2

Review of Literature

The literature pertaining to the diversity and population dynamics of Orthoptera fauna and their relationship with meteorological parameters and host plant as well as to understand their morphology and molecular evolutionary history in a different region is reviewed under the following headings:

2.1 Status of Orthopterans diversity in India

Stal (1873) worked on Orthopteran fauna belonging to the family Locustidae and established new genera in this family. Saussure (1884 and 1888) and Boliver (1902,1909 &1917-1918) worked on the Orthoptera inhabiting in Indian Subcontinant. Uvarov (1921, 1924, 1927 &1942) contributed to the Indian species of Orthopteran fauna in the distributional records.

The major work on Indian Orthoptera (Caelifera) was published by Kirby (1914) who made a faunistic description in his book of *Fauna of British India* which is very helpful even today, wherein 329 species belonging to 124 genera and eight subfamilies were reported. Shishodia and Hazra (1985) reported 36 species of Orthoptera fauna from the Namdapha Wild Life Sanctuary of Tirap District, Arunachal Pradesh. Tandon (1988) studied subfamily Oxyinae represented in the Indian region by nine genera and 22 species.

Muralirangan *et al.* (1992) studied on short-horned grasshoppers (Acridoidea) in different parts of Tamil Nadu. They have recorded 20 species of acridids under eight subfamilies namely, Hemiacridinae, Oxyinae, Coptacridinae, Tropidopolinae, Caloptinae, Eyprepocnemidinae, Catantopinae and Cyrtacanthacridinae. Shrinivasan and Muralirangan (1992) collected 18 acridids species under four subfamilies (Acridinae, Truxalinae, Comphocerinae and Locustinae) in Tamil Nadu.

Sanjayan (1994) sampled grasshopper in an agroecosystem of Tamil Nadu on major crops such as *Oryza sativa, Arachis hypogaea, Phaseolus radiatus, Sorghum vulgare,* as well as fodder crops *Coix lachryma* and *Panicum maximum.* He has listed the 33 species belonging to two families of the order Orthoptera namely Pyrgomorphidae and Acrididae.

The following 10 species are more commonly encountered and regarded as core species: *Acrida exaltata, Aiolopus thalassinus, Atractomorpha crenulata, Diabolocatantops pinguis, Eyprepocnemis alacris alacris, Oxya nitidula, Oxya fuscovittata*, *Spathosternum prasiniferum prasiniferum, Orthacris maindroni* and *Chrotogonus oxypterus.*

Ghosh (1996) included 900 species of Orthoptera from India and 790 species belonging to 329 genera are reported in 'Faunal Diversity in India' by Tandon and Hazra (1998). Joshi *et al.* (1999) evaluated the species composition and community structure of the acridoid fauna in selected habitats of a moist deciduous forest in India.

Chitra *et al.* (2000) recorded the presence of 50 species of Orthoptera which included eight long-homed grasshoppers, 28 short horned grasshoppers, three crickets, one tree cricket and 10 pygmy grasshoppers in rice ecosystem at paddy breeding station and wetlands of Tamil Nadu Agricultural University, Coimbatore. Dey and Hazra (2003) descried the diversity and distribution of Orthoptera fauna in Kolkata. Altogether 35 species under 29 genera of the families Pyrgomorphidae and Acrididae were found.

Kandibane *et al.* (2004) revealed the occurrence of 21 species of grasshoppers and four species of crickets in the rice ecosystem. Among the short-horned grasshoppers, two species, *viz*., *Oxya nittitula* and *O. fuscovittata* were the common and dominant taxa in both the ecosystems. Among the long-horned grasshoppers (Tettigoniidae), *Spheneroptera gracilis*, *Conocephalus maculatus*, *C. chinensis* and *Holochlora albida* were the common species but *C. maculatus* was the dominant taxon. Four species of crickets, namely *Metioche vitatticollis*, *Telogryllus* sp., *Modygryllus* sp. and *Gryllodes sigillatus* were common. Among them, *M. vitatticollis* was dominant and more abundant.

Mayya *et al.* (2005) documented 28 species of short-horned grasshoppers (Acrididae) from Dakshina Kannada District, Karnataka. *Acrida exaltata, Dociostaurus sp.* and *Stauroderus bicolor* were relatively abundant than other species from subfamily Acridinae. *Morphacris fasciata, Dittopternis venusta, Oedaleus abruptus* and *Acrotylus humbertianus* were very much abundant than the other species from subfamily Oedipodinae.

Senthilkumar *et al.* (2006) listed the 25 species of Orthopterans under 21 genera and 12 families from Gibbon Wildlife Sanctuary, Assam. Chandra *et al.,* (2007) recorded 139 species of Orthoptera belonging to 12 families in Madhya Pradesh and Chattisgarh.

Muralidharan (2009) investigated the presence of 17 grasshopper species which were active from July to March with peak period of activity in the month of December. Shishodia and Gupta (2009) observed 165 species of grasshoppers under 16 families in Himachal Pradesh.

Ananthaselvi *et al.* (2009) identified 31 species of acridids belonging to the families Acrididae and Pyrgomorphidae. Acrididae represented by 25 species (10 subfamilies and 22 genera) and Pyrgomorphidae comprised of six species (5 genera). The highest number of species (6) were recorded from the subfamily Locustinae of Acrididae family. Among the Acridids collected, 18 species were recorded as core species and other 13 species were designated as a satellite species based on their moderate or sporadic distribution. The feeding guild of recorded acridids revealed that nine species are grass feeders, one species is a dicot feeder and 21 species are mixed feeders.

Paulraj *et al.* (2009) surveyed the grasshoppers diversity among different host plants in nine localities of Tamil Nadu. The presence of 33 grasshopper species grouped under four families were recorded. Family Acrididae was found to be the predominant group of grasshoppers. Among the different habitats, grasses supported the highest number of species. The painted grasshopper *Poekilocerus pictus* was collected from many plants viz., *Calotropis*, curry leaf, grass, groundnut, okra and on the ground.

Senthilkumar (2010) noticed 36 species of Orthopteras belonging to 30 genera and four families in different habitats viz., forestlands, savannahs and grasslands of the Kaziranga National Park (KNP) at Assam. Family Acrididae had the largest species representation (19 species) followed by Tettigoniidae (nine species) and Mantidae (five species) while Gryllidae was represented by three species only.

Shishodia *et al.* (2010) encountered 1033 species/ subspecies belonging to 400 genera and 21 families of Orthoptera from India. Acrididae (285 species and 135 genera), Pyrgomorphidae (47 species and 21 genera), Gryllidae (231 species and 74 genera), Tettigoniidae (160 species and 68 genera). Thirty-three species of locusts and grasshoppers have been reported by Usmani *et al.* (2010) from Western Uttar Pradesh.

Akhtar *et al.* (2012) undertook grasshopper fauna from Uttar Pradesh state of India during the consecutive years 2010 and 2011 from rice fields. Totally, 26 species of grasshoppers representing 14 genera, 12 tribes, eight subfamilies belonging to two families have been recorded. Family Acrididae and subfamily Oedipodinae had most diversity. Usmani *et al.* (2012) reported 34 grasshopper species belonging to 25 genera, two families, 10 subfamilies and 19 tribes from Bihar and Jharkhand. Maximum number of grasshoppers collected from subfamily Oedipodinae (9 species) followed by Oxyinae (4 species), Acridinae (4 species), Gomphocerinae (3 species), Catantopinae (3 species), Cyrtacanthacridinae (3 species), Pyrgomorphinae (3 species), Tropidopolinae (2 species), Hemiacridinae (2 species) and Spathosterninae (1 species).

Nayeem and Usmani (2012) sampled 41 grasshopper and locust species belonging to 28 genera of 10 subfamilies, three families and four tribes from Jharkhand, India. Usmani and Nayeem (2012) collected 37 species of locusts and grasshoppers representing 26 genera, four tribes and 12 subfamilies belonging to the families Pyrgomorphidae, Catantopidae and Acrididae from different localities of Bihar. Agnes Deepa *et al.* (2012) observed nearly 5681 different species of insects belonging to 12 orders including Odonata, Orthoptera, Phasmida, Dermatera, Isoptera, Hemiptera, Coleoptera, Diptera, Dictyoptera, Araneae, Hymenoptera and Lepidoptera in grassland ecosystem in Avalanche area (Ooty) of Western Ghat, Tamil Nadu, India. Based on the overall occurrence, maximum number of individuals were recorded in the order of Orthoptera (813).

Saha and Haldar (2013) noted 29 acridid species, belonging to two families (Acrididae and Pyrgomorphidae) and nine subfamilies (Acridinae, Truxalinae, Hemiacridinae, Coptacridinae, Oxyinae, Catantopinae, Eyprepocnemidinae, Tropidopolinae and Pyrgomorphinae). Family Acrididae was represented by 24 and 27 species, constituting about 93.6% and 89.7% while Pyrgomorphidae was represented by two species, constituting about 6.4% and 10.3% during first and second year respectively.

Waghmare *et al.* (2013) carried out the work on short horned grasshopper from selected areas of Solapur district. Seven species were documented in various habitat like hilly area, grasslands, shrubby area, grasslands plus shrubby area and agricultural fields from Solapur districts. Seven species belonging to seven different genera *Acrida, Gastrimargus, Trilophidia, Catantops, Calaptenopsis, Chrotogonus* and *Atractomorpha.* Genus *Acrida* and *Gastrimargus* were found to be dominant genera in grasslands where as *Chrotogonus* were the dominant genera in harvested agricultural fields and genus *Trilophidia* was found only on branches of shrubs.

Kumar and Usmani (2014) captured 37 species of locusts and grasshoppers representing 25 genera and 11 subfamilies belonging to the family Acrididae from different localities of Rajasthan and collected 760 specimens of family Acrididae from different habitats of various cultivated and non-cultivated areas of Rajasthan. Rafi *et al.* (2014) recorded 1465 specimens of grasshoppers belonging to the family Acrididae from 45 districts of Central and Eastern Uttar Pradesh, wherein 48 species of grasshoppers representing 28 genera, 16 tribes and 10 subfamilies were found. Subfamily Oedipodinae imparts 29% of the total species followed by Eyprepocnemidinae 17%, Oxyinae 15%, Hemiacridinae 13%, Acridinae, 10%, Catantopinae, Cyrtacanthacridinae and Gomphocerinae 4% and Spathosterninae and Tropidopolinae 2% respectively.

Balakrishnan *et al.* (2014) monitored the biodiversity of insect fauna in different coastal habitat of Tamil Nadu, Southeast coast of India in order to eventually contribute to biodiversity conservation as well as to management of coastal habitat in India. A total of 929 insects belonging to 23 families and six orders were recorded from the three sites. The dominant species in the marine habitat were Lepidoptera (24%), Coleoptera (26%), Diptera (18%), Heteroptera (13%), Hemiptera (11%) and Orthoptera (8%).

Prabakar (2015) documented 384 species in the order Orthoptera belongs to the superfamily Acridoidea consists of two families, 14 subfamilies, 80 genera and 126 species in Tamil Nadu. The superfamily Pyrgomorphoidea consists of two families two subfamilies, 13 genera and 35 species. Whereas the superfamily Tetrigoidea consists of only one family under three subfamilies, 11 genera and 37 species. The superfamily Grylloidea consists of eight families, five subfamilies, 33 genera and 121 species and lastly the superfamily Tettigonioidea consists of only one family under six subfamilies, 10 genera and 65 species.

Arya *et al.* (2015) evaluated the composition, abundance, density and diversity of grasshoppers in the Western Himalayas, India. A total of 1269 individuals of grasshoppers belonging to two families and 14 species were recorded during their study period. Acrididae was the dominant family with eight species and constituting 87.55% of the total number of individuals of grasshoppers followed by Tettigoniidae with six species constituting 12.45% of the total number of individuals of grasshoppers. *Xenocatantops karnyi* was the most abundant species of grasshopper recorded from their study area followed by *Aulacobothrus* *luteipus* and *Oedipoda himalayana* respectively. *Letena linearis*, *Elimaea* sp. and *Himertula kinnerari* were less abundant species of grasshoppers recorded during their study period.

Thakkar *et al.* (2015) reported 45 species belonging to 33 genera under seven families from South Gujarat, India. Family Acrididae was found to be the most dominant and was represented with 18 species, second dominant family was Tettigoniidae and Gryllidae with nine species. Pyrgomorphidae ranked third with three species and family Tetrigidae, Gryllotalpidae and Rhaphidophoridae was represented by two species each.

Bhusnar (2015) conducted the diversity of acridids at Solapur District. Totally, 18 species from seven subfamilies were identified with their average population. *P. infumata* was recorded as dominant species. Kumar and Usmani (2015) surveyed acridid fauna in different habitats in different regions of Haryana State. Captured 36 species belonging to 23 genera and eight subfamilies. Oedipodinae (28%) was the most dominant subfamily. *Spathosternum prasiniferum prasiniferum* was found to be most abundant species.

Gupta and Chandra (2016) studied the faunal diversity of Orthoptera of Gomerda Wildlife Sanctuary, Raigarh District of Chhattisgarh. Altogether 47 species pertaining to 44 genera under seven families were reported. More and Nikam (2016) recorded 17 species of grasshoppers belonging of 17 genera of three families from Tilari forest, Chandgad, Kolhapur District of Maharashtra. Family Acrididae was dominant (8 species), followed by Tettigoniidae (6 species) and Pyrgomorphidae (3 species).

Vijayababu *et al.* (2016) carried out the diversity of insects in sugarcane field at Managaseri village, Virudhunagar District, Tamil Nadu, India. During their study period Hemiptera, Coleoptera, Lepidoptera, Orthoptera and Hymenoptera insects were identified. A total of 132 Orthopterans were recorded under five species, *Schistocera americana* (27), *Hieroglyphus banyan* (47), *Chorthippus albomarginatus* (23), *Chorthippus brunneus* (27) and *Amblycorypha oblongifolia* (8).

Divya and Senthilkumar (2017) determined 28 species of Orthoptera belonging to 27 genera and four families from the Institute of Forest Genetics and Tree Breeding (IFGTB), Coimbatore. The family Acrididae had the largest species representation (13 species) followed by Tettigoniidae (9 species) while Gryllidae and Pyrgomorphidae were represented by three species each respectively.

Sharma (2017) collected the 17 species belonging to 15 genera and two families from Takhni-Rehmapur Wildlife Sanctuary (Hoshiarpur and Punjab), India. The family Acrididae dominated with 15 species followed by Pyrgomorphidae with two species. The family Acrididae was represented by eight subfamilies i.e., Acridinae, Oedipodinae, Catantopinae, Oxyinae, Eyprepocnemidinae, Spathosterninae, Coptacridinae and Gomphocerinae.

Pareek *et al.* (2017) carried out acridid faunal surveys in maize ecosystem from Southern Rajasthan. Surveyed 10 acridid species belonging to six subfamilies (Acridinae, Catantopinae, Hemiacridinae, Oedopodinae, Oxyinae and Truxalinae) and identified as *Acrida* spp., *Aiolopus thalassinus*, *Catantops pinguis*, *Gastrimargus africanus*, *Hieroglyphus nigrorepletus*, *Oxya* spp., *Phlaoeba infumata*, *Spathosternum prasiniferum*, *Trilophidia annulata* and *Truxalis* spp.

Raghavender and Vastrad (2017) plotted the diversity of short horned grasshoppers from agricultural and forest ecosystems of Dharwad. Sampled 42 species belonging to 33 genera and 10 subfamilies of Acrididae and Pyrgomorphidae. Oedipodinae was the most species rich subfamily followed by Catantopinae in both agriculture and forest ecosystems. *Spathosternum prasiniferum* was the most abundant species in both ecosystems. Gupta and Chandra (2017) presented the distributional record of the Orthoptera fauna of Achanakmar Wildlife Sanctuary, Bilaspur, Chhattisgarh, India. Thirty-three species pertaining to 30 genera under five families were reported.

Chinnaraj *et al.* (2018) undertook diversity of soil arthropods in organic and conventional agricultural farms. Totally, 8983 soil arthropods belonging to twenty-seven families were observed among these 4969 (53.32%) individuals from the organic farm and 4014 (44.68%) from the conventional farm. Among them, more than 800 individuals of Orthopterans were recorded in both organic and convention farm.

Senguttavan and Kuttalam (2018) documented 2866 arthropod fauna under four orders (Hymenoptera, Lepidoptera, Mantodea and Orthoptera) from cabbage ecosystem at Coimbatore, Kotagiri, Ooty, Tamil Nadu. A total of 92 individuals of Orthopterans belonging to three families namely, Gryllidae, Pyrgomorphidae and Tettigoniidae were recorded.

Das *et al.* (2018) encountered 74 species of Orthoptera represented by 58 genera of 9 families from the surroundings and islands of Chilika Lake, Odisha. The family Acrididae was found to be the most dominant and represented by 28 species, followed by Tetrigidae (12), Gryllidae (10), Tettigonidae (8), Pygromorphidae (6), Gryllotalpidae and Tridactylidae with three species each, Trigonodiidae and Gryllacrididae with two species each respectively.

Kumar *et al.* (2018a) estimated the population density and biomass of grasshoppers (Orthoptera) from the Nanda Devi Biosphere Reserve (NDBR), West Himalaya, India. Totally, 14 species of grasshopper belonging to 14 genera of two families were recorded. Acrididae was the most dominant family with eight species and eight genera followed by Tettigoniidae with six species and six genera. Higher density and biomass values of the grasshoppers were recorded during the rainy season while minimum values of density and biomass are recorded during the winter season.

Kumar *et al.* (2018b) surveyed Acridoidea in the Ladakh region of Jammu and Kashmir State of India, a total of 33 specimens of grasshoppers were collected. The collected grasshoppers comprised of 10 species belonging to eight genera and four subfamilies under two families of Acridoidea. The maximum numbers of species (7) belong to the subfamily Oedipodinae.

Gaikwad *et al.* (2018) analysed checklist of short-horned grasshopper species from the forest area of Kolhapur district, Maharashtra, India. Over all, 40 species of the suborder Caelifera were estimated belonging to four families viz. Acrididae, Chorotypidae, Pyrgomorphidae and Tetrigidae. The family Acrididae was dominant with 27 species followed by family Tetrigidae with eight species, family Pyrgomorphidae with four species and family Chorotypidae with one species.

Rajapandian and Natchiappan *et al.* (2020) monitored the diversity and distributional pattern of Orthoptera fauna in Nagarhole tiger reserve, Hunsur, Karnataka, India. Totally, 42 species belonging to 32 genera under 14 sub families and four families were recorded.

Suganya *et al.* (2020) studied grasshopper fauna in different habitats such as grasslands, shrubs and human altered area of Bharathiar University Campus, Coimbatore, Tamil Nadu, India. Totally, 25 species of grasshopper representing 22 genera belonging to 18 tribes, 10 subfamilies under three families were recorded. Acrididae was the most dominant family with 14 species under 12 genera of six subfamilies and nine tribes followed Pyrgomorphidae with six species under five genera, two subfamilies and four tribes, Tettigoniidae with five species under five genera, two subfamily and five tribes. Different subfamilies of grasshopper, Oedipodinae was the most dominant group. Grassland was found to be the most common habitat for grasshoppers (46.5%).

Meeran *et al.* (2021) surveyed the insect diversity in paddy fields at Uthamapalayam, Theni district, Tamil Nadu, India from December 2019 to February 2020. A total of 587 insects belonging to 26 species and nine orders, *viz*., Coleoptera, Diptera, Hemiptera, Hymenoptera, Lepidoptera, Mantodea, Odonata, Orthoptera and Thysanoptera were recorded. The most abundant order was Orthoptera with 145 individuals categorized under six species namely *Acrida exaltata, Acrotylus humbertianus, Hieroglyphus banian, Hieroglyphus oryzivorus, Oxya japonica* and *Oxya nitidula.*

Suganya and Manimegalai (2021a) captured 2966 acridids belonging to 21 species, 15 genera and 12 tribes under eight subfamilies were recorded. Dominant species were *Spathosternum prasiniferum, Trilophidia annulata, Leva indica, Acrotylus patruelis, Oxya japonica japonica, Oedaleus abruptus and Phlaeoba infumata* found in all the zones as well as all the seasons. *Spathosternum prasiniferum* was found to be the most dominant species compared to other species of acridids. Oedipodinae was the most species rich subfamily, amounting to 41.37% of total collected species.

2.2 Endemic Orthoptera in India

Bhowmik (1993) provided the status of grasshopper fauna and discussed the endemic and non-endemic taxa both at generic (Fig - 1) and species levels (Fig - 2).

Tandon and Hazra, (1998) reported over 17,250 species are known to science throughout the world. More than 1,750 species, about 10% of the total world species, have been recorded from India and nearly an equal number are yet to be discovered. Studies mentioned 200 endemic orthopteran species occurring in India. Therefore, the endemicity of the order comes round about 11% of the total species occurring in India.

Superfamily Acridoidea showed maximum diversity and is divided into five families of which family Acrididae and Pyrgomorphidae are widely distributed in India. Acrididae is divided into 17 subfamilies and altogether over 6,000 species under 1,000 genera are known from the world, of which 310 species under 138 genera and 14 subfamilies are known from India. Family Pyrgomorphidae is divided into two subfamilies. The subfamily Pyrgormorphinae includes 440 species under 148 genera from the world, of which 40 species under 19 genera are known from India. Family Tettigoniidae has diversity with about 4,000 species under 21 subfamilies throughout the world. India is represented by about 80 species under 72 genera and 6 subfamilies (Tandon and Hazra, 1998).

Superfamily Tettigonoidea is divided into four families of which the family Tettigoniidae has diversity with about 4,000 species under 21 subfamilies throughout the world. India is represented by about 80 species under 72 genera and six subfamilies. Superfamily Grylloidea has 12 families, with 2,250 species and 364 genera in the world of which 181 species and 64 genera have been discovered from India (Tandon and Hazra, 1998).

Chandra and Gupta (2013) reported 1033 species / subspecies belonging to 398 genera and 21 families of Orthoptera are known from India. Of which, 563 species / subspecies belonging to 19 families and 70 genera are endemic to India. It is also analysed that 54 genera under nine families are monotypic. Among all the states and union terrritories, Tamil Nadu possesses maximum number of 113 species pertaining to 20 genera and nine families (Table - 1). However, among the families of Orthoptera, family Gryllidae includes maximum number of 142 endemic species (Table - 2).

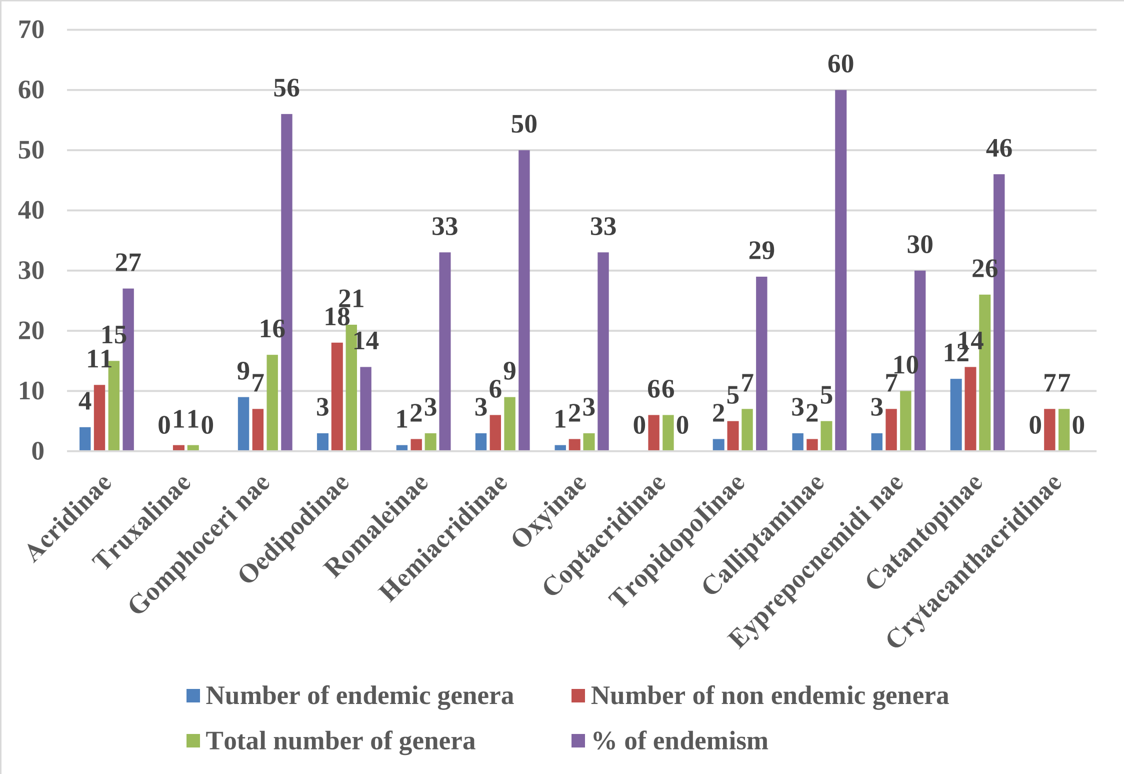

Figure - 1

Status of Indian genera of Acrididae

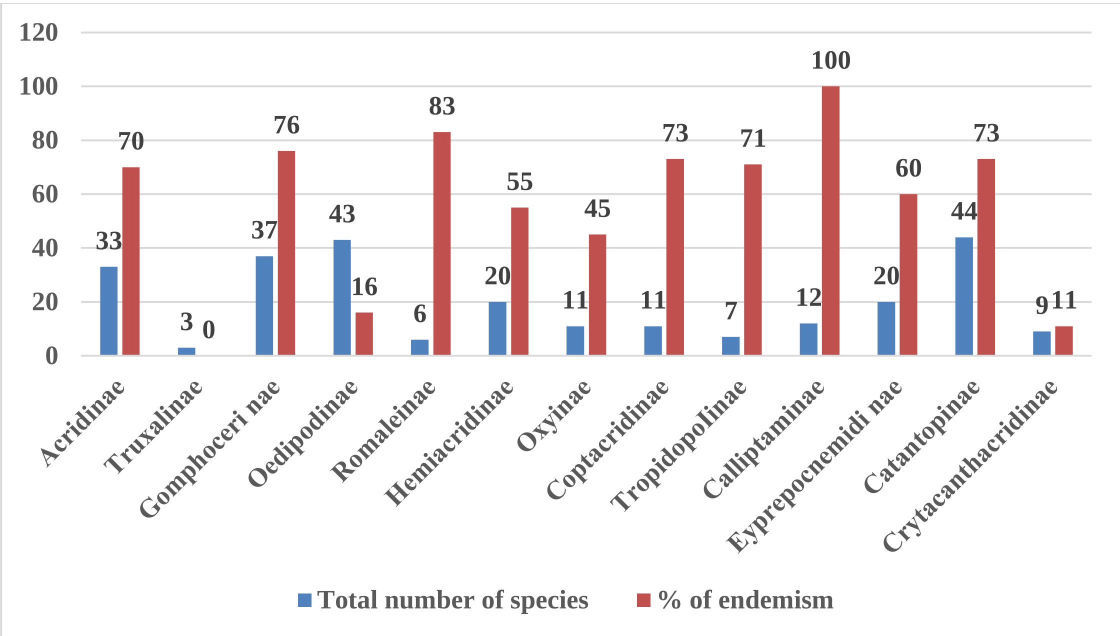

Figure - 2

Status of Indian species of Acrididae

Table - 1

State-wise species diversity of Orthopteran fauna in India

States	Families	Genera	Endemic Genera	Species	Endemic Species
Andaman & Nicobar Islands	10	67	2	85	12
Andhra Pradesh	5	69	-	84	-
Arunachal Pradesh	9	92	-	149	11
Assam	13	126	1	221	25
Bihar	8	90	1	123	5
Chandigarh	5	22	-	36	-
Chhattisgarh	9	66	-	81	3
Delhi	7	54	-	65	-
Goa	6	32	-	37	-
Gujarat	7	20	-	22	-
Haryana	4	25	-	30	2
Himachal Pradesh	10	101	-	158	3
Jammu & Kashmir	9	56	1	77	16
Jharkhand	5	14	-	14	-
Karnataka	10	112	4	155	10
Kerala	13	99	3	129	23
Lakshadweep Island	4	7	-	8	-
Madhya Pradesh	9	87	-	121	-
Maharashtra	9	101	1	146	19
Manipur	6	86	-	120	2
Meghalaya	9	105	4	161	16
Mizoram	6	35	-	42	1
Nagaland	5	36	-	46	-
Orissa	11	97	-	129	9
Pondicherry	6	17	-	19	3
Haryana	4	25	-	30	2
Punjab	9	36	-	51	2
Rajasthan	9	66	1	87	6
Sikkim	10	90	-	123	10
Tamil Nadu	13	208	20	341	114
Tripura	8	70	-	105	2
Uttarakhand	10	92	-	144	6
Uttar Pradesh	9	67	-	100	4
West Bengal	12	171	3	278	37

Table - 2

Family - wise endemic genera and species in India

Sl. No.	Families	Endemic Genera	Endemic Species
1.	Acrididae	28	136
2.	Dericorythidae	-	3
3.	Chorotypidae	2	7
4.	Eumastacidae	1	7
5.	Mastacideidae	2	8
6.	Pyrgomorphidae	8	28
7.	Tetrigidae	6	78
8.	Tridactylidae	-	6
9.	Gryllidae	10	142
10.	Gryllotalpidae	-	2
11.	Mogoplistidae	-	6
12.	Myrmecophilidae	-	3
13.	Prophalangopsidae	1	1
14.	Rhaphidophoridae	-	8
15.	Schizodactylidae	-	3
16.	Anostostomatidae	2	3
17.	Gryllacrididae	-	36
18.	Stenopelmatidae	-	3
19.	Tettigoniidae	10	83
	Total	70	563

2.3 Studies on abiotic factors associated with grasshopper population

Dempster (1963) monitored the influence of weather on population dynamics of grasshoppers and locusts. Ali (1982) assessed the effect of temperature and humidity on the development and fertility of grasshopper, *Acride exaltata*. Julka *et al.* (1982) analysed the influence of abiotic factors such as rainfall, average relative humidity, average minimum and maximum temperature on acridid population. Johnson and Worobec (1988) investigated the changes in abundance of adult grasshoppers in relation to rainfall in Alberta. Joern and

Gaines (1990) performed to understand the role of weather on grasshopper population dynamics. Kohler *et al.* (1999) studied the grasshopper population dynamics in relation to meteorological factors.

Karpakakunjaram *et al.* (2002) explored the effects of abiotic factors on the population of an acridid grasshopper, *Diabolocatantops pinguis.* Powell *et al.* (2007) examined the regional relationships between climate, soil moistureand grasshopper populations in Alberta. Cool and wet weather in the spring and warm and dry weather in the fall and early winter were strongly associated with low populations. Jonas and Joern (2007) addressed the effects of fire frequency, bison grazing and weather on Grasshopper communities.

Azim and Reshi (2008) observed the effect of temperature and humidity on population of three species of grasshoppers (*Sphingonotus longipennis, Acrida exaltata* and *Oedaleus abruptus*) in the Kashmir valley. Nath *et al.* (2010) analysed the correlation of meteorological parameters (monthly average rainfall, monthly mean maximum and minimum temperatures) with population dynamics of five different species of grasshopper for the first time in Darjeeling (Lebong and Happy Valley) of the eastern Himalayan region of India.

Laws and Belovsky (2010) measured the climate related factors influence on the grasshopper population. Nufio *et al.* (2010) documented the impacts of climate change on phenological responses of grasshopper species and communities.

De Wysiecki *et al.* (2011) conducted to evaluate the influence of weather (precipitation and temperature) and plant communities on grasshopper density. Kati *et al.* (2012) studied the role of disturbance and environmental factors on butterfly and grasshopper diversity patterns in humid Mediterranean grasslands.

Nattier *et al.* (2013) attempted to understand the evolution of species distributions in relation to climate and soil types. The genus *Caledonula* is a good model to understand the origin of micro endemism in the context of recent and mixed influences of climate and soil type.

Saha and Haldar (2013) evaluated the acridoid community (abundance, species richness and diversity) across seasons (Monsoon, pre-monsoon and post monsoon) within selected habitats representing a range of anthropogenic disturbances on dry deciduous. This analysis inferred that the three-factor interaction i.e., species, site and season have significant effect on abundance percentage of acridid populations.

Kenyeres and Cservenka (2014) tested the influence of different grassland management types on Orthoptera assemblages of humid grasslands and to examined the effects and interactions of local (grass height, temperatureand humidity) and regional (annual and monthly rainfall and temperatures) habitat parameters on them.

Antonatos *et al*. (2014) investigated the seasonal population fluctuation of orthopteran assemblages and determined the spatial distribution of the most abundant species of Orthoptera among two habitats in Greece. Jonas *et al.* (2015) assessed the relationships of weather variables (including time-lagged responses) to population dynamics of the nine most abundant grasshopper species.

Vidhya and Gopinath (2017) determined the climatic changes and availability of food sources in the environment has influenced the biodiversity of grasshopper population. Hussain *et al.* (2017) planned to estimate the diversity, distribution and seasonal variations of grasshoppers population in croplands of Sialkot, Punjab, Pakistan

Kuruvila *et al.* (2019) estimated the effect of seasonal variations in the grasshopper diversity at selected high and low range areas. Totally, 15 species belonging to four families were recorded during the study period. Family Acrididae has the maximum species diversity (10) followed by family Tettigoniidae which included three species. While comparing the seasonal variations, the monsoon season showed high species diversity than the summer season in both the areas.

Poniatowski *et al.* (2020) measured the relative impacts of changes in land use and climate on distributional changes in grasshoppers. Suganya and Manimegalai (2021a) evaluated to describe the geographical and seasonal variation effects on diversity and abundance of acridids fauna (Orthopetra: Acrididae) in India.

2.4 Morphometrics studies on Orthopterans

Gaines (1991) examined the degree of variation in body size and wing length among selected grasshoppers from Nebraska's Sandhills Grasslands, Arapaho Prairie, in Arthur County, NE. It was assumed that increasing wing lengths and body sizes are indicative of increasing dispersal and reproductive capabilities respectively.

Vastrad (1994) studied morphometrics of main life forms of 31 species of acridoides of Dharwad region Karnataka, India based on terricole, arboricole, herbicole and graminicole. The parameters, total length, maximum width of sternum and height of meta thorax were analysed.

Petit (2006) analysed the geometric morphometrics variation in the Acrididae wings: sex, stridulation and character. Geometric morphometrics dealt with eight landmarks located in the proximal region of tegmina, including median field.

Sesarini and Remis (2008) calculated molecular and morphometric variation in chromosomally differentiated population of the grasshopper *Sinipta dalmani* from Entre Rios and Buenos Aires provinces. There is considerable morphometric variation was observed between populations and this variation correlates with latitude and temperature.

Shah *et al.* (2008) compared the external morphology of three grasshopper species, *Acrotylus humbertianus* (Saussure), *Acrotylus insubricus* (Scopoli) and *Acrotylus longipes longipes* (Charpentier) on the basis of key characters. These species are very closely related with their morphological characteristic features, which are difficult to key out.

Adis *et al.* (2008) studied the morphometric differences in the grasshopper *Cornops aquaticum* from South America and South Africa and tested the following hypotheses: 1. South African and South American populations of *C. aquaticum* differ in morphology. 2.The South African population is more similar to other isolated populations from South America than to nonisolated populations. 3. Morphology differs with geography. 4. Morphology differs with host plant.

Akman and Whitman (2008) used linear regression, nonlinear regression and principal component analysis to examine the relationships among morphology, fecundityand mating variables for lab-reared adult female *Romalea microptera* (Romaleidae) grasshoppers. Morphological variables included head width, pronotum length, femur length, adult eclosion mass, maximum mass reached before the first ovipositionand maximum mass reached before the second oviposition. Fecundity variables included clutch size Pod 1, clutch size Pod 2, total eggs Pods 1 + 2, mass Pod 1, mass Pod 2, time between adult eclosion and Pod 1, time between Pod 1 and Pod 2 and time between eclosion and Pod 2. Mating variables included number of matings and age of first mating.

Yamagishi and Tanaka (2009) investigated the morphological characteristics of adult locusts (*Locusta migratoria*) after the outbreaks in Japan. Head width, hind femur length and forewing length of adult locusts were measured with digital callipers to determine the classical morphometric ratios, F/C and E/F ratios to evaluate their phase status. Maximum body length from the head to the tip of wings was also measured. Song (2009) studied the shapes and sizes of two functionally different genital structures of four *Schistocera* species using geometric morphometric analyses. Both shape and size fail as a species-specific character when examined individually because there were extensive overlaps of both variables among species.

Bamidele and Muse (2012) demonstrated the morphological similarities between the male and female of *Zonocerus variegatus* populations in southern Nigeria. However, the study confirmed the existence of some morphological differences within the male and female population from different locations. Cisneiros *et al.* (2012) described the morphometric variations in the grasshopper, *Chromacris speciosa* from two locations in the state of Pernambuco, Brazil. Morphometric measurements took into account the different body parts and appendages. Statistical analysis of the measurements revealed significant differences in the size of the specimens between the two locations. These findings provided the morphological evidence for intraspecific variation in morphological characteristics of the *C. speciosa* populations from the two locations.

Matojo and Yarro (2013) examined the anatomic morphometrics of Tettigoniid *Ruspolia differens* (Orthoptera: Conocephalidae) from North-West Tanzania with a critical focus on the shapes, sizes, orientationsand markings of its salient external structures including the vertex, antennae, sternum, pronotum, metathorax, tympanum, leg segments, tibial markings, stridulatory apparati, terminal segmentsand eggs. Laiolo *et al.* (2013) studied the local climate determines intra- and interspecific variation in sexual size dimorphism in mountain grasshopper communities

Seino *et al.* (2013) reported the morphometric studies on short-horn grasshopper species belonging to the subfamily Oedipodinae collected from six localities in the Menoua Division of Cameroon (*Gastrimagus africanus*, *Heteropternis thoracica, Morphacris fasciata and Trilophidia conturbata*). The data on habitat, altitudinal zonation, cytogenetics and description of the species were included.

Silva *et al.* (2014) find out the morphometric characteristics (total length, body length, wing length and measurement of the hind femur) of *C. aquaticum* in the Pantanal of Mato Grosso, Brazil as well as to assess possible differences in each stage of development between the sexes and among seasonal periods (flood, high water, low water and dry).

Bamidele and Muse (2014) determined the geographical variations of the weights and certain reproductive structures of male and female variegated grasshopper, *Z. variegatus* in Southern Nigeria. These findings indicated the increase in body weights of males and females was accompanied by corresponding and significant increase in the gut weights of male and female *Z. variegatus* in all the locations.

Kekeunou *et al.* (2014) assessed the effect of *Vernonia amygdalina* (Asteraceae) and *Manihot esculenta* (Euphorbiaceae) host plant on the survival, developmental duration, courtship, mating, oviposition and adult morphology of *Z. variegatus*. The results revealed that *Z. variegatus* survivorship was more than 83% and was not affected by diet change.

Akhtar *et al.* (2014b) studied *Hieroglyphus banian* and *Hieroglyphus nigrorepletus* morphometry measurement of four important differentiating parts of body (body length, pronotum length, tegmina length and hind femur length). Mean value and Standard Deviation of male and female of both the species showed the interspecific variation.

Mariottini *et al.* (2015) evaluated the morphometric differences between individuals of a *Dichroplus maculipennis* population in the Southern Pampas region of Argentina during non-outbreak and outbreak conditions including the magnitude of sexual size dimorphism related to variation in density. Six morphometric characters were measured and two ratios (F/C and E/F) usually used to discriminate between solitarious and gregarious individuals in true locust species. *D. maculipennis* showed female biased sexual size dimorphism in both outbreak and non-outbreak conditions.

Dharbal *et al.* (2015) analysed the body size variation in different geographical population of grasshopper, *Neorthacris acuticeps acuticeps* with reference to different geographical climatic conditions. Body size of males is more influenced by geographical conditions than females which show least variation in between the regions.

Ito (2015) characterized the morphology of the grasshopper tribe Podismini in Japan and their transformation series are discussed by examination of the body parts. Lal *et al.* (2015) compared the different body parts (length of body, length antennae, length pronotum, length tegmina, maximum width of tegmina, length of hind femur, maximum width of hind femurand length of hind tibia) of three *Acrotylus* species, *Acrotylus longipes longipes*, *Acrotylus humbertianusand Acrotylus longipes subfasciatus* along with their host plants and confirmed the significant morphological differences.

Barcebal *et al.* (2015) assessed the variability in the shape of grasshopper mandibles from selected places in Mindanao, Philippines through outline-based geometric morphometrics. The observed differences in the mandible shape could be due to differences in the consumption of food and foraging locations with varying environmental conditions. The use of geometric morphometric tools in this study contributed to a more quantitative way in describing the differences.

Guang-Hua *et al.* (2015) conducted the quantitative study of wing shape variation in five grasshopper species of the genus, *Oxya*. Geometric morphometric methods, including landmarks, centroid size, principal component analysisand thin-plate spline, were used to analyse the wing shape variation. Wing size and wing shape were significantly different among the five *Oxya* speciesand the similarity of the fore and hind wing between different species is consistent with the phylogenetic relationships between them. The variable areas of the fore wing were the precostal area, costal areaand anal areaand the variable areas of the hind-wing were the subcostal area, costal areaand jugal area.

Bai *et al.* (2016) used geometric morphometric methods to measure the differences in the wing shape and body size of *Trilophidia annulata* among 39 geographical populations in Chinaand a regression analysis was applied to identify the major environmental factors contributing to the observed morphological variations. The results showed that the size of the forewing and hindwing were significantly different among populations.

Mugleston *et al.* (2016) explained the better understand of the evolution of crypsis via leaf-like wings in katydids. This study provided a simple ratio method that can be used to differentiate the leaf-like and nonleaf-like wing forms. Geometric morphometrics were used to validate the ratio method. Thus, modern GM techniques validated thorax to wing ratio method, making this simple ratio an operational method for identifying the presence of leaflike wings in katydids. Noguerales *et al.* (2016) selected a total of 167 adult specimens (94 males and 73 females) of montane grasshopper for linear and geometric morphometric analyses of body size and forewing length (FWL) and shape.

Feng *et al.* (2016) studied geographical variation in size and density-dependent polyphenism among populations of the bamboo locust (*Ceracris kiangsu*). In total, four hundred and twenty-eight (428) individual adults were subjected to geometric morpometrics. All landmarks were measured to millimeter by direct calliper measurement. They established three landmarks of body size: maximum width of head, pronotum width and length. Seven morphological traits on wings were measured; all landmarks were located at wing vein intersections and termination points and considered to be the best characters for describing wing shape variation in *C. kiangsu*.

Tajamul and Ahmad (2016) described the comparative morphometric variations of each post embryonic developmental stage of rice grasshopper, *Oxya japonica* from different climatic zones of Kashmir province. Measurements of body parts including total body length, antennal length, pronotum length, pronotum width, head length, prothoracic leg, mesothoracic leg, metathoracic leg, abdominal length, abdominal widthand hind femur length of instar and adults stage. Statistical analysis of the measurements revealed a progressive increase and significant differences in the morphology of various instars and adults. Studies revealed the growth and development of *O. japonica* is a highly fertile species and its fecundity is affected by various abiotic factors.

Kisfali *et al.* (2017) examined the morphometric and molecular differentiation in the species of the *Pseudopodisma* genus (*P. fieberi, P. transilvanica, P. nagyi)* based on external morphology and cytochrome *b* (*Cyt*B) gene sequences of specimens collected from various localities within the distribution range of the genus. Eighteen morphometric characters were used in this study were body length, eyes distance, fore tibia length, head length, head width, mesosternum lobe length, mesosternum lobe width, pronotum length, pronotum width, pronotum lateral side length, pronotum lateral side width, sternum length, sternum width, third femur length, third femur width, third tibia length, tegmen lengthand tegmen width. Among these, six most eligible morphometric characters of males and females were selected for linear discriminant analysis.

Muschett *et al.* (2017) noticed the variation in fighting behaviour of *Kosicuscola tristis* in an Australian alpine grasshopper throughout the breeding season and tested the several hypotheses related to temperature, body size, mating behaviourand female quality.

Kohler *et al.* (2017) measured the altitudinal variation in the morphology and colour in the colour-polymorphic meadow grasshopper, *Pseudochorthippus parallelus*. Pronotum length did not change with altitude, while post femur length decreased significantly in both sexes. Tegmen (forewing) length decreased in males, but not in females.

Padmanabha (2018) explained the comparative morphometry and kinematics in different species of grasshoppers from Mysuru city, Karnataka, India. The grasshopper nymphs, *Phlaeoba panteli* was fastest with highest velocity but least body length and hind leg length. *Gastrimargus africanus* was highest body weight, body length and hind leg length. *Oxya nitidula* was with lowest body weight, speed, velocity but highest distance covered per jump. *Aiolopus thalassinus* was with highest body weight but least speed, velocity and distance per hop. This result suggested the body weight may decrease the speed, velocityand hop distance in the grasshopper species.

Silva *et al.* (2018) examined the variation in the shape and size of pronotum, hind femurand head in the males of *Orphulella punctata* from three different Brazilian biomes. A total of 150 specimens were analyzed from three populations. The results of MANOVA indicated significant differences ($p<0.01$) in the shape of the analyzed structures of *O. punctata* from the different biomes. The results of ANOVA demonstrated significant differences ($p<0.05$) in the size of all analyzed structures.

Jakhrani and Sultana (2018) studied the morphometric variations in *Hieroglyphus oryzivorus* (Hemiacridinae: Acrididae: Orthoptera) from Sindh, Pakistan. In the Macropterous form, the total body length was 32.664.5 mm in the male and 48.433.59 mm in the female; in the Brachypterous form, the total body length was 26.70.25 mm in the male and 39.84.90 mm in the female. The primary difference in the case of the tegmina in both forms was also noted: in the male, it was 22.15.21 mm, while in the Macropterous form, it was 25.332.94 mm; in the Brachypterous form, it was 8.830.28 mm in male and 16.954.21 mm in female.

Yadav *et al.* (2018) determined the morphological variation and relative abundance along environmental gradients in a widespread agricultural pest, native to Australia, the wingless grasshopper *Phaulacridium vittatum*. Tested the correlations between body size, wing presenceand stripe polymorphism with environmental variables. Body size and stripe polymorphism were positively associated with solar radiationand wing was positively associated with foliage projective cover (FPC). There were no associations between body size or morphological traits with relative abundance. However, relative abundance was positively associated with latitude, soil moistureand wind speed, but was negatively associated with FPC. These results suggested that environmental and climatic conditions strongly influence the relative abundance and the distribution of morphotypes in *P. vittatum*, which is likely to affect dispersal and fitness in different landscapes.

Rosetti and Remis (2018) analysed the spatial pattern of wing dimorphism and intraspecific morphometric variation in nine natural populations of the grasshopper *Dichroplus vittatus* in Argentina. Considerable body size differences among populations, between sexes and wing morphs were detected. Noguerales *et al.* (2018) characterized the positions of the landmarks in the pronotum and forewing shape of the different subspecies of the *Chorthippus binotatus* group species complex using geometric morphometrics.

Rouibah *et al.* (2019) conducted the landmark based geometric morphometrics study in the wing shape of *Calliptamus barbarus* (Orthoptera: Acrididae) in Algeria. They performed by three mathematical operations: rotation, translation and scaling using the TPS software. Eleven landmarks were selected at vein intersections of the wing.

Bughio *et al.* (2019) studied the morphology of the genus *Acrotylus* (Acridoidea: Orthoptera) from Pakistan. Morphometric parameters such as length of body, antennae, pronotum, tegmina, hind femurand hind tibia measurements were detected from the five species of *Acrotylus* genus (*Acrotylus humbertianus*, *Acrotylus insubricus insubricus*, *Acrotylus patruelis*, *Acrotylus longipes longipes* and *Acrotylus longipes subfasciatus*). MeghaUrs *et al.* (2020) applied morphometric geometric method to analyse the wing structure in twenty species of grasshoppers. The wing venation pattern of grasshoppers bear evolutionary significance and represents a typical Orthoptera wing type.

Suganya and Manimegalai (2021b) discussed the variation in the length of body, antenna, head, pronotum, forewingand hind femur in the males of *Aulacobothrus luteipes* from two different region of Coimbatore, Tamil Nadu, India. The minimum and maximum length of body parts of male population from two different locations were statistically different from each other. The mean ± standard deviation revealed the length of measured parts (body, antenna, forewing, hind femur) varied with the two geographical sites, while head length and pronotum length showed a similarity with size.

Suganya and Manimegalai (2021c) studied the wing shape of male and female *Trilophidia annulata* from Coimbatore, Tamil Nadu, India using landmark-based geometric morphometrics. This study provides detailed information on the wing shape variation and morphological features of *T. annulata*, thereby suggesting wing morphometric data revealed intra-specific variation of *T. annulata* species. Khan *et al.* (2022) described the diversity of grasshopper through analysis of different parameters like morphometric measurement such as length of body, length of wings, length of femur, length of tibia, length of tarsi, length of antennaeand length of pronotum.

2.5 Molecular studies on Orthopterans

Walton and Butlin (1997) examined the phylogenetic hypothesis for 28 individuals within the genus of *Chitaura* from Sulawesi, Indonesia based on DNA sequences of the mitochondrial cytochrome oxidase 1 gene. Butlin *et al.* (1998) studied on biogeography of Sulawesi grasshoppers, genus *Chitaura* based on the DNA sequence data from the mitochondrial cytochrome oxidase 1 locus.

Chapco *et al.* (1999) clarified the taxonomic relationships of several species of *Melanoplus* grasshopper genus. Portions of three mitochondrial genes (cytb, COIIand 16S ribosomal RNA) were sequenced and phylogenetically analysed using (weighted and unweighted) Parsimony and Neighbor- joining methods.

Flook *et al.* (1999) studied the phylogenetic analysis of mitochondrial and nuclear rDNA sequences from species of all the superfamilies of the insect order Orthoptera. Studies confirmed that mitochondrial sequences provided good resolution of the youngest superfamilies and nuclear rDNA sequences were necessary to separate the basal groups.

Litzenberger and Chapco (2001) analysed the sequence data obtained from portions of four mitochondrial genes (cyt b, COII, ND2and COI) to test the hypothesis that molecular phylogeney of selected Eurasian podismines grasshopper and assessed the validity of the different sub tribal assignations of genera.

Ren *et al.* (2002) performed the mtDNA Cyt b sequences (432 bp) in 10 individuals from eight different families of Acridoidea in China. The homologous sequences were compared and used frequency of nucleotide was calculated and the molecular phylogenetic tree constructed by Neighbor-Joining method using *T. japonica* as outgroup. Neighbor-joining tree suggested that 11 individuals from the eight families clustered in four groups among which Gomphoceridae and Pamphagidae firstly clustered and then together with Arcypteridae and Acrididae to form group I; Cluster II was made of three species from Catantopidae, *O. japonica*, *O. chinensis* and *O. intricata*; Pyrgmorphidae and Oedipodidae formed group III and Chrotogonidae single as cluster IV, respectively.

Ren *et al.* (2004) obtained the 432bp DNA sequences of the mitochondrial cytochrome b gene from 91 individuals of nine *Oxya* species and two outgroups (*Gesonula punctifrons* and *Acrida cinerea*). Phylogenetic analyses for the molecular data set were carried out using the Maximum parsimony and Neighbor-joining methods. The results showed that the nine *Oxya* species form four well-supported clades.

Colombo *et al.* (2005) used the molecular and morphological characters to test the monophyly of the genus and to evaluate chromosome evolution. Twenty-seven species from *Dichroplus* and related genera were included in the analysis. Morphological characters refer to the general morphology, male genitalia and female structures. Molecular studies were performed sequencing part of two mitochondrial genes, cytochrome oxidase I and II.

Huo *et al.* (2007) sequenced the mitochondrial DNA cytochrome *b* gene *(Cyt b*) of 25 species from the superfamily Acridoidae and the homologous sequences of 19 species of grasshoppers were downloaded from the GenBank data library. The purpose was to developed a molecular phylogeny of the Acrypteridaeand interpreted the phylogenetic position of the family within the superfamily of Acridoidea.

Schultz *et al.* (2007) focused on the phylogeny of East African endemic flightless grasshopper species to understand the evolution of regional endemism based on DNA sequences (16S rRNA locus) and determined the fit of these results with the existing taxonomy.

Nai-Xin *et al.* (2008) extracted the homologous sequence of the mitochondrial cytochrome b (Cytb) and cytochrome c oxidase subunit I (COI) genes from 17 species representing five subfamilies (Melanoplinae, Catantoopinae, Cyrtacanthacridinae, Oedipodinae and Gomphocerinae) of the Acrididae from China. The concatenated sequence from both genes was 1998bp in length and consisting of 1266 bp and 732 bp for COI and Cytb respectively.

Dian-feng *et al.* (2008) investigated the sequence data from 24 species of Acrididae in China. The sequence constitutions and variations were analysed and the molecular phylogenetic trees were reconstructed based on the combined sequence data (795 bp length in total) of 12S rDNA and 16S rDNA using the grasshopper *Pyrgomorpha conica* of Pyrgomorphidae as the outgroup. The results showed that the rates of the two kinds of transitions were obviously much higher than that of the four kinds of transversions in these combined 12S+16S rDNA sequence data.

Trewick *et al.* (2008) applied a DNA barcoding approach using mtDNA sequences from the cytochrome oxidase I gene to examine diversity in a group of endemic New Zealand grasshoppers belonging to the genus *Sigaus*. The mtDNA data revealed high genetic distances among individuals of a single morpho-species, but this diversity was geographically partitioned.

Zhang and Huang (2008) provided the complete sequence of *Oxya chinensis* mitochondrial genome. The initiation codon of the cytochrome oxidase subunit I gene in the mitochondrial genome of *O. chinensis* appears to be ATC, instead of the tetranucleotides that have been reported in *Locusta migratoria* (*L. migratoria*) mitochondrial genome. The result of phylogenetic analysis based on the dataset containing 12 concatenated protein sequences confirmed the close relationship of *O. chinensis* with *L. migratoria.*

Vedenina and Mugue (2011) constructed the molecular phylogeny based on COI gene analysis with acoustic and courtship behaviour to understand the driving forces of speciation in Eurasian Gomphocerinae. In 50 grasshopper species of Gomphocerinae, a barcoding region of mitochondrial gene COI was sequenced and analyzed.

Li *et al.* (2011) reported the first comprehensive phylogenetic analysis of the family Catantopidae at the tribal level based on the morphology. The purpose of the study was conducted to understand an exploratory phylogenetic analysis of the phylogenetic relationship within the family and provided an objective evaluation of the usefulness of morphological characters in phylogeny reconstruction of the acridoids in general and the Catantopids in particular.

Zhang *et al.* (2011) examined the phylogenetic relationships of Pamphagidae from China based on cytochrome oxidase subunit II (*COII*) mtDNA sequences (684 bp). Twenty-seven species of Acridoidea from 20 genera were sequenced to obtain mtDNA data, along with four species from the GenBank nucleotide database. The purpose of this study was analysed the phylogenetic relationships among subfamilies within Pamphagidae and interpreting the phylogenetic position of this family within the Acridoidea superfamily.

Kindler *et al.* (2012) analysed genetic divergence, population structureand biogeographic patterns in the band-winged grasshopper *Oedaleus decorus* in Europe. Phylogenetic relationships were determined using sequences of two mitochondrial loci (ctr, ND2) with Neighbour-joining and Bayesian methods. Additionally, genetic differentiation was calculated based on mitochondrial DNA and 11 microsatellite markers using F-statistics, model-free multivariateand model-based Bayesian clustering approaches. Phylogenetic analyses detected consistently two highly divergent, allopatrically distributed lineages within *O. decorus*.

Matojo and Hosea (2013) explored phylogenetic relationship of the longhorn grasshopper *Ruspolia differens* from Northwest Tanzania based on 18S ribosomal nuclear sequences. Mugleston *et al.* (2013) inferred the phylogenetic relationships of Tettigoniidae (katydids and bush-crickets) using molecular sequence data. Six genes (18S rDNA, 28S rDNA, cytochrome oxidase II, Histone 3, Tubulin Alpha I and Wingless) were sequenced for 135 ingroup taxa representing 16 of the 19 extant katydid subfamilies.

Nazir *et al.* (2014) studied to resolve conflicts in the identification of 26 grasshopper species of the family Acrididae (Orthoptera) from Poonch division of Azad Jammu Kashmir, Pakistan on the basis of the morphology and DNA barcoding. Specimens were identified taxonomically and DNA sequenced for the cytochrome c oxidase (COI) barcode region. These findings showed the usefulness of barcode data in discriminating grasshopper species.

Dong *et al.* (2015) inferred the phylogenetic relationships among families within Acridoidea and tested the monophyly of Acridoidea. Phylogenetic relationships of Acridoidea were examined using mitochondrial cytochrome oxidase subunit sequences (COI, COII and COIII). Fourteen grasshopper species of 13 genera from seven families were sequenced to obtain mitochondrial genes data and 22 grasshopper species were obtained from the GenBank nucleotide database. Phylogenic trees were reconstructed using Maximum Like-lihood (ML) and Maximum Parsimony (MP) methods, Tettigonioidea and Gryllotalpoidea as outgroups.

Zhao *et al.* (2016) identified the colour-marking polymorphic morphs of pygmy grasshopper species, *Tetrix bolivari* from both grass and sand microhabitats in China using the protein-coding cytochrome c oxidase subunit I (COI) region as a DNA barcode. Neighbor- joining clustering and pairwise distances indicated that all specimens collected showing colour-marking polymorphism species of *T. bolivari.*

Jayashree and Channaveerappa (2016) constructed the phylogenetic relationships of six species of Pyrgomorphidae using nuclear genome through RAPD-PCR. The phylogenetic tree constructed based on similarity matrix depicts monophyletic origin of Pyrgomorphidae species and also predicts origin of congeneric species from different nodes.

Hawlitschek *et al.* (2016) explained the DNA barcoding study on the insect order Orthoptera was generated in collaboration between four barcoding projects in three countries, viz. Barcoding Fauna Bavarica (Germany), German Barcode of Life, Austrian Barcode of Life and Swiss Barcode of Life. Data set includes 748 COI sequences from 127 of the 162 taxa (78.4%) recorded in the three countries.

Rouibah *et al.* (2016) examined the molecular phylogenetic and phylogeographic study of two forms of *Calliptamus barbarous* from two regions of Algeria based on the sequence analysis of these two mitochondrial genes: cytochrome oxidase subunit 1 (COI) and the 16S RNA.

Muhammedali *et al.* (2017) applied DNA barcoding method for identification of *Conocephalus dorsalis* from Northern Kerala using cytochrome oxidase subunit I gene as mitochondria. The COI gene of *C. dorsalis,* 589bp are sequenced and obtained was deposited in the NCBI GenBank.

Grzywacz and Tatsuta (2017) explored the phylogenetic relationship of Japanese Podismini grasshoppers by comparing partial sequences of cytochrome c oxidase subunit I (COI) mitochondrial gene. Forty Podismine species and 37 species from other tribes of the Melanoplinae (Dactylotini, Dichroplini, Melanopliniand Jivarini) were used in the analysis. All the Japanese Podismini, except *Anapodisma* were placed in a well-supported subclade.

Marino-Perez and Song (2017) inferred a phylogenetic analysis of Pyrgomorphidae based on 119 morphological characters with 269 character states, covering 28 out of 31 current recognized tribes. They aimed to test the monophyly of the family and subfamilies and described the phylogenetic relationships among major clades within the family.

Song *et al.* (2018) described the first comprehensive phylogeny of grasshoppers based on mitochondrial genomes and nuclear genes to test monophyly of the family and different subfamilies as well as to understand the evolutionary relationships among them.

Li *et al.* (2020) characterized complete mitochondrial genomes (mitogenomes) of three species, *Oxya japonica japonica* (15,427 bp), *Oxya hainanensis* (15,443 bp) and *Oxya agavisa* robusta (15,552 bp) collected from China. The three mitogenomes contained a typical gene set of metazoan mitogenomes and shared the same gene order with other Acridid grasshoppers, including the rearrangement of tRNAAsp and tRNALys. Analyses of pairwise genetic distances showed that ATP8 was the least conserved gene, while COI the most conserved. Determined the position of *Oxya* grasshoppers in the phylogeny of Acrididae and reconstructed the phylogenetic trees among 64 species from across 11 subfamilies using nucleotide sequences of mitogenomes.

Wang *et al.* (2021) explored the phylogeny and the relationships among Chinese species of the genus *Tonkinacris* from China using the mitochondrial COI barcode and the complete sequences of ITS1 and ITS2 of the nuclear ribosomal DNA.