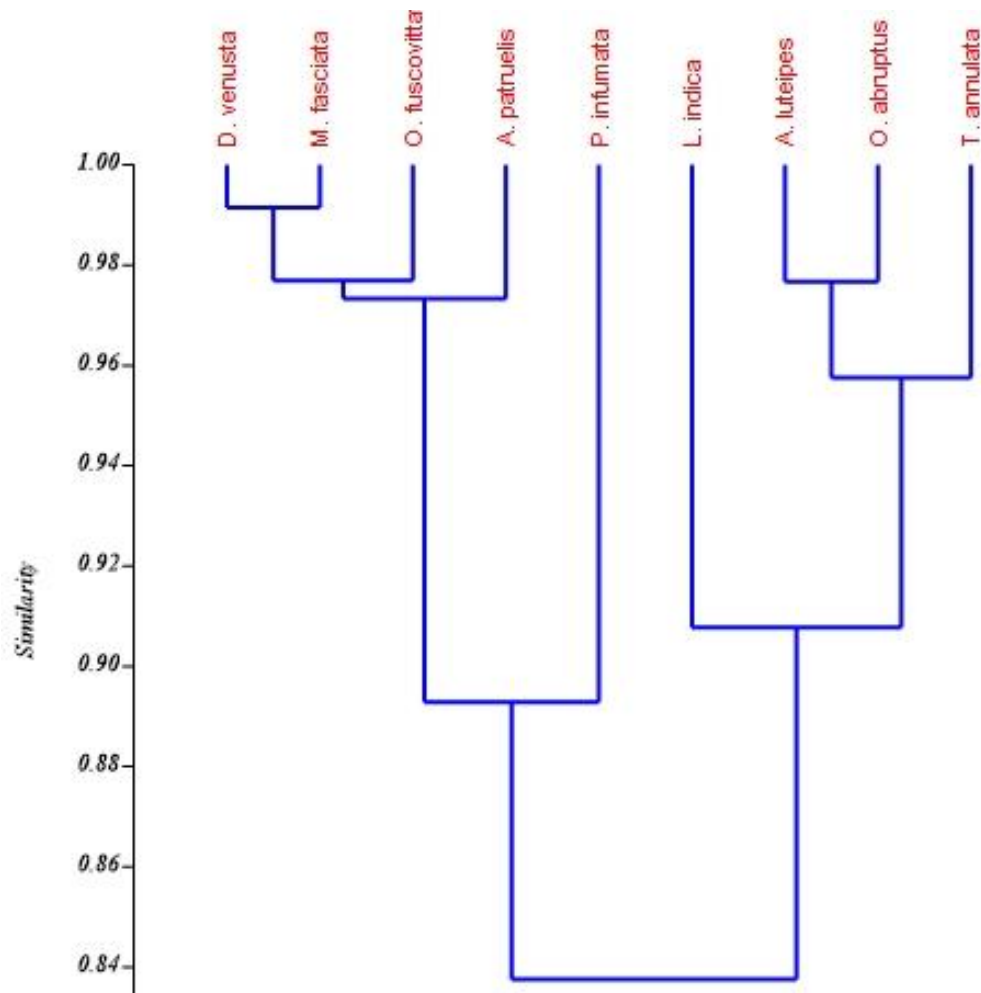


Figure -53

### Morphometric relationship among acridids using cluster analysis

The morphometric parameters similarity matrix among nine acridids were depicted in figure - 54. Body length and fore wing length formed a first cluster and sharing 0.90% similarity in species, antenna length and hind femur length formed a second cluster and sharing 0.84% similarity whereas head length and pronotum length formed a third cluster and sharing 0.91% similarity. Survivorship curve results also revealed that the similarity of morphometric parameters recognized in the cluster analysis were evident (Fig - 55).

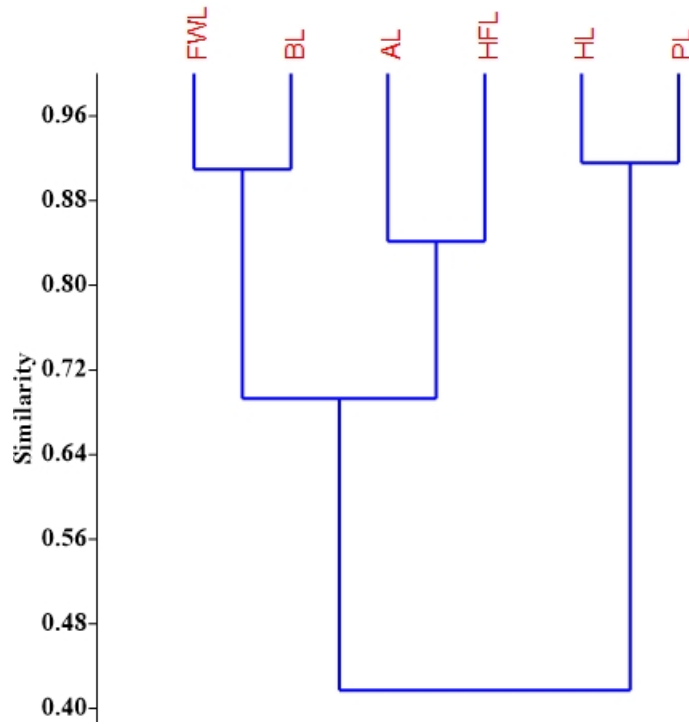


Figure - 54

Similarity of morphometric features among acridids using cluster analysis

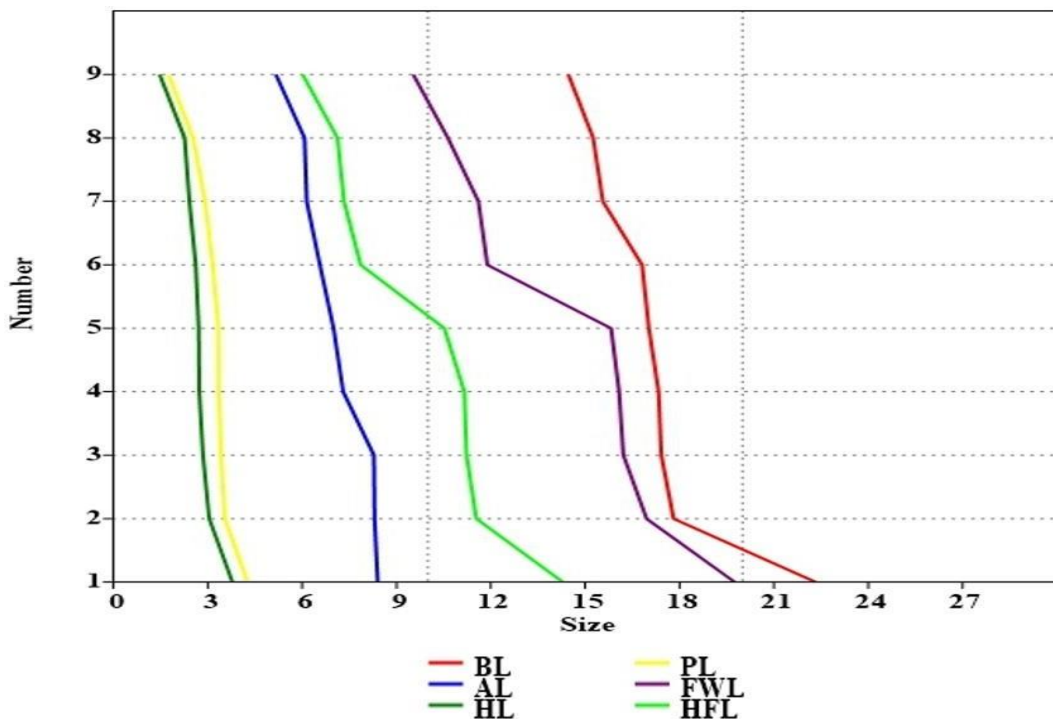


Figure - 55

Survivorship curve showing similarity of morphometric parameters

### Geometric morphometrics

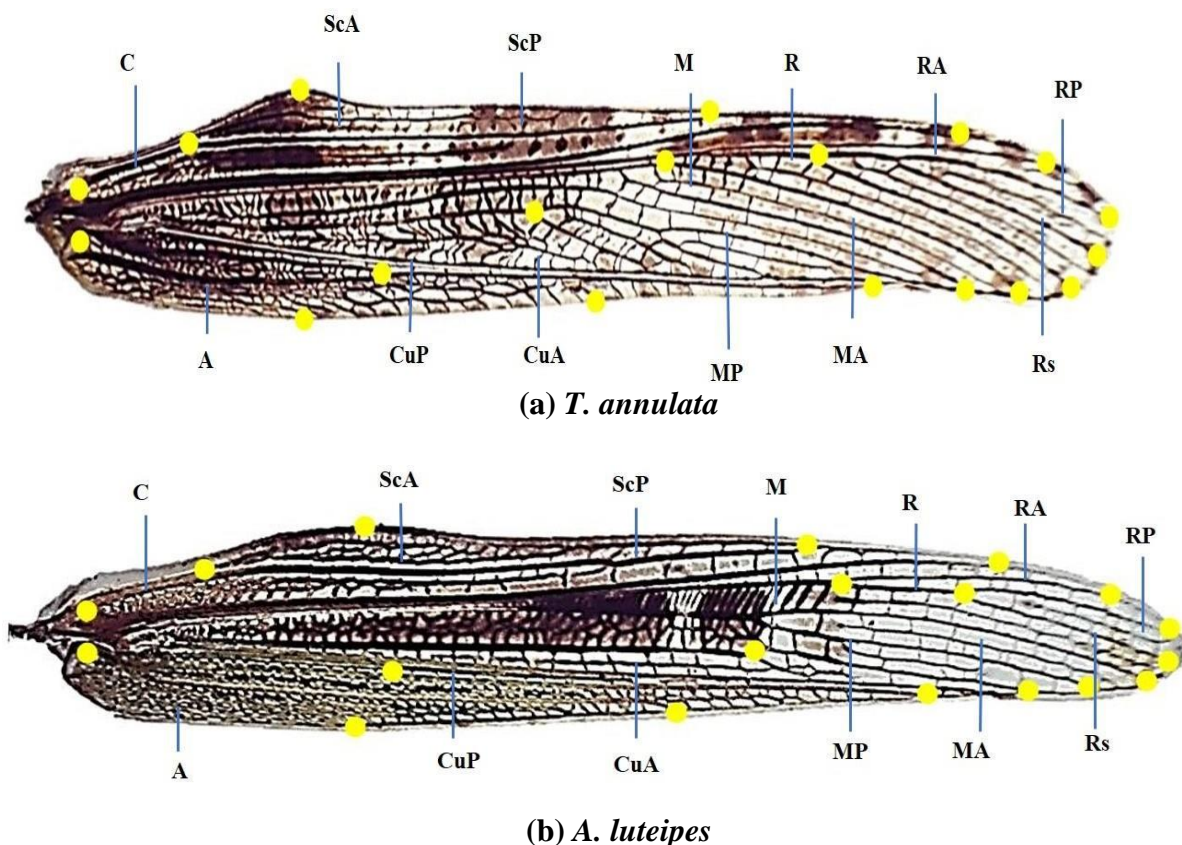
The advancement of using landmark based geometric morphometric techniques will be helpful in identification and acquiring a better understanding of the shape variation of numerous numbers of species. The geometric morphometric study was conducted on 180 individuals (20 individuals from each species) wings of nine *acridids*.

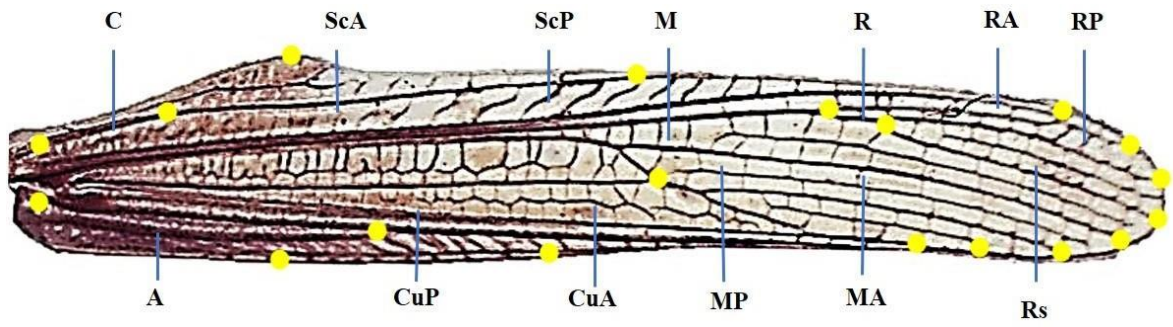
### Wing structure and wing vein nomenclature

In this study, wing veins nomenclature and 19 homologous landmarks were identified in each individual of nine acridids species in order to characterize the shape variation (Plate - X). The landmark locations were selected based on the wing veins intersection, wing margin, cross veins, veins branch point, major veins and termination of the wing veins. These landmark coordinates produce an accurate morphometric description of the wing. The position of each landmark description was depicted in table - 35.

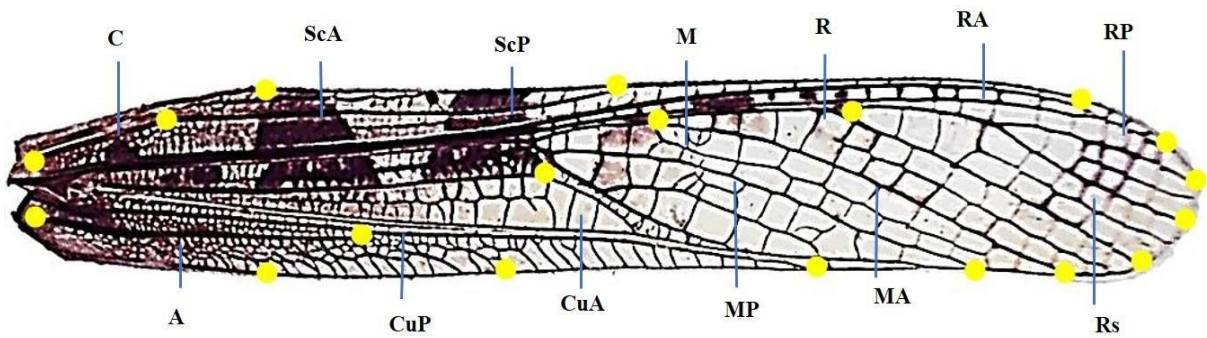
#### Plate - X (a to i)

#### Position of 19 landmarks in the right forewing of acridids

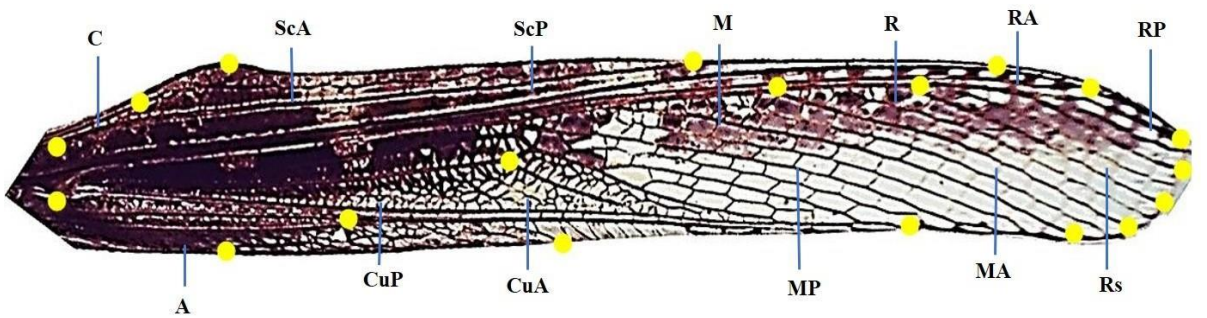




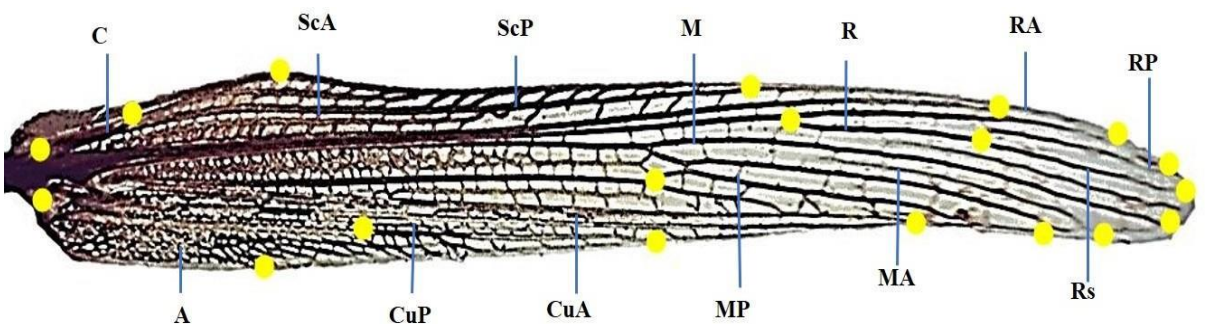
(c) *L. indica*



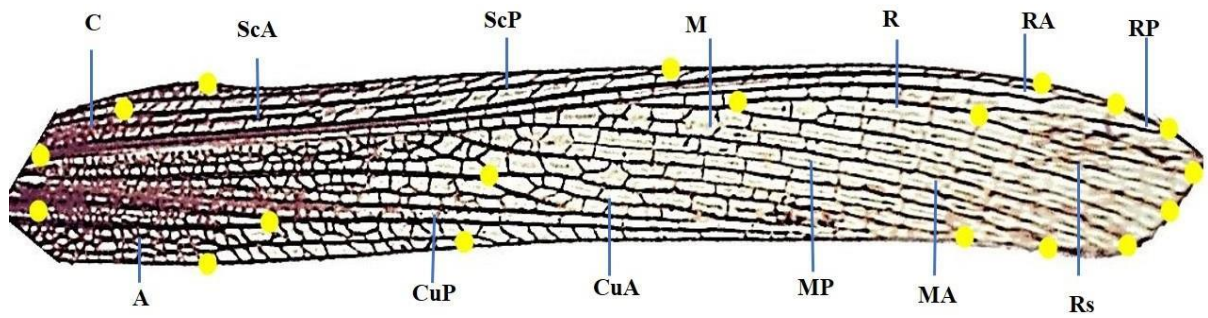
(d) *O. abruptus*



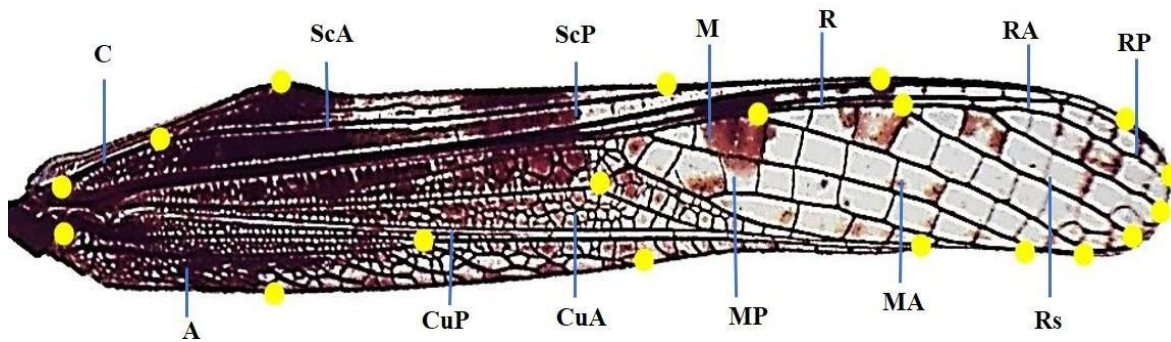
(e) *D. venusta*



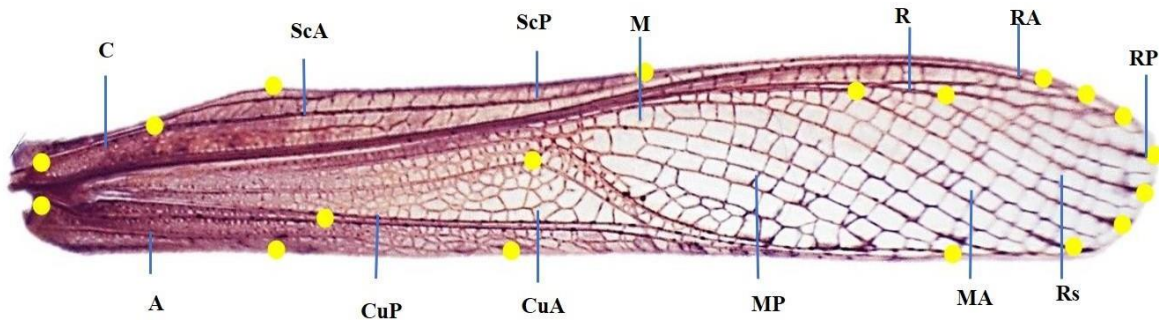
(f) *O. fuscovittata*



(g) *P. infumata*



(h) *A. patruelis*



(i) *M. fasciata*

Note: C: Costa, ScA: Sub costa Anterior, ScP: Sub costa Posterior, M: Median, MA: Median Anterior, MP: Median Posterior, R: Radial, RA: Radial Anterior, RP: Radial Posterior, Rs: Radial sector, CuA: Cubitus Anterior, CuP: Cubitus Posterior, A: Anal vein

**Table - 35**  
**Description of 19 landmarks location in the wing structure of acridid species**

Landmarks	Description
1	Origin of subcostal vein, interaction between the radial and subcostal
2	Base of the precostal area
3	The tip of precostal vertex
4	The point of subcostal anterior margin with leading edge
5	The radius extension on front edge of wing
6-10	Distal edge of wing and interaction of radius branches
11	The point of median anterior with posterior border
12	Cross point of median vein with distal edge
13	The edge of anal area and cubitus anterior with posterior
14	Point of hind edge and vertex vertical line (Width of wing)
15	Insertion points of median with cubitus vein
16	Cross point of anal vein and the vertex vertical line
17	Interaction of cubitus anterior with posterior
18,19	Insertion points of radial sector vein

The wing structure showed that the *P. infumata* population wings bear larger landmark distance while *L. indica* population wings endure smaller landmark distance than other species of acridids. In each population of acridids, maximum distance was observed in landmarks 19- 1(subcostal vein to radial sector vein) and minimum distance was observed in landmarks 7-8 (distal edge of wing) (Table - 36).

Table - 36

## Maximum, minimum and mean landmarks length of acridid species

Species	<i>T. annulata</i>	<i>A. luteipes</i>	<i>L. indica</i>	<i>O. abruptus</i>	<i>D. venusta</i>	<i>O. fuscovittata</i>	<i>P. infumata</i>	<i>A. patruelis</i>	<i>M. fasciata</i>
<b>Minimum landmark length</b>									
<b>L1-2</b>	85.44	72.2	63.57	83.19	90.43	82.57	57.8	78.77	98.48
<b>L2-3</b>	107.45	103.09	66.48	78.85	128.92	81.74	81.6	107.54	98.09
<b>L3-4</b>	286	327.06	81.06	278.22	443.76	328.18	426.04	304.01	379.34
<b>L4-5</b>	172.07	122.33	194	263.49	283.39	181.28	215.33	109.11	214.39
<b>L5-6</b>	69.35	55.66	127.91	56.08	208.48	70.6	58.69	99.36	81.63
<b>L6-7</b>	29.02	33.02	22.83	35.23	76.29	25.61	40.71	42.49	36.72
<b>L7-8</b>	28.84	26.48	15.3	25.18	40.26	17.12	36.4	27.46	32.76
<b>L8-9</b>	37.34	21.63	20.25	38.95	46.84	26.08	32.76	41.59	37.8
<b>L9-10</b>	46.53	38.6	29.12	43.1	66.96	41.01	48.55	40.61	40.25
<b>L10-11</b>	38.83	49	36.01	34.01	102.40	54.33	41.19	41.98	57.22
<b>L11-12</b>	47.68	49.25	33	52.01	98.09	42.01	64	43.19	72.44
<b>L12-13</b>	142.01	162.31	110	162.52	309.13	96	207.06	185.39	194.01
<b>L13-14</b>	201.12	242.25	141.23	183.04	325.57	260.02	272.24	213	188
<b>L14-15</b>	182.63	195.73	129.28	175.14	198.76	171.45	154.81	189.07	200.09
<b>L15-16</b>	242.6	265.01	181.47	247.4	321.42	288	212.24	260.07	217.83
<b>L16-17</b>	132.23	240.93	135.52	148.69	251.47	151.7	194.43	164.34	199.91
<b>L17-18</b>	252.19	171.06	113.51	256.4	362.82	135.71	223.81	235.33	395.13
<b>L18-19</b>	81.01	81.5	44.18	91.2	158.86	106.04	115.43	91	91
<b>L19-1</b>	523.17	618.45	437.12	533.15	719.60	525.86	417	588.58	763.93
<b>Maximum landmark length</b>									
<b>L1-2</b>	130.92	117.39	106.25	140.46	108.41	117.88	109.48	113.65	138.05
<b>L2-3</b>	165.39	165.89	104.06	137.53	161.38	130.5	133.81	149.35	146.01
<b>L3-4</b>	465.47	437.03	135.24	369.35	473	475.15	618.18	384.19	459.85
<b>L4-5</b>	395.83	270.41	290	432.26	454.49	300.01	456.97	411.76	474.01
<b>L5-6</b>	197.94	146.11	190.54	158.45	321.17	134.84	190.39	323.59	266.01
<b>L6-7</b>	81.84	90.34	53.34	77.03	132.8	69.46	92.96	173.28	114.63
<b>L7-8</b>	64.85	67.18	35.23	60.96	54.64	46.84	80.5	86.98	79.51
<b>L8-9</b>	80.02	51.31	57.01	74.24	87.21	95.08	62.29	74	111.02

Species	<i>T. annulata</i>	<i>A. luteipes</i>	<i>L. indica</i>	<i>O. abruptus</i>	<i>D. venusta</i>	<i>O. fuscovittata</i>	<i>P. infumata</i>	<i>A. patruelis</i>	<i>M. fasciata</i>
L9-10	86.28	68.03	61.01	88.09	118.07	108	113.16	89.44	106.12
L10-11	87.02	100.04	75.11	122.04	122	129.03	148.35	98.33	136.01
L11-12	97	106.17	74.01	140.03	123.1	118.04	160.31	125.04	178.07
L12-13	324.5	267	253.79	266.07	359.36	257.12	553.06	353.27	403.21
L13-14	424	361.27	253.57	337.33	366.17	437.16	482.37	348.9	379.64
L14-15	276.8	263.41	168.32	254.47	215.37	233.45	220.33	245.35	260.41
L15-16	389.24	355.74	252.13	355.11	351.21	399.06	347.31	351.09	368.01
L16-17	241.57	322.22	206.05	232.28	609.59	292.03	674.71	274.97	329.31
L17-18	490.86	276.15	268	401.42	430.8	343.05	626.16	384.95	529.44
L18-19	149.86	178.02	133.18	163.11	286.4	212.68	292.21	175.41	196.01
L19-1	865.56	695.78	561.65	771.37	811.16	704.77	934.14	829.4	926.52
<b>Mean landmark length</b>									
L1-2	107.22	99.26	78.67	109.17	90.43	101.56	91.43	96.17	120.42
L2-3	130.72	137.94	82.45	117.93	128.92	102.28	109.3	128.85	125.48
L3-4	386.72	379.07	107.53	317.04	443.76	407.24	511.27	341.89	408.36
L4-5	289.07	188.48	231.5	360.38	283.39	233.98	329.31	247.84	343.58
L5-6	114.82	97.21	157.86	111.84	208.48	103.88	131.21	178.75	169.55
L6-7	53.72	63.92	33.91	52.75	76.29	53.15	67.58	75.34	73.93
L7-8	38.77	38.59	25.16	43.57	40.26	31.26	49.12	47.28	47.48
L8-9	49.44	34.02	30.68	55.14	46.84	54.79	49.84	57.41	56.03
L9-10	62.5	53.44	42.32	71.05	66.96	69.02	79.8	65.17	75.93
L10-11	60.36	70.91	54.44	78.36	102.4	76.09	97.42	68.68	87.76
L11-12	68.93	77.71	53.73	99.62	98.09	73.68	100.64	71.37	113.79
L12-13	238.84	211.88	157.99	213.42	309.13	188.58	316.12	239.29	296.75
L13-14	307.96	298.5	193.09	254.62	325.57	326.08	391.29	284.9	301.76
L14-15	225.08	223.73	147.55	218.41	198.76	194.57	191.53	211.16	233.55
L15-16	306.51	314.07	215.32	297.86	321.42	330.26	269.75	310.05	304.64
L16-17	176.4	273.55	164.98	187.15	251.47	207.65	248.53	210.6	250.83
L17-18	365.83	211.87	173.56	340.51	362.82	272.6	491.58	288.37	439.87
L18-19	110.46	137.59	74.67	131.2	158.86	152.62	218.92	126.15	137.25
L19-1	729.68	656.18	474.62	680.42	719.6	648.53	746.56	674.8	846.29

### **Landmarks distribution and consensus configuration among acridid species**

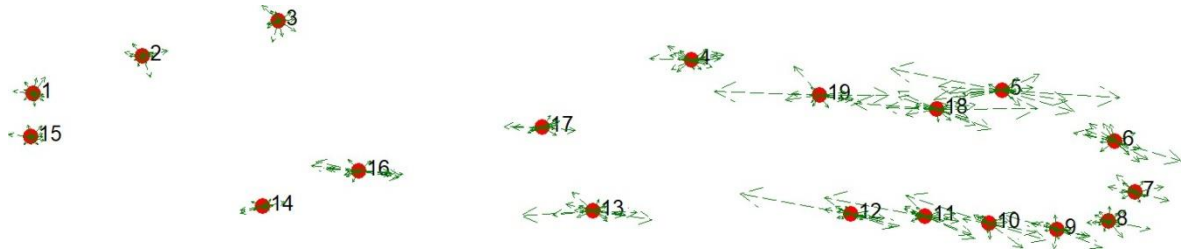
Plots (red) and vectors (green) were represented with number in plate - XI indicates the mean and distribution of the 19 landmarks of each individual wings of nine acridids species from the study area. The values of consensus configuration of the 19 landmarks of each individual of acridids were depicted in table - 37. The vector analysis of the consensus data of the 19 landmarks revealed the mean magnitude of acridids. The position of landmarks 5, 12, 13, 18 and 19 in *T. annulata*, landmarks 4, 5, 13 and 18 in *A. luteipes*, landmarks 4, 12, 13 and 18 in *L. indica*, landmarks 5, 12, 13, 18 and 19 in *O. abruptus*, landmarks 4, 5, 10, 11, 12 and 13 in *D. venusta*, landmarks 4, 5, 13, 17, 18 and 19 in *O. fuscovittata*, landmarks 4, 5, 10, 11, 12 and 13 in *P. infumata*, landmarks 5, 6, 18 and 19 in *A. patruelis* and landmarks 5, 6, 12, 18 and 19 in *M. fasciata* showed more variation to the average wing shape (Plate - XI). These landmark variations were sufficient to detect the shape difference in nine acridids. In the 5<sup>th</sup> position of the wing landmarks had greater variation in all acridid species (Fig - 56).

Among the nine acridids species, variability was observed high in *T. annulata* population while lesser variation was recorded in *A. luteipes* population. The base of the wings showed less variation in each population of acridids species whereas variation was mainly occurred at the middle and distal part of the wings. Mean, distribution and consensus configuration of 19 landmarks distance of each population wings varies within and between the acridids.

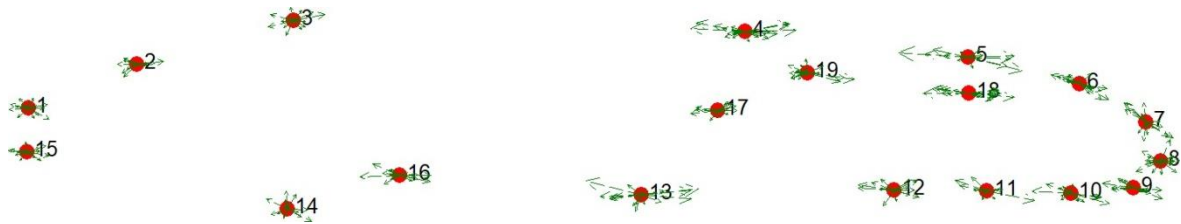
Uniform component estimated by sweeping the partial warps from the projections of the aligned coordinates into the tangent space and using SVD (Singular value decomposition) to extract the non-singular dimensions. Among the 19 landmarks, relative contribution was recorded high in the 8<sup>th</sup> position of wing landmarks in all acridids species. (Fig- 57).

Plate - XI

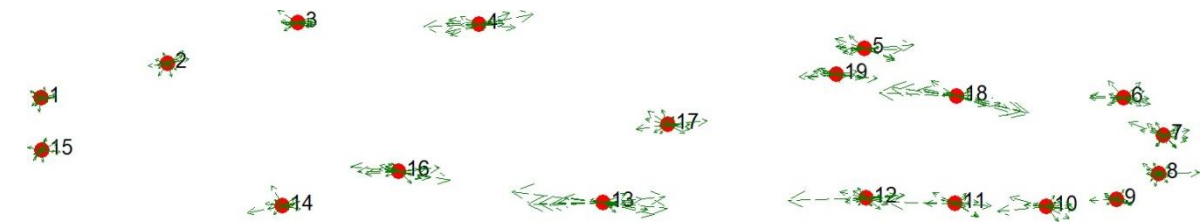
Consensus configuration of 19 landmarks in the fore wing of acridids (a to i)



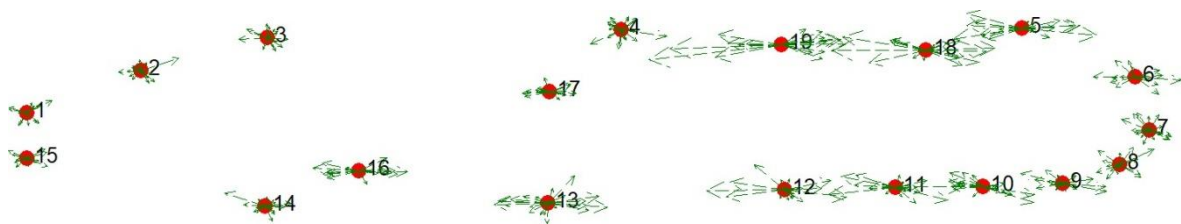
(a) *T. annulata*



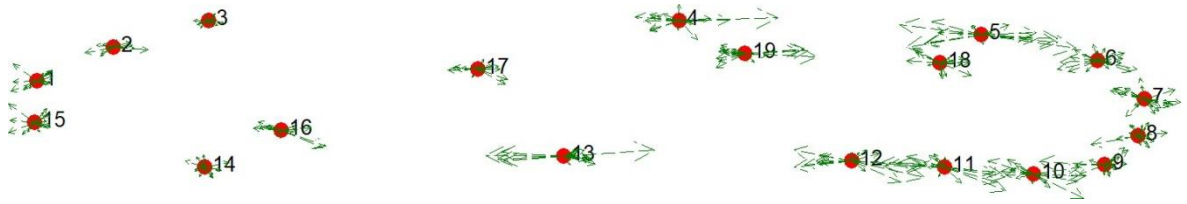
(b) *A. luteipes*



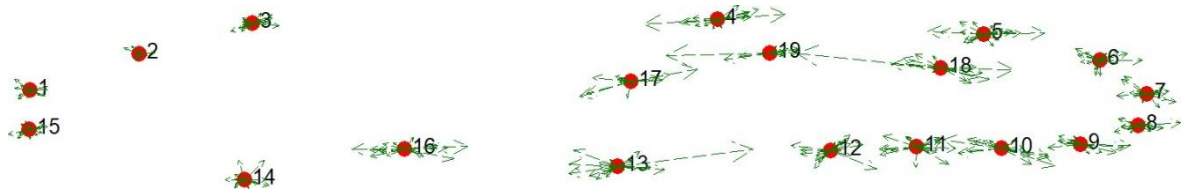
(c) *L. indica*



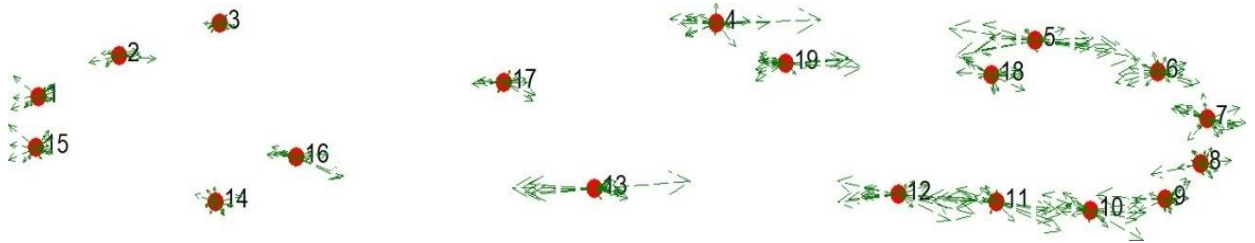
(d) *O. abruptus*



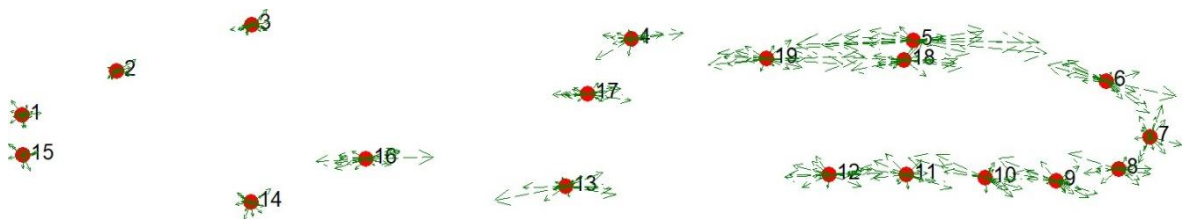
(e) *D. venusta*



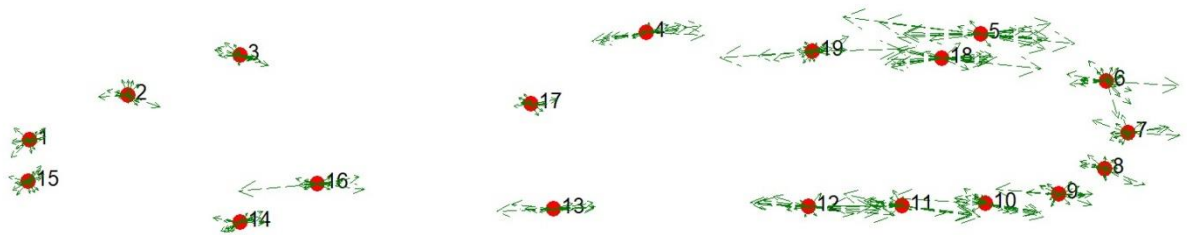
(f) *O. fuscovittata*



(g) *P. infumata*



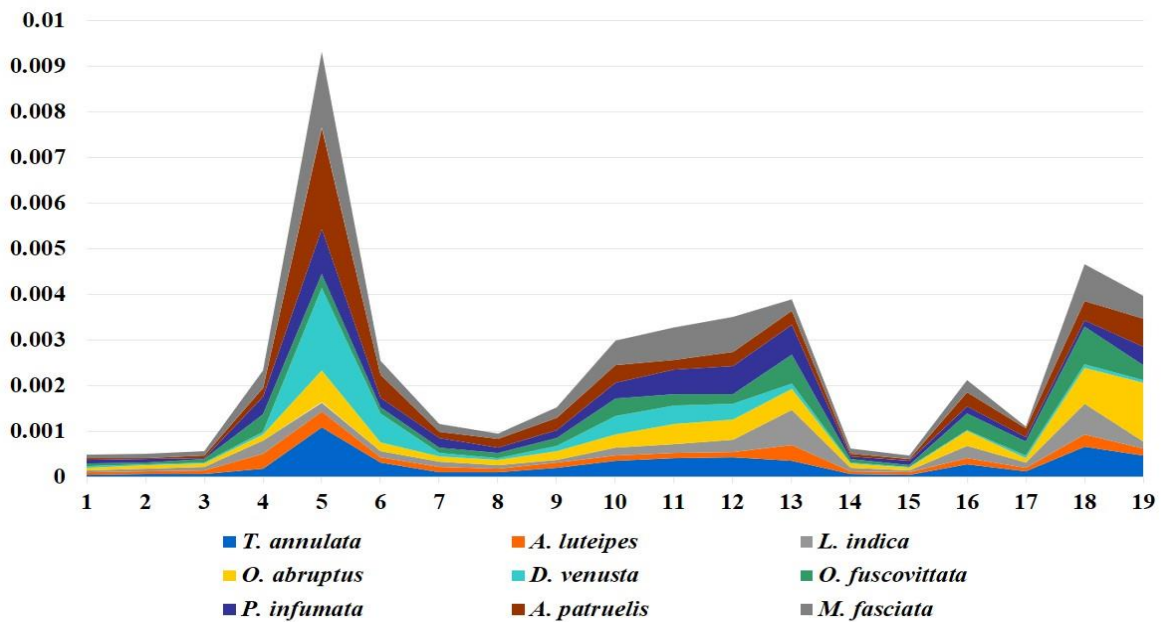
(h) *A. patruelis*



(i) *M. fasciata*

**Table - 37**  
**Consensus configuration of acridid species**

Landmarks	<i>T. annulata</i>	<i>A. luteipes</i>	<i>L. indica</i>	<i>O. abruptus</i>	<i>D. venusta</i>	<i>O. fuscovittata</i>	<i>P. infumata</i>	<i>A. patruelis</i>	<i>M. fasciata</i>
L1	-0.38709	-0.40219	-0.38551	-0.38218	-0.36713	-0.39315	-0.35931	-0.38551	-0.37521
L2	-0.32133	-0.33823	-0.31015	-0.31383	-0.32285	-0.32733	-0.31548	-0.32829	-0.31677
L3	-0.24008	-0.24564	-0.2324	-0.23836	-0.25631	-0.25949	-0.2607	-0.24681	-0.24979
L4	0.00833	0.02065	-0.12453	-0.02692	-0.0046	0.02082	0.00977	-0.0176	-0.00827
L5	0.19545	0.15216	0.10528	0.21235	0.14964	0.18132	0.18353	0.1528	0.19087
L6	0.26288	0.21807	0.25982	0.28	0.26391	0.25103	0.25044	0.26893	0.26526
L7	0.27498	0.25684	0.28382	0.28813	0.28864	0.27947	0.277	0.29559	0.27822
L8	0.25899	0.26581	0.28107	0.27057	0.27806	0.27443	0.2734	0.2765	0.26435
L9	0.22796	0.24965	0.25567	0.23634	0.25552	0.23954	0.25425	0.23898	0.23702
L10	0.18728	0.21299	0.2139	0.18887	0.21751	0.19204	0.21349	0.19623	0.19339
L11	0.1488	0.16312	0.15935	0.13681	0.15942	0.1405	0.16218	0.14831	0.14378
L12	0.10407	0.10823	0.10646	0.07027	0.10363	0.0892	0.10882	0.10176	0.08846
L13	-0.05088	-0.04042	-0.05062	-0.07065	-0.07129	-0.03939	-0.0565	-0.0572	-0.0634
L14	-0.24909	-0.24945	-0.24184	-0.23969	-0.25632	-0.26394	-0.26275	-0.24755	-0.24977
L15	-0.38845	-0.40285	-0.38524	-0.38187	-0.36617	-0.39369	-0.36051	-0.38486	-0.37577
L16	-0.19165	-0.18331	-0.17233	-0.18355	-0.18442	-0.16755	-0.21914	-0.17805	-0.20382
L17	-0.08117	0.00435	-0.01169	-0.0701	-0.08698	-0.03146	-0.10577	-0.04413	-0.07685
L18	0.15579	0.15278	0.16034	0.1551	0.1391	0.15545	0.15977	0.14686	0.16774
L19	0.08519	0.05744	0.0886	0.06873	0.06066	0.0522	0.04751	0.06404	0.09057



**Figure -56**  
**Variance at each landmarks for aligned specimens**

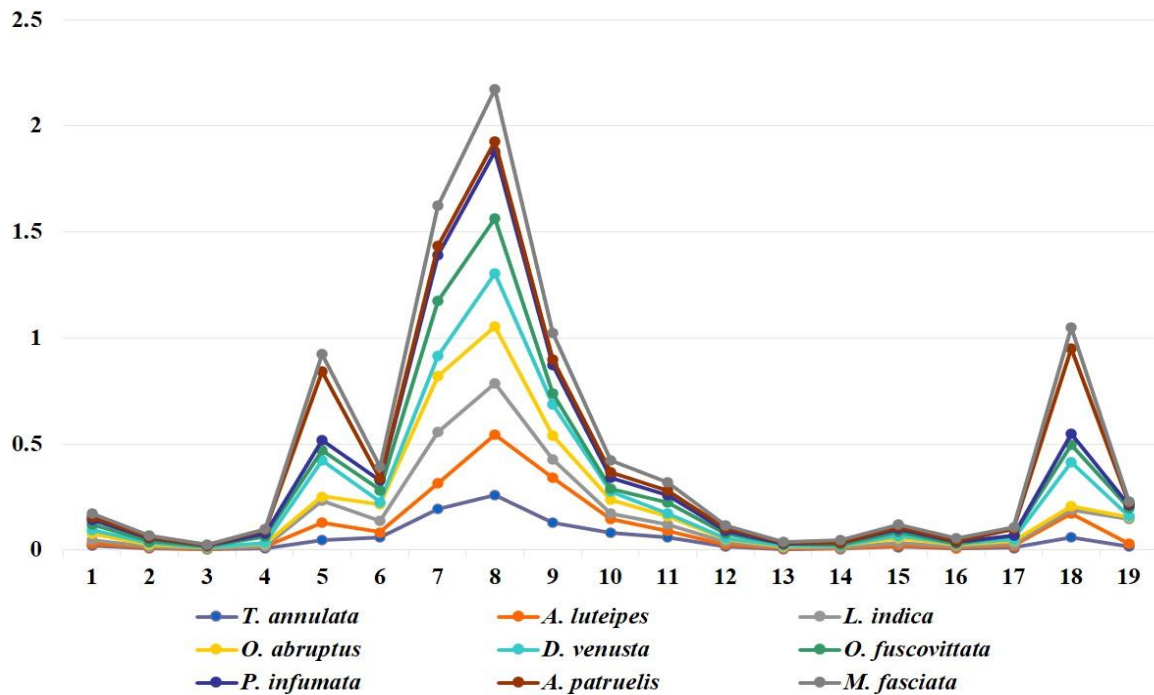


Figure - 57

### Relative contribution of each landmark of acridids

#### Relative warp analysis

In tps-Relw program, the relative warp ordination plot was performed by using the unit, centroid size scaling method and orthogonal alignment projection method. Singular values, warp % and cumulative % were explained by 19 relative warps in nine species of acridids as shown in table - 38. The first two relative warps accounted for a highest proportion of variance in each species of acridids. In the male population, first two warp values in *T. annulata*, *A. luteipes*, *L. indica*, *O. abruptus*, *D. venusta*, *O. fuscovittata*, *P. infumata*, *A. patruelis* and *M. fasciata* were 50.94% (55.67% + 12.15%), 52.17% (29.40% + 19.55%), 56.23% (28.51% + 23.66%), 53.86% (46.47% + 22.60%), 59.13% (69.94% + 17.95%), 52.85% (33.27% + 21.77%), 53.86% (41.57% + 23.59%), 59.13% (48.40% + 19.27%) and 52.85% (51.72% + 21.86%) respectively. Warp value in *A. luteipes* population wings revealed for the lowest variance across all the acridids. The relative warp analysis showed significant shape differences within and between acridids in studied site.

Table - 38

## Relative warp analysis of fore wing shape of acridids

<i>T. annulata</i>							
Relative warp	Singular values	Warp %	Cum%	10	0.02988	0.90%	97.80%
1	0.23509	55.67%	55.67%	11	0.02447	0.60%	98.40%
2	0.10983	12.15%	67.82%	12	0.02326	0.54%	98.95%
3	0.09354	8.81%	76.64%	13	0.01832	0.34%	99.28%
4	0.08489	7.26%	83.90%	14	0.01582	0.25%	99.54%
5	0.07095	5.07%	88.97%	15	0.01316	0.17%	99.71%
6	0.0565	3.22%	92.18%	16	0.01033	0.11%	99.82%
7	0.04235	1.81%	93.99%	17	0.00866	0.08%	99.89%
8	0.03894	1.53%	95.52%	18	0.00819	0.07%	99.96%
9	0.03705	1.38%	96.90%	19	0.00618	0.04%	100.00%
<i>A. luteipes</i>							
Relative warp	Singular values	Warp %	Cum%	10	0.03035	1.76%	96.86%
1	0.124	29.40%	29.40%	11	0.02284	1.00%	97.86%
2	0.1011	19.55%	48.95%	12	0.01936	0.72%	98.57%
3	0.0802	12.30%	61.25%	13	0.0148	0.42%	98.99%
4	0.06678	8.53%	69.78%	14	0.01339	0.34%	99.33%
5	0.06426	7.90%	77.67%	15	0.01205	0.28%	99.61%
6	0.05472	5.73%	83.40%	16	0.0083	0.13%	99.74%
7	0.05118	5.01%	88.41%	17	0.008	0.12%	99.87%
8	0.04385	3.68%	92.09%	18	0.0071	0.10%	99.96%
9	0.03967	3.01%	95.10%	19	0.00444	0.04%	100.00%
<i>L. indica</i>							
Relative warp	Singular values	Warp %	Cum%	10	0.02853	1.14%	96.71%
1	0.14264	28.51%	28.51%	11	0.02706	1.03%	97.74%
2	0.12994	23.66%	52.16%	12	0.02287	0.73%	98.47%
3	0.10181	14.52%	66.68%	13	0.02056	0.59%	99.06%
4	0.08577	10.31%	76.99%	14	0.01559	0.34%	99.40%
5	0.06971	6.81%	83.80%	15	0.01142	0.18%	99.59%
6	0.05816	4.74%	88.54%	16	0.00991	0.14%	99.72%
7	0.0464	3.02%	91.55%	17	0.00923	0.12%	99.84%
8	0.04129	2.39%	93.94%	18	0.00835	0.10%	99.94%
9	0.03408	1.63%	95.57%	19	0.00656	0.06%	100.00%
<i>O. abruptus</i>							
Relative warp	Singular values	Warp %	Cum%	10	0.02776	0.68%	97.68%
1	0.22953	46.47%	46.47%	11	0.02585	0.59%	98.27%
2	0.16006	22.60%	69.07%	12	0.02356	0.49%	98.76%
3	0.10791	10.27%	79.34%	13	0.02031	0.36%	99.12%
4	0.08114	5.81%	85.15%	14	0.01963	0.34%	99.46%
5	0.07156	4.52%	89.66%	15	0.01477	0.19%	99.65%
6	0.0588	3.05%	92.71%	16	0.01301	0.15%	99.80%
7	0.04854	2.08%	94.79%	17	0.00964	0.08%	99.89%
8	0.03887	1.33%	96.12%	18	0.00841	0.06%	99.95%
9	0.03151	0.88%	97.00%	19	0.00764	0.05%	100.00%

<i>D. venusta</i>							
Relative warp	Singular values	Warp %	Cum%	10	0.01626	0.32%	98.72%
1	0.23936	69.94%	69.94%	11	0.01513	0.28%	99.00%
2	0.12127	17.95%	87.90%	12	0.01436	0.25%	99.25%
3	0.06261	4.79%	92.68%	13	0.013	0.21%	99.45%
4	0.03997	1.95%	94.63%	14	0.01262	0.19%	99.65%
5	0.02968	1.08%	95.71%	15	0.0103	0.13%	99.78%
6	0.02805	0.96%	96.67%	16	0.00858	0.09%	99.87%
7	0.02405	0.71%	97.37%	17	0.0073	0.07%	99.93%
8	0.02197	0.59%	97.96%	18	0.00614	0.05%	99.98%
9	0.01879	0.43%	98.39%	19	0.00407	0.02%	100.00%
<i>O. fuscovittata</i>							
Relative warp	Singular values	Warp %	Cum%	10	0.03135	1.07%	97.34%
1	0.17456	33.27%	33.27%	11	0.03031	1.00%	98.35%
2	0.14121	21.77%	55.04%	12	0.02317	0.59%	98.93%
3	0.10462	11.95%	66.99%	13	0.01807	0.36%	99.29%
4	0.08898	8.64%	75.64%	14	0.01651	0.30%	99.59%
5	0.0847	7.83%	83.47%	15	0.01064	0.12%	99.71%
6	0.07686	6.45%	89.92%	16	0.00993	0.11%	99.82%
7	0.04967	2.69%	92.61%	17	0.00838	0.08%	99.89%
8	0.04143	1.87%	94.49%	18	0.00719	0.06%	99.95%
9	0.04042	1.78%	96.27%	19	0.00669	0.05%	100.00%
<i>P. infumata</i>							
Relative warp	Singular values	Warp %	Cum%	10	0.02776	0.76%	98.70%
1	0.20592	41.57%	41.57%	11	0.02054	0.41%	99.12%
2	0.15513	23.59%	65.16%	12	0.01669	0.27%	99.39%
3	0.1255	15.44%	80.61%	13	0.01429	0.20%	99.59%
4	0.08683	7.39%	88.00%	14	0.01254	0.15%	99.75%
5	0.06196	3.76%	91.76%	15	0.01011	0.10%	99.85%
6	0.04733	2.20%	93.96%	16	0.00892	0.08%	99.92%
7	0.04384	1.88%	95.84%	17	0.00611	0.04%	99.96%
8	0.03578	1.26%	97.10%	18	0.00484	0.02%	99.98%
9	0.02947	0.85%	97.95%	19	0.00418	0.02%	100.00%
<i>A. patruelis</i>							
Relative warp	Singular values	Warp %	Cum%	10	0.03381	0.92%	97.53%
1	0.24463	48.40%	48.40%	11	0.03101	0.78%	98.30%
2	0.15435	19.27%	67.67%	12	0.02481	0.50%	98.80%
3	0.11277	10.28%	77.95%	13	0.02188	0.39%	99.19%
4	0.09037	6.60%	84.56%	14	0.01872	0.28%	99.47%
5	0.07822	4.95%	89.51%	15	0.01526	0.19%	99.66%
6	0.05857	2.77%	92.28%	16	0.01367	0.15%	99.81%
7	0.04691	1.78%	94.06%	17	0.01058	0.09%	99.90%
8	0.0435	1.53%	95.59%	18	0.00887	0.06%	99.97%
9	0.03534	1.01%	96.60%	19	0.00651	0.03%	100.00%

<i>M. fasciata</i>							
Relative warp	Singular values	Warp %	Cum%	10	0.0271	0.54%	98.74%
1	0.26534	51.72%	51.72%	11	0.02308	0.39%	99.13%
2	0.17249	21.86%	73.58%	12	0.01724	0.22%	99.35%
3	0.10045	7.41%	81.00%	13	0.01631	0.20%	99.55%
4	0.08354	5.13%	86.12%	14	0.01402	0.14%	99.69%
5	0.07826	4.50%	90.62%	15	0.01188	0.10%	99.79%
6	0.05703	2.39%	93.01%	16	0.0099	0.07%	99.87%
7	0.05567	2.28%	95.29%	17	0.00878	0.06%	99.92%
8	0.04907	1.77%	97.06%	18	0.00782	0.04%	99.97%
9	0.03947	1.14%	98.20%	19	0.00659	0.03%	100.00%

**Procrustes and tangent space distance**

In tps-small program, to project the aligned coordinates orthogonally into tangent space, it provides distances smaller than procrustes distances. Minimum, maximum and mean value for procrustes distance and tangent space distance within population were relatively same in all the studied acridids except *A. patruelis* (maximum value showed a small variance between procrustes and tangent distance) but quite variation showed between nine acridid species. The minimum procrustes distance and tangent space distance were observed in *D. venusta* (0.02) whereas maximum distance was observed in *T. annulata* (0.16). The mean procrustes distance and tangent space distance were relatively same in *A. luteipes*, *L. indica* and *D. venusta* (0.05); *T. annulata*, *O. fuscovittata* and *P. infumata* (0.06); *O. abruptus*, *A. patruelis* and *M. fasciata* (0.07). The correlation between the two distance was found to be very strong (Table - 39).

**Table - 39**

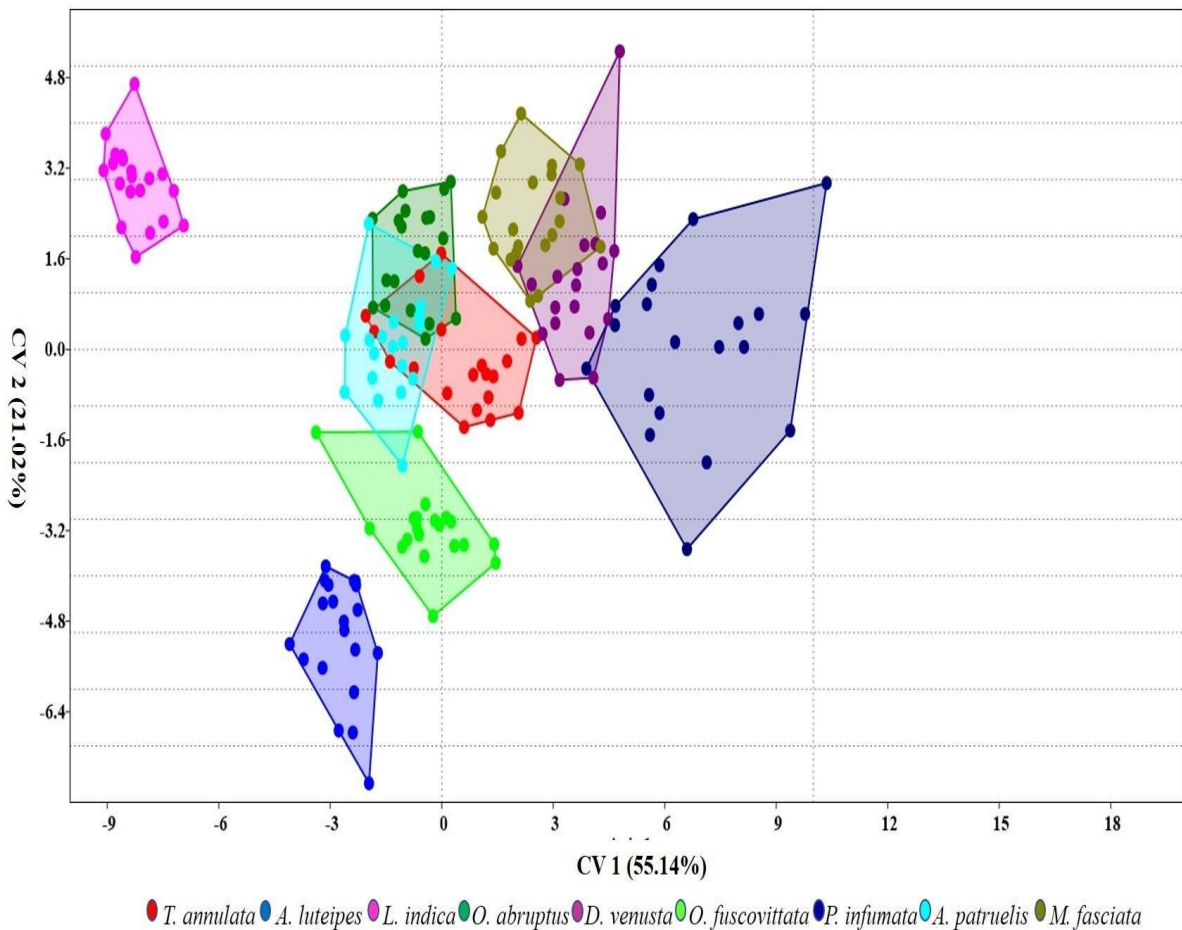
**Comparison of procrustes and tangent space distance in acridid species**

	Statistics	<i>T. annulata</i>	<i>A. luteipes</i>	<i>L. indica</i>	<i>O. abruptus</i>	<i>D. venusta</i>	<i>O. fuscovittata</i>	<i>P. infumata</i>	<i>A. patruelis</i>	<i>M. fasciata</i>
<b>Procrustes distance</b>	<b>Min</b>	0.03	0.03	0.04	0.05	0.02	0.03	0.03	0.03	0.03
	<b>Max</b>	0.16	0.07	0.10	0.12	0.13	0.12	0.11	0.12	0.12
	<b>Mean</b>	0.06	0.05	0.05	0.07	0.05	0.06	0.06	0.07	0.07
<b>Tangent distance</b>	<b>Min</b>	0.03	0.03	0.04	0.05	0.02	0.03	0.03	0.03	0.03
	<b>Max</b>	0.16	0.07	0.10	0.12	0.13	0.12	0.11	0.11	0.12
	<b>Mean</b>	0.06	0.05	0.05	0.07	0.05	0.06	0.06	0.07	0.07

**Canonical Variate Analysis (CVA)**

Based on the CVA wing variance results, correlation distance between the wing shapes of each species of acridid variability clearly showed that the differences were highly significant. The accumulative contribution ratio of the first two PCs accounted together for 36.99 % (CV1 = 55.14% + CV2 = 21.02%) of the total shape variance and eigenvalues were (CV1 =16.72, CV2=6.37) (Fig - 58).

Each polygon so distinctly illustrates the clear difference between the wing shapes of acridids. The scatter plots of CVA showed that some cluster on the right of the plots and some cluster on the left whereas some cluster formed on the centre (Fig - 58). Studied species were statistically different from each other in wing morphological characters and the parameters was found ( $p < 0.001$ ) (Table - 40).



**Figure - 58**

**Canonical variate axes of the wing shape of acridids**

Table - 40

## Canonical variate analysis of landmark scores among acridids

Wilk's Lambda = 0.0001132	Pillai trace = 4.62
df1 = 152	df1 = 152
df2 = 1149	df2 = 1280
F = 18.17	F = 11.51
P (same) = 5.147E-218	P (same) = 3.973E-155

**Discussion**

This study indicates that the different morphometric parameters (body length, head length, antenna length, pronotum length, hind femur length and fore wing length) of nine acridids populations showed variation in one individual to other individuals (within species) as well as one species to another species (between species). Similarly, according to Whitman (2008), body size in Orthoptera varies within and between species, mainly due to environmental influences. Cisneiros *et al.* (2012) studied the intraspecific variability in morphological features such as body, pronotum, head, femur and wings in *C. speciosa* grasshopper populations. Bamidele and Muse (2012) showed that male and female *Z. variegatus* from different geographical regions had statistically significant morphological traits.

The present observation indicated that the length of the antenna, head, pronotum, forewing and hind femur of nine acridids varied according to their body size. According to Perrin (1998) body size is an important characteristic of organisms because it closely correlates with various ecological, physiological and life cycle traits and influences fertility, fitness and speciation. Price (1997) discovered that adult size is often linked to nymphal developmental conditions, with well-fed larvae producing larger adults. Bai *et al.* (2016) reported that body size variability is one of the most remarkable properties of most insects and there are significant relationship between body size and a number of environmental conditions associated with insects. Temperature is an important environmental component that influences insect dispersion and growth.

The results indicated that different morphological parameters of *O. fuscovittata* showed the highest percentages of variance (within species) whereas *D. venusta* and *M. fasciata* showed lesser variance compared with other acridids. The observed variation

within *O. fuscovittata* may be due to the less favorable condition for their individual development. The smaller flexibility in *D. venusta* and *M. fasciata* morphology may reflect developmental reproductive constraints and different feeding habitats can increase their individual fitness.

Mean length of the head and pronotum showed the least variance in respect to the other examined parameters of acridids. According to Silva *et al.* (2014), the hind femur measurement in nymphs shows the least fluctuation compared to other examined parameters. Cluster analysis showed the positive relationship between the body length and fore wing length; antenna length and hind femur length; head length and pronotum length among acridids, indicating that fore wing length can be used to determine body length of acridids. Similarly, Bamidele and Muse (2012) reported that either fore wing and hind wing length can be used to determine the body length of *Z. variegatus*. The larger body size of *T. annulata* with bigger wing size and the wing size could be used as a proxy for body size. Tajamul and Ahmad (2016) found a strong positive association between total body length and femur length, as well as total body length and antenna length, in their regression study. Intra and interspecific variation in morphology of acridids can be attributed to differences in their diet that would affect individual species growth and development. Differences in foraging habitat, ecological factor and environmental changes such as habitat destruction or disturbance could explain the variation in food preference and feeding behaviours. Their distribution across different places and different plants/habitats shows the change of their life history traits and morphological traits. The size of an individual adult locust depends on species, sex, nutrition and phase (Bouachi and Simpson, 2003; Gray *et al.*, 2009; Gotham and Song, 2013). Adis *et al.* (2008) reported that *Cornops aquaticum* morphology differs depending on geography and host plant. This variation can be influenced by genetics or the environment.

Morphometric analyses of selected nine species determine the inter-species variation and show dynamic speciation. The observed differences in morphological features among and between acridids, confirms the effectiveness of using this morphological trait as being the best way to differentiate the nine acridid species.

In the present work, quantified and compared the wing morphological variation in the nine acridids species of Orthopterans based on the geometric morphometrics. The structure

and shape of the wing showed significant variances between the acridids and also detailed morphometric feature of nine acridids wing veins nomenclature were recorded. One of the most important traits used to identify insects is their wing vein (Bai *et al.*, 2011). The appeared variability in the wing structure and the wing veins were used as morphological characteristics to separate one species from another species of acridids. According to Laurito *et al.* (2015) traditional morphometric features can be used in taxonomic keys by detecting shape changes at a broad structural level or between two or more landmarks. As a result, geometric morphometrics would be used to discover areas of variability that would be difficult to find if searched exhaustively.

Landmark-based geometric morphometrics works based on the configurations of landmarks in a coordinate system. Present work estimated the 19 landmark coordinates in each species' wings of acridids. Based on the consensus configuration data, the same approximate wing structure and wing veins nomenclature existed within individuals of acridids but the quite difference has existed in the landmarks location in the wing veins. The distribution of landmark distance in within species suggests that the existence of wing polymorphism. According to Bai *et al.* (2016) *T. annulata* body size and wings showed considerable variability among populations. Riget *et al.* (2008) observed differences in wing morphology might be influenced by the random mating process within the individuals, greater population density, food preference, heat pressure, influence of parasite, diseases, sexual selection and some genetic components. Also, the study shows that the wing variations might be attributed to the flight system and flapping kinematics (Demayo *et al.* 2011).

In this study, showed that wing shapes exhibited significant differences among the nine acridids species, based upon the results of consensus configuration. Wing shape deformation was noted mainly at the middle and distal parts of the fore wing. According to Bai *et al.* (2016) the forewing shape of *T. annulata* changed dramatically across 39 populations, with wing shape deformation appeared mainly at the end of the forewing.

Relative warp ordination plots exposed that wing shape of nine acridids were distinct and also identified non-affine shape in the wings of nine acridids populations. Wing shape variations were observed high in the first two relative warps of each species of acridids. Manimegalai *et al.* (2009) reported that the method of relative warps had been used to

identify the co-variation very efficiently. Relative warps are linear combinations of affine and non-affine shape components that describe the variation in specimens (Rohlf, 2003).

The variation between Procrustes and tangent space distance showed the same amount within species of acridids but quite differences occurred between the acridids values and a very high correlation was found within individual species of acridids. The correlation between the two distances (1.0000) were the same in each species. According to Leslie *et al.* (2000) correlations between these distances were always greater than 0.99. The Procrustes distance assess the degree of difference between shapes, allowing shape space to be defined and characterised, as well as the development of particular statistical procedures (Rohlf, 2002).

Based on the CVA results, wing shape showed a clear separation from one species to other species. The non-intersection of the polygons in the wing shape analysis demonstrates that wing vein features are more relevant in determining species diversity. The distance between the landmarks in each wing structure could be used to calculate the variability. Analysis of the size and shape of the adult wing structure may lead to the discovery of new beneficial traits for distinguishing morphologically similar species and resolving taxonomic issues (Dobigny *et al.*, 2002; Go´mez *et al.*, 2013).

Furthermore, these findings demonstrated the importance of using a different statistical method, displaying multiple sources of phenotypic information from the wing of acridids and capturing subtle patterns of different characterization. The observed variation within and between acridid populations might be attributed to differences in environmental factors in the area such longitude, altitude, climatic variables, habitat destruction, foraging habitat and vegetation. Hence, the wing morphology differences could be associated with natural selection (Green, 2000). The major elements determining grasshopper wing shape are microclimate and habitat characteristics (Picaud and Petit, 2008; Mitteroecker and Gunz, 2009). In nature, genetic drift is the main force that produces significant differences in shape (Dujardin *et al.*, 2003). Beasley *et al.* (2012) demonstrated that solar radiation has a considerable effect on grasshopper wings, with late-maturing individuals' wing size decreasing as radiation levels increased. Grasshopper wing size alter dramatically depending on the climates and some have evolved long, short and even small wings resulting in a loss of flight ability (Berggren *et al.*, 2012).

**Phase - V****4.5 Molecular Phylogenetic Analysis of Acridids**

The examination of DNA information has become a frequently used strategy for inferring relationships of various taxa or genes. Molecular phylogenetic investigation is a prime step for examining the evolutionary relationships within and between the species. One of the most effective approaches for identifying species is to use a molecular tool, which will reflect identical features in closely related species. The complementary approach of COI gene-based identification and phylogenetic relationship of commonly available nine acridids specie (*T. annulata*, *L. indica*, *A. patruelis*, *O. abruptus*, *O. fuscovittata*, *P. infumata*, *A. luteipes*, *M. fasciata* and *D. venusta* comes under four subfamilies) were investigated in this study. In addition, the species selected for molecular analysis from the same family (Acrididae) of Orthopterans.

**Molecular identification based on COI gene**

Genomic DNA was extracted from the femur tissue of nine acridids. The quality of genomic DNA suggested an appreciable amplified PCR product size of around 700 bp and the samples had an appreciable yield of >10 kilobyte (kb) (Fig - 59). Cytochrome c oxidase subunit I typing was performed to ascertain the species level identity and establish evolutionary divergence among the selected species. COI gene was used to study the inter-specific variation and infer phylogenetics relationships among the selected acridids.

The sequenced species were submitted to the BLAST for performing similarity search for matching the sequence to the already existing data in the NCBI database. The parameters for similarity search (BLAST) are listed in table - 41. All of the sequences accurately matched their own haplotypes in the NCBI with a high percentage of identities. The identity ranged between 97 to 100%. All of the sequences were aligned, modified and the COI regions base pair sizes ranged from 481 to 580 (Plate - XII & table - 42). These were submitted to the NCBI GenBank and authenticated with respective accession numbers, OK037584.1, OK037585.1, OK037586.1, OK037587.1, OK037588.1, OK037583.1, OK037590.1 and OK039226 (Appendix - 2 to 8).

**Multiple sequence analysis of the nucleotide sequence of selected acridid species**

From the multiple sequence analysis results, the number of identical amino acid residues (131), similar identical amino acid residues (48) and various amino acid residues

were observed. The Multiple Align Show results determined a higher amount of variation amino acid residues in the nucleotide composition (Fig - 60).

### **Nucleotide composition**

Analysis of the COI gene sequence revealed a significant variation in sequence length, nucleotide content, distribution frequency and base content among the nine species of acridids used in this study.

Total nucleotide content (sequence length bp), Adenine, Thymine, Guanine, Cytosine, A+T content and G+C content of *T. annulata*, *L. indica*, *A. patruelis*, *O. abruptus*, *O. fuscovittata*, *P. infumata*, *A. luteipes*, *M. fasciata* and *D. venusta* were shown in table - 42. Overall composition, Adenine was ranged from 30.34% (*O. abruptus*) to 34.74% (*D. venusta*); Thymine content varied from 34.23 % (*A. luteipes*) to 36.90% (*O. abruptus*); Guanine length fluctuated from 14.56% (*M. fasciata*) to 18.70 % (*L. indica*); Cytosine ranged from 14.83% (*O. abruptus*) to 20.28% (*M. fasciata*); A+T content ranged from 66.16% (*M. fasciata*) to 67.24% (*O. abruptus*); G+C varied from 32.76% (*O. abruptus*) to 34.84% (*M. fasciata*). A+T contents were higher than G+ C contents in all the acridids. Variation in the nucleotide sequence of the homologous region provides a fundamental description of genetic variation within species level.

### **Codon position**

Saturation was assessed for the COI fragment's of three codon locations by plotting the number of substitutions versus the uncorrected p-distance (Fig- 61). The rate of codon positions were varied among three codons. The average transition (Ts) and transversion (Tv) substitution in first, second and third codons were (0.08 and 0.10), (0.10 and 0.20) and (0.12 and 0.08), respectively. The scatter plot of Ts and Tv for third codon and first codon decreased with considerable scattering. However, in the second codons position increased along the uncorrected p-distance in saturation plots indicate that Ts and Tv exhibited a marked genetic difference in plot patterns, both the codon substitutions were minimum for certain pairs of taxa and the substitution rates were stabilised. However, the exact saturation of the sequences did not occur.

### **Substantial saturation of COI sequences**

Plotting the substitutions against the overall F84 genetic distance, the condition of substantial saturation of the selected COI sequences can be determined (Fig - 62). The x-

axes 'F84 distance' is based on the F84 substitution model and is expected to increase linearly with divergence time. The sequence's saturation was determined; both Ts and Tv had a linear relationship, indicating that the sequences were not saturated.

The substitution saturation test of the COI sequence transitions and transversions showed that the number of transversions (TV) outnumbered transitions (TS). If sequences are saturated with substitutions, they have less phylogenetic information and are unable to give deeper insights into phylogenetic signals. In addition, the considerable saturation test demonstrated that *I<sub>ss</sub>* has a lower value than *I<sub>ss.c</sub>* [ $0.6582 (I_{ss}) < 0.7553 (I_{ss.c})$ ] (Table - 43). As a result, it was clear that the selected sequences did not experience significant saturation and could be used for DNA barcoding and phylogenetic analysis.

### **Synonymous and non-synonymous substitution rates**

In figure - 63, synonymous and non-synonymous substitutions were denoted by *K<sub>a</sub>* and *K<sub>s</sub>*, respectively. Along the y-axis, a graph depicting the elevation of the *K<sub>s</sub>* (Synonymous substitution) against the *K<sub>a</sub>* (Non-synonymous substitution). *K<sub>s</sub>* was found higher than *K<sub>a</sub>*.

### **Maximum likelihood estimation of substitution matrix and transition/transversion bias**

The probability of substitution (*r*) from one base (row) to another base is given for each entry (column). The Kimura 2-parameter model was used to estimate substitution patterns and rates. Relative values should be considered while analysing instantaneous *r*. The estimated transition/transversion bias (*R*) is 0.84. The sum of *r* values is set 100 for simplicity. The nucleotide occurrences are A = 25.00%, T = 25.00%, C = 25.00% and G = 25.00%. A tree topology was automatically constructed to estimate ML values. For this calculation, the greatest Log-likelihood was -2336.934. Nine nucleotide sequences were used in the study. All of the position that had gaps or missing data were removed. The total number of positions in the final dataset was 420 (Table - 44).

### **Evolutionary divergence distance among acridids**

The number of base substitutions per site from averaging over all sequence pairs and Standard error is shown in table - 44. The genetic difference among the selected acridids was estimated to measure the interspecific variation (Table - 45). The overall interspecific Kimura 2-parameter model genetic divergence of different genera within Acrididae ranged

from about 0.127 to 1.219. Minimum divergence was observed between *O. fuscovittata* and *P. infumata*. Maximum divergence was noted between *L. indica* and *D. venusta*. The pair wise comparison of *T. annulata*, *A. luteipes*, *L. indica*, *O. abruptus*, *D. venusta*, *O. fuscovittata*, *P. infumata*, *A. patruelis* and *M. fasciata* genetic divergence distance varied from 0.13 to 1.071, 0.134 to 1.095, 1.078 to 1.219, 0.16 to 1.13, 0.14 to 1.219, 0.127 to 1.078, 0.127 to 1.091, 0.135 to 1.169 and 0.151 to 1.107 respectively (Table - 46). Overall, the interspecific genetic distance among selected acridids species exhibited significant divergence. Analyses were conducted using the Kimura 2-parameter model. The analysis involved nine nucleotide sequences. All the positions containing gaps and missing data were eliminated. There were a total of 420 positions in the final dataset.

### **Molecular phylogenetic analysis**

The COI sequences of the dataset of nine species were represented in a phylogenetic tree (Fig - 64 & 65). The nucleotide divergence among the nine species of acridids formed distinctive clusters. Phylogenetic analysis revealed the interspecific variation among selected acridids based on the nucleotide composition. The both NJ tree and ML tree suggested that nine individuals from the four subfamilies clustered in four different groups, among which Oedipodinae species firstly clustered to form group one; Acridinae was formed second cluster in NJ and third cluster in ML tree; Oxyinae was formed third cluster in NJ and second cluster in ML tree; Gomphocerinae was formed fourth cluster in both NJ and ML tree. The highest evolutionary relationship was found between *O. abruptus* and *M. fasciata* in both trees.

Based on the sequences availability in the NCBI database, the congeneric and conspecific divergences were determined (Table - 47). The NJ tree constructed from the species of the present study and haplotypes retrieved from Genbank formed distinctive clusters (Fig - 66). Four haplotypes of *T. annulata*, five of *A. luteipes*, four of *A. patruelis* and five of *P. infumata* separated from a single parent clade to form three branches; six haplotypes of *O. fuscovittata* formed in clade II; *D. venusta* formed separately in clade IV; two haplotypes of *M. fasciata* combined in clade V; four haplotypes of *T. annulata* and *D. venusta* formed together in clade II. Two haplotypes of *M. fasciata* combined in clade III. Genus *Oedaleus* grouped in clade VI; *L. indica* and four different genera to form two

branches from clade VII; two haplotypes of *Acrotylus* genera formed in last clade. Different genera haplotypes were found in the same cluster, indicating a low genetic distance and in separate clusters, indicating a higher genetic distance. The haplotypes of *O. fuscovittata*, *P. infumata*, *L. indica* and genus *Oedaleus* grouped a single clade which is considered as monophyletic group, while the rest of the species branched with different clades, these are considered as polyphyletic group.

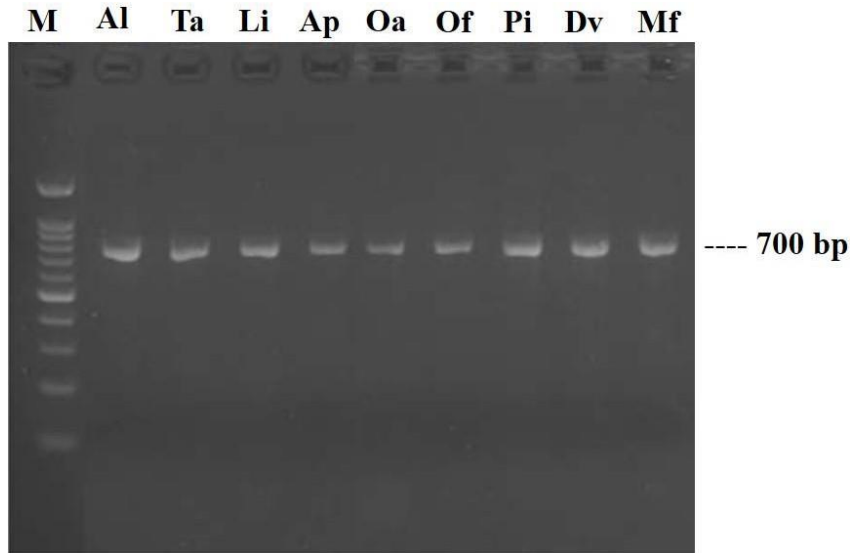


Figure - 59

PCR amplified acridids samples resolved on 1% AGE

Note: Amplification of the mitochondrial COI gene of selected acridids; M- Marker, Al- *Aulacobothrus luteipes*, Ta- *Trilophidia annulata*, Li- *Leva indica*, Ap- *Acrotylus patruelis*, Oa- *Oedaleus abruptus*, Of- *Oxya fuscovittata*, Pi- *Phaleoba infumata*, Dv- *Ditopternis venusta*, Mf- *Morphacris fasciata*.

Plate - XII

Mitochondrial DNA sequence based on COI gene of acridids (a to i)

(a) *Trilophidia annulata*

TCAATAATTGGAGATGATCAAATTTATAATGTAATTATTACGGCACACGCATTTGT  
TATAATTTTCTTTATAGTTATACCAATTATAATTGGAGGATTTGGAAATTGATTAGTT  
CCATTAATAATTGGAGCACCAGATATAGCCTTTCCCCGAATAAATAACATAAGATTT  
TGATTATTACCACCATCATTAAATCCTCCTCCTATCATCCTCAATAGTTGATAGCGGAG  
CCGGTACAGGATGAACAGTTTACCCCCATTAGCAGGAGCTATTGCTCATGGAGGA  
GCATCAGTAGATTTAGCTATTTTTTCTTGCATTTAGCAGGTGTTTCTTCCATTCTAG

GAGCAGTTAATTTTATTACAACAGTAATTAATATACGATCAGAAAGAATAACTTTAG  
ATCAAACACCATTATTTGTTTGATCTGTTGCAATTACAGCAATTTTATTACTGTTATC  
TTTACCTGTATTAGCAGGAGCT

(b) *Aulacothrus luteipes*

AACTCTATACTTCTTATTTGGAGCATGAGCAGGAATAGTAGGAACATCAATAAGTAT  
AATTATTCGAGCTGAACTTGGACAACCAGGATCTTTAATTGGAGATGATCAAATCTA  
TAATGTAATTATTACAGCACATGCATTTGTAATGATTTTTTTTTATAGTAATACCTATT  
ATAATTGGGGGATTTGGAAATTGACTCGTTCCTTAATAATTGGTGCACCAGATATA  
GCATTTCCACGAATAAATAATATGAGATTTTGATTATTACCACCATCATTAACTTT  
TAATTACTTCTTCTATAGTTGACATAGGGGCAGGCACAGGATGAACAGTTTACCCAC  
CTCTAGCAGGAGCTATTGCACACGGAGGAGGATCCGTTGATCTAGCTATTTTCTCCC  
TTCATTTAGCCGGTGTATCCTCTATTCTAGGAGCAGTAACTTTATTACTACAGCAAT  
TAATATACGATCTGAAAGTATAACCCTAGATCAAACACCATTATTTGTCTGATCAGT  
TGCTATTACAGCATTATTGTTACTTTTATCACTACCTGT

(c) *Leva indica*

TAAAACCTGGTAGAGATAGTAGAAGTAATAGGGCTGTAATTGCTACTGATCAAACAA  
ATAGGGGTGTTTGATCGAGTGTTATTCTTTCTGATCGTATATTAATTGCTGTTGTAAT  
AAAATTTACTGCTCCTAGAATTGATGAAATACCTGCTAGGTGTAATGAAAAGATGGC  
TAAGTCAACTGAAGCACCTCCGTGCGCAATAGCTCCTGCTAGGGGGGGGTAACTG  
TTCATCCTGTACCACCACCATTATCAACTATTGAAGACGTGAGAAGAAGTGTTAAAG  
ATGGTGGAAAAAGTCAGAATCTTATATTATTTATTCGAGGAAATGCTATATCTGGTG  
CTCCAATTATTAAGGTACTAATCAATTCCAAATCCACCAATTATAATAGGTATAA  
CTATAAAGAAAATTATTACGAATGCGTGAGCTGAAATAATTACTTTATAAATTTGAT  
CATCTCCAATTAGAGATCCTGGTTGCCGAGTTCTGCACGAATAATTATTCTTATTGA  
TGTTCCAATTATTCCAGCTCAGGCTCCAAATATAAAGTATAATGTACCAATATCTTT  
ATGATTTTGTGA

(d) *Oedalus abruptus*

CACCTTATACTTTATATTTGGAGCATGAGCAGGAATAGTAGGAACATCAATAAGAAT  
AATTATTCGAGCAGAACTAGGACAACCAGGATCAATAATTGGAGATGATCAAATCT  
ATAACGTAATTATTACAGCACATGCATTTGTAATAATTTTCTTTATAGTTATAACCAAT  
TATAATTGGAGGATTTGGAAACTGATTAGTTCCATTAATAATTGGAGCACCAGATAT  
AGCATTCCCACGAATAAATAACATAAGATTTTGATTATTACCACCATCATTAACT  
CTTAATTCTATCCTCTTTAGTAGAAAATGGAGTAGGAACAGGATGAACAGTTTATCC  
ACCATTAGCAAGAGTTATTGCACACAGAGGAGCATCCGTAGATATAGCAATTTTTTC

---

ATTACACCTAGCAGGTATTTTCATCAATTCTTGGAGCAATTA ACTTCATTACAACAGC  
AATCAATATACGACCAAATAATATAACTCTTGAACAAACACCGTTATTTGTATGATC  
AGTAGCAATTACAGCATTACTTCTATTGCTATCTCTACCAG

(e) *Ditopternis venusta*

GAGATGATCAAATCTATAATGTAGTTATCACAGCACATGCATTTATTATAATTTTCTT  
TATAGTAATACCAATTATAATTGGAGGATTTGGAAATTGACTTGTACCACTAATAAT  
TGGAGCACCAGATATAGCATTCCCACGAATAACAATATAAGATTTTGAATGTTACC  
ACCATCATTAACACTCCTTATTTTATCCTCAATAATTGATGGAGGAGCAGGGACAGG  
ATGAACAGTATACCCACCAGTAGCAGGAGCTATTGCACACGGAGGTGCATCAGTAG  
ATCTAGCAATTTTTCATTACATTTAGCAGGAATTTTCATCAATTCTAGGAGCAGTTAA  
TTTTATTACAACAGCAATTAATATACGATCAAACAGAATAACCTTAGACCAAACACC  
ACTATTTGTTTGATCAGTTGCAATTACAGCATTATTATTACTTTCACTTCCAGTA  
TTAGCTGGAGCTATTACTATACTATTA ACTGACCGAAACTTAAATACGTCATTCTTTG  
ACCCA

(f) *Oxya fuscovittata*

GATGATCAAATTTATAATGTAATTATTACAGCACACGCATTTGTTATAATTTTTTTCA  
TAGTTATAACCAATTATAATTGGTGGATTTGGTAATTGATTAGTTCATTAATAATTGG  
AGCACCAGACATAGCATTTCACGAATAAATAATATAAGATTTTGATTATTACCACC  
ATCTTTAACACTTCTTATTATATCCTCTATAGTAGATAATGGAGCTGGGACAGGATG  
GACAGTTTACCCCCACTAGCAGGAGCTATTGCACACGGAGGATCTTCAGTAGATCT  
AGCCATTTTTTCACTTCATCTTGCTGGTGTTCATCAATTCTTGGAGCAGTAAATTTT  
ATTACAACAGCAATTAATATACGATCAGAAAGAATAACACTTGATCAAACACCATT  
ATTTGTTTGATCAGTAGCTATTACAGCTCTTTTATTATTATTATCATTACCAGTTTTAG  
CTGGAGCTATTACAATATTATTAACAGACCGAAACCTAAATACATCATTCTTTGACC  
CTGCAGGTGGAGGTGACCCAATTTTATATCAACACCTATTCTGATTTTTTGGTCA

(g) *Phlaeoba infumata*

TGATCTGGAATAGTAGGAACATCAATAAGAATAATTATTCGTGCAGAACTTGGTCAA  
CCTGGATCAATAATTGGAGATGATCAAATCTATAATGTAATTATTACAGCACATGCA  
TTTGAATAATTTTCTTTATAGTTATAACCAATTATAATTGGTGGATTTGGTAATTGAC  
TAGTACCATTAATAATTGGAGCACCAGATATAGCATTCCCTCGAATAAATAATATGA  
GATTCTGACTATTACCACCATCACTAACCCTTCTACTTACATCTTCAATAGTTGATAT  
AGGTGCAGGTACAGGTTGAACTGTATACCCACCAGTAGCTGGTGCTATTGCCACGG

---

AGGAGCATCTGTAGATTTAGCCATCTTTTCACTTCATTTAGCTGGTGTTCATCAATT  
CTAGGTGCAGTAAATTTTATTACAACAGCAATTAATATACGGTCAGAAAGAATAAC  
ATTTGATCAAACACCATTATTTGTATGATCAGTTGCTATCACAGCA\

(h) *Acrotylus patruelis*

CAAATCATAAGGATATTGGTACCTTATATTTTATATTTGGAGCATGAGCAGGAATAG  
TGGGAACATCAATAAGAATAATTATTCGTGCAGAATTAGGACAACCAGGATCTATA  
ATTGGAGATGACCAAATTTATAATGTTATTATTACAGCCCACGCATTCGTTATAATTT  
TCTTCATGGTTATACCTATTATAATTGGAGGATTCGGAAATTGACTTGTACCATTAAT  
AATTGGAGCACCAGATATAGCATTCCCACGAATAAATAATATAAGATTCTGACTTTT  
ACCACCATCACTGACCCTTCTTCTTCTTCTCTATAGTGGATAGCGGAGCTGGTACA  
GGATGAACAGTTTACCCCCACTAGCTGGAGCTATTGCTCACGGAGGAGCATCCGTA  
GATCTAGCCATTTTTTCACTCCACCTAGCAGGTGTATCATCAATTCTAGGAGCAGTTA  
ATTCATTACAACCTGCAATTAATATACGATCAGATAGAATAACAATAGACCAAACCC  
CTTTATTTGTATGATCAGTAGCAATTACAGCTTTACTATTATTATTATCATTACCAGT  
TCTTGC

(i) *Morphacris fasciata*

TTAGGACAACCAGGATCAATAATTGGAGATGACCAAATCTATAATGTAATTATTACA  
GCCCATGCATTTGTTATAATTTTCTTTATAGTTATACCAATTATAATTGGAGGATTTG  
GAAATTGGCTAGTACCATTAATAATTGGAGCACCAGACATAGCATTCCCCGAATAA  
ATAATATAAGATTTTGATTATTACCCCCATCATTAACTTTTACTTTTATCCTCAAT  
GGTTAATAATGGGGCTGGTACAGGCTGGACAGTATACCCACCACTAGCCAGAGTTA  
TTGCACATAGAGGGGCATCTGTAGATCTAGCCATTTTCTCTTTACATTTAGCAGGTAT  
TTCATCAATTCTAGGAGCAATCAATTTTATTACAACAGCAATTAATATACGATCAAA  
TAACATAACATTAGATCAAGCACCTTATTTGTTTGATCAGTTGCAATTACAGCTCTT  
TTATTACTACTATCATTACCTGTTCTAGCAGGAGCAATTACTATACTATTAACCGACC  
GAAATCTAAATACATCATTCTTTGACCCTGCTGGAGGAGGAGACCCAATTCTTTATT  
CAA

Figure - 60

Multiple sequence alignment of the acridids species using multiple align show

T.annulata	A	G	A	T	G	A	T	C	A	A	A	T	T	A	T	A	A	T	G	T	A	A	T	T	A	T	T	A	C	G	G	C	A	C	A	C	G	C	A	52				
A.patruelis	A	G	A	T	G	A	T	C	A	A	A	T	T	A	T	A	A	T	G	T	A	T	T	A	T	T	A	T	T	A	C	A	G	C	C	A	C	A	C	G	C	A	158	
O.abruptus	A	G	A	T	G	A	T	C	A	A	A	T	T	A	T	A	A	C	G	T	A	A	T	T	A	T	T	A	C	A	G	C	A	C	A	T	G	C	A		139			
O.fuscovittata	-	G	A	T	G	A	T	C	A	A	A	T	T	A	T	A	A	T	G	T	A	A	T	T	A	T	T	A	C	A	G	C	A	C	A	C	G	C	A	39				
P.infumata	A	G	A	T	G	A	T	C	A	A	A	T	T	A	T	A	A	T	G	T	A	A	T	T	A	T	T	A	C	A	G	C	A	C	A	T	G	C	A	114				
A.luteipes	A	G	A	T	G	A	T	C	A	A	A	T	T	A	T	A	A	T	G	T	A	A	T	T	A	T	T	A	C	A	G	C	A	C	A	T	G	C	A	139				
M.fasciata	A	G	A	T	G	A	T	C	A	A	A	T	T	A	T	A	A	T	G	T	A	A	T	T	A	T	T	A	C	A	G	C	C	A	T	G	C	A	66					
D.venusta	A	G	A	T	G	A	T	C	A	A	A	T	T	A	T	A	A	T	G	T	A	G	T	T	A	T	T	A	C	A	G	C	A	C	A	T	G	C	A	41				
L.indica	G	G	G	T	G	T	T	T	G	A	-	-	-	T	C	G	A	G	T	G	T	A	T	T	C	T	T	T	C	T	G	A	C	A	T	G	A	T	A	97				
T.annulata	T	T	T	G	T	T	A	T	A	A	T	T	T	T	C	T	T	A	T	A	G	T	T	A	T	A	T	A	C	C	A	A	T	T	A	T	A	A	T	T	G	92		
A.patruelis	T	T	C	G	T	T	A	T	A	A	T	T	T	T	C	T	T	C	A	T	G	T	T	A	T	A	T	A	C	C	T	A	T	T	A	T	A	A	T	T	G	198		
O.abruptus	T	T	T	G	T	A	T	A	A	T	T	T	T	T	C	T	T	A	T	A	G	T	T	A	T	A	T	A	C	C	A	A	T	T	A	T	A	A	T	T	G	179		
O.fuscovittata	T	T	T	G	T	T	A	T	A	A	T	T	T	T	T	T	C	A	T	A	G	T	T	A	T	A	T	A	C	C	A	A	T	T	A	T	A	A	T	T	G	79		
P.infumata	T	T	T	G	T	A	T	A	A	T	T	T	T	T	T	C	T	T	A	T	A	G	T	T	A	T	A	T	A	C	C	A	A	T	T	A	T	A	A	T	T	G	154	
A.luteipes	T	T	T	G	T	A	T	A	A	T	T	T	T	T	T	T	T	T	A	T	A	G	T	A	A	T	A	T	A	C	C	T	A	T	T	A	T	A	A	T	T	G	179	
M.fasciata	T	T	T	G	T	T	A	T	A	A	T	T	T	T	T	C	T	T	A	T	A	G	T	T	A	T	A	T	A	C	C	A	A	T	T	A	T	A	A	T	T	G	106	
D.venusta	T	T	T	A	T	T	A	T	A	A	T	T	T	T	T	C	T	T	A	T	A	G	T	A	A	T	A	T	A	C	C	A	A	T	T	A	T	A	A	T	T	G	81	
L.indica	T	T	A	A	T	T	G	C	T	G	T	T	G	T	A	A	T	A	A	A	T	T	T	A	C	T	G	C	T	C	T	A	G	A	A	T	T	G	A	A	T	T	G	137
T.annulata	G	A	G	G	A	T	T	T	G	G	A	A	A	T	T	G	A	T	T	A	G	T	T	C	C	A	T	T	A	A	T	A	A	T	T	G	G	-	A	G	131			
A.patruelis	G	A	G	G	A	T	T	C	G	G	A	A	A	T	T	G	A	C	T	T	G	T	A	C	C	A	T	T	A	A	T	A	A	T	T	G	G	-	A	G	237			
O.abruptus	G	A	G	G	A	T	T	T	G	G	A	A	A	C	T	G	A	T	T	A	G	T	T	C	C	A	T	T	A	A	T	A	A	T	T	G	G	-	A	G	218			
O.fuscovittata	G	T	G	G	A	T	T	T	G	G	T	A	A	T	T	G	A	T	T	A	G	T	T	C	C	A	T	T	A	A	T	A	A	T	T	G	G	-	A	G	118			
P.infumata	G	T	G	G	A	T	T	T	G	G	T	A	A	T	T	T	G	A	C	T	A	G	T	A	C	C	A	T	T	A	A	T	A	A	T	T	G	G	-	A	G	193		
A.luteipes	G	G	G	G	A	T	T	T	G	G	A	A	A	T	T	G	A	C	T	C	G	T	T	C	C	T	T	A	A	T	A	A	T	T	G	G	-	T	G	218				
M.fasciata	G	A	G	G	A	T	T	T	G	G	A	A	A	T	T	G	G	C	T	A	G	T	A	C	C	A	T	T	A	A	T	A	A	T	T	G	G	-	A	G	145			
D.venusta	G	A	G	G	A	T	T	T	G	G	A	A	A	T	T	G	A	C	T	T	G	T	A	C	C	A	C	T	T	A	A	T	A	A	T	T	G	G	-	A	G	120		
L.indica	A	T	G	A	A	A	T	-	-	-	-	A	C	C	T	G	C	T	A	G	T	G	T	A	A	T	G	A	A	A	G	A	T	G	G	C	T	A		173				
T.annulata	C	A	C	C	A	G	A	T	A	T	A	G	C	C	T	T	T	C	C	C	G	-	-	-	A	A	T	A	A	A	T	A	A	C	A	T	A	A	G	168				
A.patruelis	C	A	C	C	A	G	A	T	A	T	A	G	C	A	T	T	C	C	A	C	G	-	-	-	A	A	T	A	A	A	T	A	A	T	A	T	A	A	G	274				
O.abruptus	C	A	C	C	A	G	A	T	A	T	A	G	C	A	T	T	C	C	A	C	G	-	-	-	A	A	T	A	A	A	T	A	A	C	A	T	A	A	G	255				
O.fuscovittata	C	A	C	C	A	G	A	T	A	T	A	G	C	A	T	T	C	C	A	C	G	-	-	-	A	A	T	A	A	A	T	A	A	T	A	T	A	A	G	155				
P.infumata	C	A	C	C	A	G	A	T	A	T	A	G	C	A	T	T	C	C	T	C	G	-	-	-	A	A	T	A	A	A	T	A	A	T	A	T	A	G	A	230				
A.luteipes	C	A	C	C	A	G	A	T	A	T	A	G	C	A	T	T	C	C	A	C	G	-	-	-	A	A	T	A	A	A	T	A	A	T	A	T	A	G	A	255				
M.fasciata	C	A	C	C	A	G	A	T	A	T	A	G	C	A	T	T	C	C	C	C	G	-	-	-	A	A	T	A	A	A	T	A	A	T	A	T	A	A	G	182				
D.venusta	C	A	C	C	A	G	A	T	A	T	A	G	C	A	T	T	C	C	A	C	G	-	-	-	A	A	T	A	A	A	C	A	A	T	A	T	A	A	G	157				
L.indica	A	G	T	C	A	A	C	T	G	A	A	G	C	A	C	C	T	C	G	T	G	C	G	C	A	A	T	A	G	C	T	C	T	G	C	T	A	G	213					
T.annulata	A	T	T	T	T	G	A	T	T	A	T	T	A	C	C	A	T	C	A	T	T	A	A	T	C	T	C	C	T	T	A	T	A	C	A				208					
A.patruelis	A	T	T	C	T	G	A	C	T	T	T	T	A	C	C	A	T	C	A	C	T	G	A	C	C	T	T	C	T	T	C	T	T	T	C	T	T		314					
O.abruptus	A	T	T	T	T	G	A	T	T	A	T	T	A	C	C	A	T	C	A	T	T	A	A	C	A	C	T	C	T	T	A	T	T	C	T	A		295						
O.fuscovittata	A	T	T	T	T	G	A	T	T	A	T	T	A	C	C	A	T	C	T	T	T	A	A	C	A	C	T	T	C	T	T	A	T	T	A		195							
P.infumata	A	T	T	C	T	G	A	C	T	A	T	T	A	C	C	A	T	C	A	C	T	A	A	C	C	T	T	C	T	A	C	T	T	A		270								
A.luteipes	A	T	T	T	T	G	A	T	T	A	T	T	A	C	C	A	T	C	A	T	T	A	A	C	A	C	T	T	T	T	A	T	T	A		295								
M.fasciata	A	T	T	T	T	G	A	T	T	A	T	T	A	C	C	C	A	T	C	A	T	T	A	A	C	A	C	T	T	T	A	C	T	T	T	A		222						
D.venusta	A	T	T	T	T	G	A	A	T	G	T	T	A	C	C	C	A	T	C	A	T	T	A	A	C	A	C	T	C	T	T	A	T	T	T	A		197						
L.indica	G	G	G	G	G	G	T	A	A	A	C	T	G	T	T	C	A	T	C	T	G	T	A	C	C	A	C	C	A	C	A	T	T	A	T	A	C	A		253				
T.annulata	T	C	C	T	C	A	A	T	A	G	T	T	G	A	T	A	G	C	G	G	A	G	C	C	G	G	T	A	C	A	G	G	A	T	G	A	A	C	A	G	248			
A.patruelis	T	C	C	T	C	T	A	T	A	G	T	G	A	T	A	G	C	G	G	A	G	C	T	G	G	T	A	C	A	G	G	A	T	G	A	A	C	A	G	354				
O.abruptus	T	C	C	T	C	T	T	A	G	T	A	G	A	A	A	A	T	G	G	A	G	T	A	G	A	A	C	A	G	G	A	T	G	A	A	C	A	G	335					
O.fuscovittata	T	C	C	T	C	T	A	T	A	G	T	A	G	A	T	A	T	G	G	A	G	C	T	G	G	A	C	A	G	G	A	T	G	A	C	A	G	235						
P.infumata	T	C	T	T	C	A	A	T	A	G	T	T	G	A	T	A	T	A	G	G	T	G	C	A	G	G	T	A	C	A	G	G	T	T	G	A	A	C	T	G	310			
A.luteipes	T	C	T	T	C	T	A	T	A	G	T	T	G	A	C	A	T	A	G	G	G	C	A	G	G	C	A	G	G	A	T	G	A	A	C	A	G	335						
M.fasciata	T	C	C	T	C	A	A	T	A	G	G	T	T	A	A	T	A	T	A	T	G	G	G	C	T	G	G	T	A	C	A	G	G	C	T	G	A	C	A	G	262			
D.venusta	T	C	C	T	C	A	A	T	A	A	T	T	G	A	T	G	A	T	G	A	G	A	G	A	G	A	C	A	G	G	A	C	A	G	G	A	C	A	G	A	C	A	G	237
L.indica	A	C	T	A	T	T	G	A	A	G	A	C	G	T	G	A	G	A	A	G	A	A	G	T	G	T	A	A	A	G	A	T	G	T	G	T	G	A	A		293			

Contd...

T.annulata	T T T A C C C C C C A T T A G C A G G A G C T A T T G C T C A T G G A G G A G C	288
A.patruelis	T T T A C C C C C C A C T A G C T G G A G C T A T T G C T C A C G G A G G A G C	394
O.abruptus	T T T A T C C A C C C A T T A G C A A G A G T T A T T G C A C A C A G A G G A G C	375
O.fuscovittata	T T T A C C C C C C A C T A G C A G G A G C T A T T G C A C A C G G A G G A T C	275
P.infumata	T A T A C C C A C C A C T A G C T G G T G C T A T T G C C C A C G G A G G A G C	350
A.luteipes	T T T A C C C A C C T C T A G C A G G A G C T A T T G C A C A C G G A G G A G G	375
M.fasciata	T A T A C C C A C C A C T A G C C A G A G T T A T T G C A C A T A G A G G G G C	302
D.venusta	T A T A C C C A C C A C T A G C A G G A G C T A T T G C A C A C G G A G G T G C	277
L.indica	A A A G T C A G A A T C T T A T A T T A T T T A T T C G A G G A A A T G C T A T	333
T.annulata	A T C A G T A G A T T T A G C T A T T T T T T C C T T G C A T T T A G C A G G T	328
A.patruelis	A T C C G T A G A T C T A G C C A T T T T T T C A C T C C A C C T A G C A G G T	434
O.abruptus	A T C C G T A G A T A T A G C A A T T T T T T C A T T A C A C C T A G C A G G T	415
O.fuscovittata	T T C A G T A G A T C T A G C C A T T T T T T C A C T T C A T C T T G C T G G T	315
P.infumata	A T C T G T A G A T T T A G C C A T C T T T T C A C T T C A T T T A G C T G G T	390
A.luteipes	A T C C G T T G A T C T A G C T A T T T T C T C C C T T C A T T T A G C C G G T	415
M.fasciata	A T C T G T A G A T C T A G C C A T T T T C T C T T T A C A T T T A G C A G G T	342
D.venusta	A T C A G T A G A T C T A G C A A T T T T T T C A T T A C A T T T A G C A G G A	317
L.indica	A T C T G G T G C T C C A A T T A T T A A A G G T A C T A A T C A A T T C C C A	373
T.annulata	G T T T C T T C A T T C T A G G A G C A G T T A A T T T T A T T A C A A C A G	368
A.patruelis	G T A T C A T C A A T T C T A G G A G C A G T T A A T T T C A T T A C A A C T G	474
O.abruptus	A T T T C A T C A A T T C T T G G A G C A A T T A A C T T C A T T A C A A C A G	455
O.fuscovittata	G T T T C A T C A A T T C T T G G A G C A G T A A A T T T T A T T A C A A C A G	355
P.infumata	G T T T C A T C A A T T C T A G G T G C A G T A A A T T T T A T T A C A A C A G	430
A.luteipes	G T A T C C T C T A T T C T A G G A G C A G T A A A C T T T A T T A C T A C A G	455
M.fasciata	A T T T C A T C A A T T C T A G G A G C A A T C A A T T T T A T T A C A A C A G	382
D.venusta	A T T T C A T C A A T T C T A G G A G C A G T T A A T T T T A T T A C A A C A G	357
L.indica	A A T C C A C C A A T T A T A A T A G G T A T A A C T A T A A A G A A A A T T A	413
T.annulata	T A A T T A A T A T A C G A T C A G A A A G A A T A A C T T T A G A - - - T C A	405
A.patruelis	C A A T T A A T A T A C G A T C A G A T A G A A T A A C A A T A G A - - - C C A	511
O.abruptus	C A A T C A A T A T A C G A C C A A A T A A T A T A A C T C T T G A - - - A C A	492
O.fuscovittata	C A A T T A A T A T A C G A T C A G A A A G A A T A A C A C T T G A - - - T C A	392
P.infumata	C A A T T A A T A T A C G G T C A G A A A G A A T A A C A T T T G A - - - T C A	467
A.luteipes	C A A T T A A T A T A C G A T C T G A A A G T A T A A C C C T A G A - - - T C A	492
M.fasciata	C A A T T A A T A T A C G A T C A A A T A A C A T A A C A T T A G A - - - T C A	419
D.venusta	C A A T T A A T A T A C G A T C A A A C A G A A T A A C C T T A G A - - - C C A	394
L.indica	T T A C G A A T G C G T G A G C T G A A A T A A T T A C T T T A T A A A T T T G	453
T.annulata	A A C A C C A T T A T T T G T T T G A T C T G T T G C A A T T A C A G C A A T T	445
A.patruelis	A A C C C C T T T A T T T G T A T G A T C A G T A G C A A T T A C A G C T T T A	551
O.abruptus	A A C A C C G T T A T T T G T A T G A T C A G T A G C A A T T A C A G C A T T A	532
O.fuscovittata	A A C A C C A T T A T T T G T T T G A T C A G T A G C T A T T A C A G C T C T T	432
P.infumata	A A C A C C A T T A T T T G T A T G A T C A G T T G C T A T C A C A G C A - - -	504
A.luteipes	A A C A C C A T T A T T T G T C T G A T C A G T T G C T A T T A C A G C A T T A	532
M.fasciata	A G C A C C C T T A T T T G T T T G A T C A G T T G C A A T T A C A G C T C T T	459
D.venusta	A A C A C C A C T A T T T G T T T G A T C A G T T G C A A T T A C A G C A T T A	434
L.indica	A T C A T C T C C A A T T A G A - G A T C C - T G G T T G C C C G A G T T C T G	491

Note: Identical amino acids residues were highlighted in brown colour and similar residues were given in blue colour. The remaining nucleotides gaps and missing data showed in colourless.

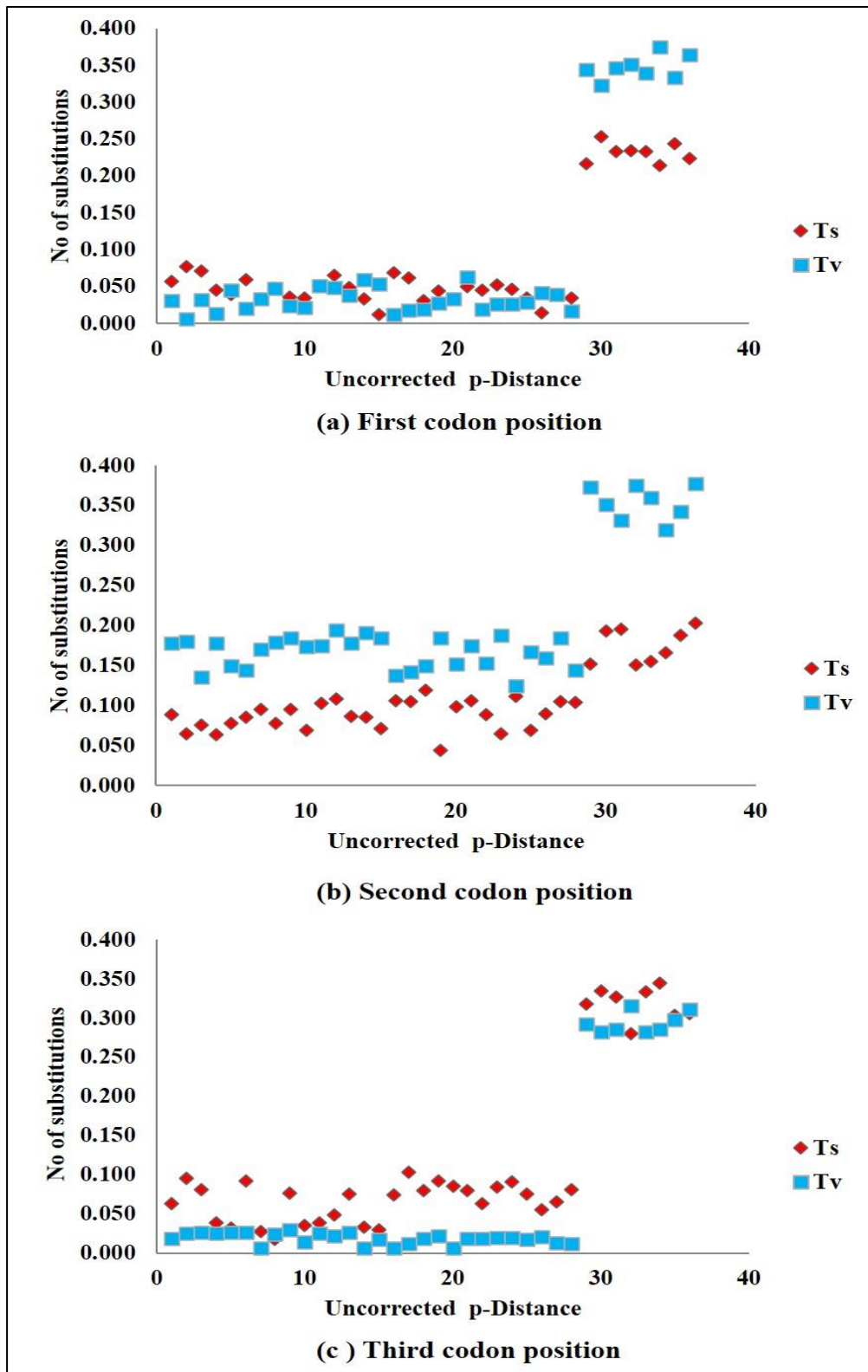


Figure - 61

Scatter plots showing the substitution rates among acridids

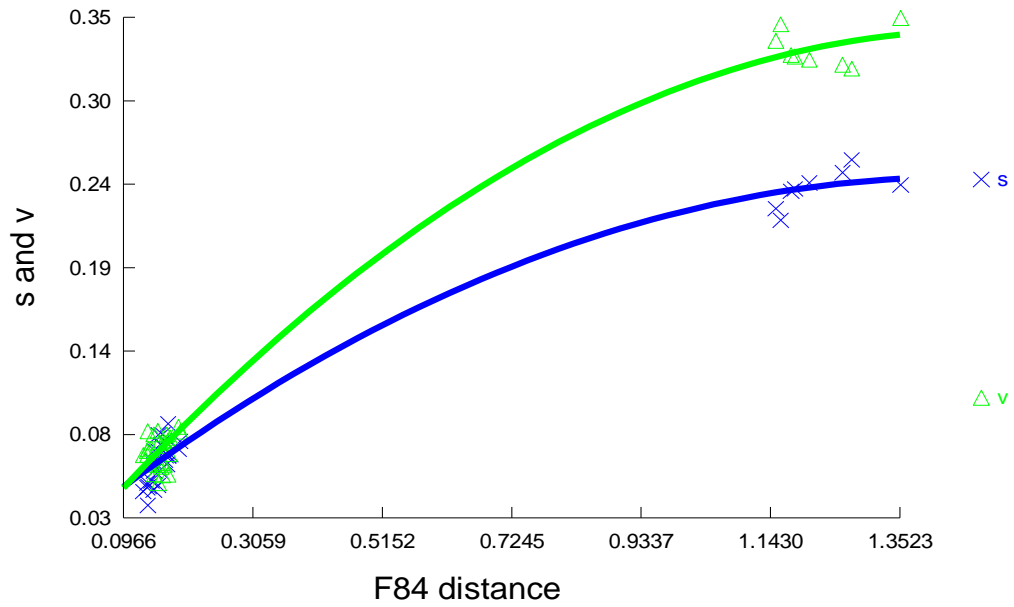


Figure - 62

Overall estimation of nucleotide sequence transition and transversion displayed against F84 genetic divergence of COI sequence

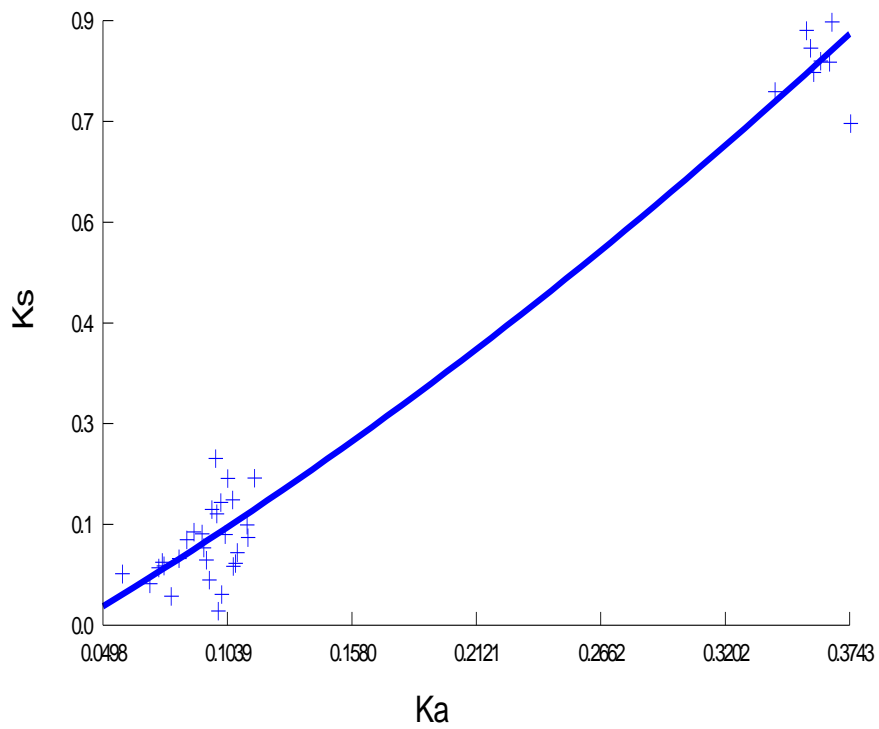


Figure - 63

Rate of non-synonymous substitutions (Ka) and synonymous substitutions (Ks)

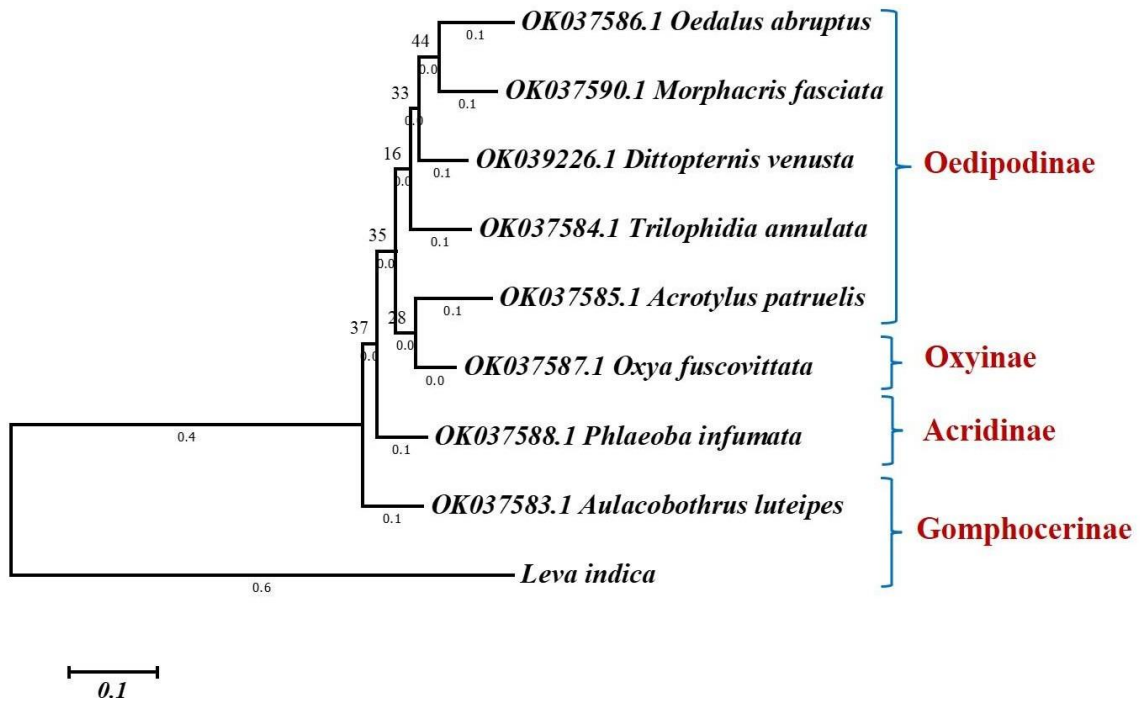


Figure - 64

Phylogenetic relationship among selected acridids using Neighbor-Joining method

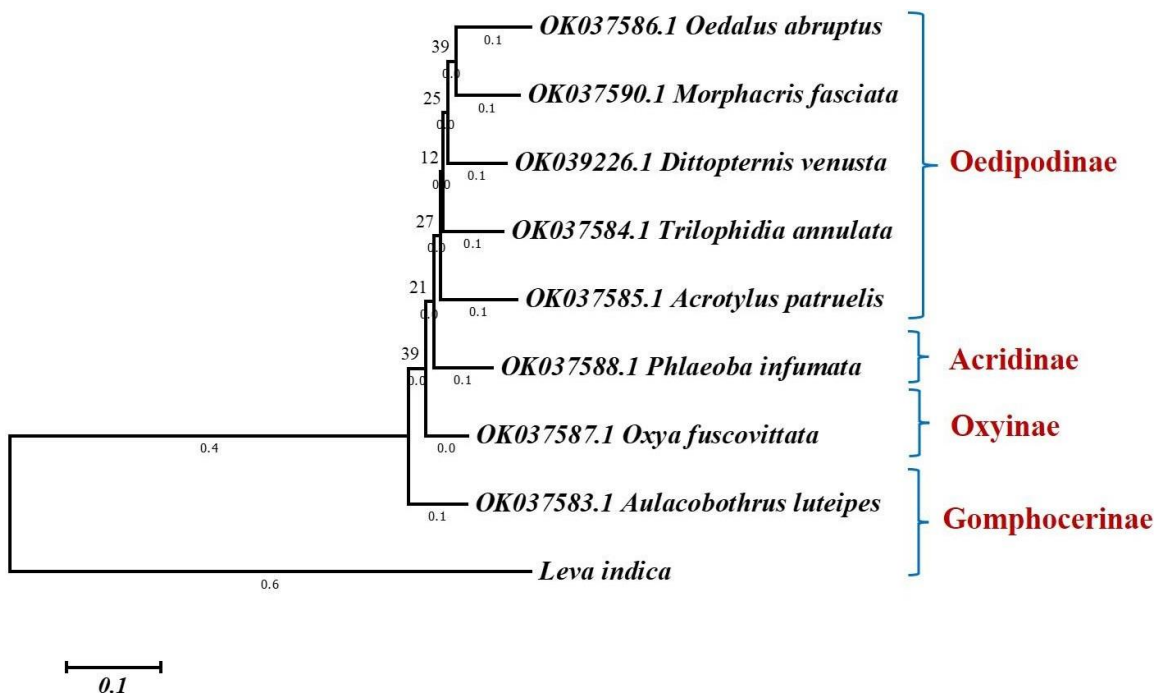


Figure - 65

Phylogenetic relationship among selected acridids using Maximum Likelihood method

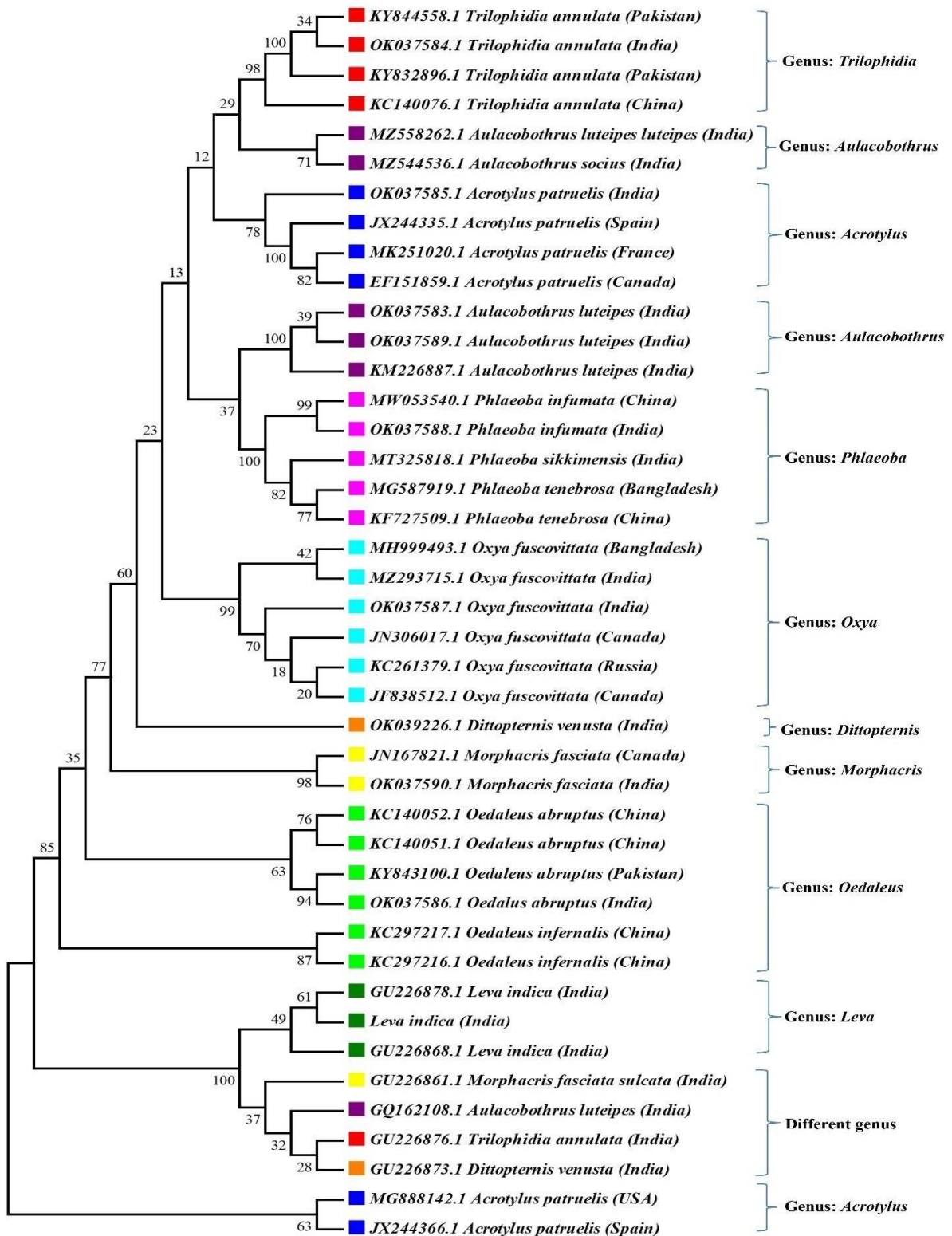


Figure - 66

Phylogenetic analysis of selected acridids and its haplotypes retrieved from NCBI database

Table - 41

## Summary of similarity identification of acridids using BLAST

Name of Queried sequence from this study	Name of subjected sequences from NCBI database	Matched location	BLAST parameters					
			Maximum score	Query coverage	E-value	No. of gaps	Percentage of identity	Strand
<i>Trilophidia annulata</i> OK037584.1	<i>Trilophidia annulata</i> GU226876.1	India	887	99	0	0	100	Plus/Minus
<i>Aulacothrus luteipes</i> OK037583.1	<i>Aulacothrus luteipes</i> KM226887.1	India	1026	100	0	0	100	Plus/Plus
<i>Leva indica</i> (Submitted to Genbank)	<i>Leva indica</i> GU226878.1	India	924	94	0	2	96.92	Plus/Plus
<i>Oedalus abruptus</i> OK037586.1	<i>Oedalus abruptus</i> KY843100.1	Canada	1024	100	0	0	100	Plus/Plus
<i>Dittopternis venusta</i> OK039226.1	<i>Dittopternis venusta</i> GU226873.1	India	924	100	0	0	98.66	Plus/Plus
<i>Oxya fuscovittata</i> OK037587.1	<i>Oxya fuscovittata</i> KC261379.1	Russia	1057	100	0	0	100	Plus/Plus
<i>Phlaeoba infumata</i> OK037588.1	<i>Phlaeoba infumata</i> MW053540.1	China	931	100	0	0	100	Plus/Plus
<i>Acrotylus patruelis</i> OK037585.1	<i>Acrotylus patruelis</i> MG888075.1	USA	1072	100	0	0	100	Plus/Plus
<i>Morphacris fasciata</i> OK037590.1	<i>Morphacris fasciata</i> GU226861.1	India	1066	100	0	0	100	Plus/Plus

Table - 42

Total number of nucleotides composition and its percentages among acridids

Species	A	C	G	T	A+T	G+C	Length
<i>T. annulata</i>	151 31.39%	83 17.26%	76 15.80%	171 35.55%	322 66.94%	159 33.06%	481
<i>A. luteipes</i>	173 31.17%	100 18.02%	92 16.58%	190 34.23%	363 65.41%	192 34.59%	555
<i>L. indica</i>	194 33.28%	93 15.95%	109 18.70%	187 32.08%	381 65.35%	202 34.65%	583
<i>O. abruptus</i>	202 30.34%	98 14.83%	82 17.93%	172 36.90%	374 67.24%	180 32.76%	554
<i>D. venusta</i>	181 34.74%	97 18.62%	76 14.59%	167 33.05%	348 66.79%	173 33.21%	521
<i>O. fuscovittata</i>	181 31.42%	102 17.91%	85 15.37%	204 35.30%	385 66.72%	187 33.28%	572
<i>P. infumata</i>	166 32.94%	89 17.66%	83 16.47%	166 32.94%	332 65.87%	172 34.13%	504
<i>A. patruelis</i>	185 34.17%	112 18.81%	96 14.78%	187 32.25%	372 66.41%	208 33.59%	580
<i>M. fasciata</i>	189 31.37%	112 20.28%	86 14.56%	190 33.80%	379 65.16%	198 34.84%	577
<b>Total</b>	1622	886	785	1634	3256	1671	4927

Table - 43

Nucleotide substitution saturation test (DAMBE) in acridids

S.no	Parameter	Value
1.	Mean H	1.2465
2.	Standard Error	0.0408
3.	Hmax	0.0408
4.	<i>I<sub>ss</sub></i>	0.6582
5.	<i>I<sub>ss.c</sub></i>	0.7553
6.	T	0.0715
7.	DF	699
8.	Prob (two tailed)	0.9430
9.	95% lower limit	0.6783
10.	95% upper limit	0.8382

Note: T: T value, DF: degree of freedom, P: probability that *I<sub>ss</sub>* is significantly lower than the critical value *I<sub>ss.c</sub>*. Two –tailed tests were performed with 10000 replications

Table - 44

## Estimation of transition/transversion bias

	A	T	C	G
A		<i>6.7969</i>	<i>6.7969</i>	<b>11.4063</b>
T	<i>6.7969</i>		<b>11.4063</b>	<i>6.7969</i>
C	<i>6.7969</i>	<b>11.4063</b>		<i>6.7969</i>
G	<b>11.4063</b>	<i>6.7969</i>	<i>6.7969</i>	

Note: Rates of different transitional substitutions are shown in bold and those of transversional substitutions are shown in italics.

Table - 45

## Average evolutionary divergence over all sequence pairs

	d	S.E
Over all	0.357	0.025

Table - 46

## K2P pair wise comparison of genetic distance among acridids

Species	<i>T. annulata</i>	<i>A. luteipes</i>	<i>L. indica</i>	<i>O. abruptus</i>	<i>D. venusta</i>	<i>O. fuscovittata</i>	<i>P. infumata</i>	<i>A. patruelis</i>	<i>M. fasciata</i>
<i>T. annulata</i>	-								
<i>A. luteipes</i>	0.164	-							
<i>L. indica</i>	1.071	1.095	-						
<i>O. abruptus</i>	0.168	0.17	1.13	-					
<i>D. venusta</i>	0.143	0.166	1.219	0.157	-				
<i>O. fuscovittata</i>	0.133	0.15	1.078	0.16	0.144	-			
<i>P. infumata</i>	0.133	0.134	1.091	0.166	0.14	0.127	-		
<i>A. patruelis</i>	0.162	0.183	1.169	0.157	0.161	0.135	0.144	-	
<i>M. fasciata</i>	0.151	0.186	1.107	0.155	0.144	0.153	0.151	0.166	-

Table - 47

## List of haplotype sequences retrieved from GenBank

S.No.	Name of the species	GenBank accession no	Locality
1.	<i>Trilophidia annulata</i>	GU226876.1	India
2.	<i>Trilophidia annulata</i>	KY844558.1	Pakistan
3.	<i>Trilophidia annulata</i>	KY832896.1	Pakistan
4.	<i>Trilophidia annulata</i>	KC140076.1	China
5.	<i>Phlaeoba infumata</i>	MW053540.1	China
6.	<i>Phlaeoba tenebrosa</i>	MG587919.1	Bangladesh
7.	<i>Phlaeoba tenebrosa</i>	KF727509.1	China
8.	<i>Phlaeoba sikkimensis</i>	MT325818.1	India
9.	<i>Acrotylus patruelis</i>	MK251020.1	France
10.	<i>Acrotylus patruelis</i>	MG888142.1	USA
11.	<i>Acrotylus patruelis</i>	EF151859.1	Canada
12.	<i>Acrotylus patruelis</i>	JX244366.1	Spain
13.	<i>Acrotylus patruelis</i>	JX244335.1	Spain
14.	<i>Oedaleus abruptus</i>	KC140052.1	China
15.	<i>Oedaleus abruptus</i>	KC140051.1	China
16.	<i>Oedaleus abruptus</i>	KY843100.1	Pakistan
17.	<i>Oedaleus infernalis</i>	KC297217.1	China
18.	<i>Oedaleus infernalis</i>	KC297216.1	China
19.	<i>Oxya fuscovittata</i>	KC261379.1	Russia
20.	<i>Oxya fuscovittata</i>	JN306017.1	Canada
21.	<i>Oxya fuscovittata</i>	MH999493.1	Bangladesh
22.	<i>Oxya fuscovittata</i>	MZ293715.1	India
23.	<i>Oxya fuscovittata</i>	JF838512.1	Canada
24.	<i>Aulacobothrus luteipes</i>	KM226887.1	India
25.	<i>Aulacobothrus luteipes</i>	GQ162108.1	India
26.	<i>Aulacobothrus luteipes luteipes</i>	MZ558262.1	India
27.	<i>Aulacobothrus luteipes</i>	OK037583.1	India
28.	<i>Aulacobothrus socius</i>	MZ544536.1	India
29.	<i>Dittopternis venusta</i>	GU226873.1	India
30.	<i>Morphacris fasciata</i>	JN167821.1	Canada
31.	<i>Morphacris fasciata sulcata</i>	GU226861.1	India
32.	<i>Leva indica</i>	GU226878.1	India
33.	<i>Leva indica</i>	GU226868.1	India

## **Discussion**

The COI molecular marker has been demonstrated informative and valuable for comparison within and between species of Acrididae in some previous studies (Huang *et al.*, 2013; Gu *et al.*, 2020; Guzmán and Confalonieri, 2010; Husemann *et al.*, 2013; Pocco *et al.*, 2015). The present research generated the COI barcodes for dominant acridids and established the utility of DNA barcodes in discriminating the species despite the prior taxonomic work.

The COI gene was used to distinguish all of the species that were used in this investigation. Based on the COI marker profile nine acridids species were accurately and successfully identified in the current study. DNA-based identification methods require achieving three significant facts: Obtaining target genomic DNA from the sample species, evaluating the target species' sequencing information is simple and utilizing the sequence data to differentiate between species and sub-species level identification (Murugan *et al.*, 2016). In this investigation, no pseudogenes were discovered in the sequence and the targeted COI gene segment allowed for accurate species identification based on taxonomic analyses. In BLAST, the maximum identity values supported the precise identification of the selected species. BLAST searches of COI sequence of acridids revealed 97 to 100% homology with sequence. BLAST finds the regions of similarity and compares nucleotides between sequenced data and the already existing sequence in the NCBI database.

The variation and similarity of nucleotide among acridids were recognized in view of the mitochondrial DNA of the COI gene. Mitochondrial DNA is used as a popular markers system in insects genetic research because of their haploid status, maternal inheritance and high rate of evolution. Further benefit of employing mtDNA in insects is that many of these loci can be amplified quickly using universal primers derived from highly conserved mitochondrial genes (Lunt *et al.*, 1996; Lanave *et al.*, 2002). These marker loci are favoured to construct phylogenies and infer evolutionary history for ecological studies due to their greater evolutionary rate (Behura, 2006). Mitochondrial genes have emerged as the most important molecular tool for studying Orthopteran genetic variation.

The assessment of nucleotide substitution in the sequence of this study showed the largest transition and transversion were found in AT and CT, while the lowest were found in GC and AG, respectively. However, the rate of transversions occurred faster than transition.

The mitochondrial COI gene sequence in this study was AT-rich, as expected and this is consistent with prior findings (Rivera and Currie, 2009). High AT contents and variables distance-dependent transition/transversion ratios (TR/TV) are typical of mtDNA in many insects (Simon *et al.*, 1994), including grasshoppers (Chapco *et al.*, 1999).

Further, the second codon had a high substitution rate compared to the first and third codon. The transversion and transitions rate revealed a steady plot pattern along the increasing p- distance, which probably suggested for negligible saturation of sequences.

Estimating synonymous and non-synonymous alterations in the nucleotide sequence could reveal a population's evolutionary divergence. The rate of synonymous substitution is substantially higher than non-synonymous substitution and is similar for many genes; synonymous substitutions can be used as a molecular clock to date the evolutionary time of closely related species (Kafatos *et al.*, 1977; Miyata *et al.*, 1980). In addition to the above, the nucleotide sequences of the current study were calculated for synonymous (Ks) and non-synonymous (Ka) and obviously, the rate of Ks clearly outperforming Ka in overall comparisons. Typically, Ka/Ks defines the ratio of the number of non-synonymous substitutions per non- synonymous site (Ka) to the number of synonymous substitutions per synonymous site (Ks); these serve as a crucial component in establishing the evolution selection pressure of an organism. As a result, Ka/Ks was estimated for the mitochondrial nucleotide sequences in this study as a useful and supportive measure. Estimating non-synonymous (Ka) and synonymous (Ks) substitution rates is critical for phylogeny reconstruction and understanding evolutionary dynamics of protein-coding regions across closely related and yet divergent species (Fay and Wu, 2003).

The wide difference in the nucleotide substitution among acridids due to species from different genus. Indeed, it was obvious that no major saturation happened in succession because the value of  $I_{ss.c}$  was bigger than  $I_{ss}$  ( $I_{ss} < I_{ss.c}$ ). This result confirmed that the sequences had not reached saturation and that they could be used to infer phylogenetic information and reconstruct phylogenies. Similar results were seen in a mosquito, a linear relationship between transitions and transversions, indicating that they were not saturated (Murugan *et al.*, 2016).

Pair-wise DNA sequence genetic distances among the Acridid species ranged significantly. It is assumed that the species group having higher divergence might be due to

the faster nucleotide substitution and divergence rate. This shows a high level of genetic divergence rate even among the species of the family Acrididae and their separate lineage, which is not necessarily manifested at the morphological level.

According to Dwivedi and Gadagkar (2009) and Murugan *et al.*, (2016) DNA sequences were characterized by summary statistics such as length and base composition; when the nucleotide sequences are compared with one another before phylogenetic analysis, additional parameters such as the ratio of two specific instantaneous rates of substitution at which transitions and transversions occur, the overall rate of nucleotide substitution and the rate variation among sites play a significant role and they are necessary for accurate reconstruction of the phylogeny. In the present study, phylogenetic tree of related individuals were clustered together and established species relationships. A phylogenetic tree is a diagram that depicts the relationships between species (or sequences) and their hypothetical common ancestors (Nei and Kumar, 2000; Felsenstein, 2001). These methods are a more effective and specific tool for discrimination between cryptic species and discovering new species based on nucleotide sequence divergence.