Leafhopper diversity blueprint along the elevation gradient of North-Western Himalayas, India.

Priyanka Thakur[1], Naresh Meshram[2], Rajinder Rana[1], Krishan Sharma[1], Sunil Rathod [2], Stuti Rai [2], Nalini Challa[1], and Mahesh Gaikwad[1]

[1]Dr Yashwant Singh Parmar University of Horticulture and Forestry
[2]Indian Agricultural Research Institute

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Abstract

Species richness pattern along the elevation gradient forms precious tools in understanding diversity gradients and their principal mechanisms. Himachal Pradesh, one of the hubs of biological diversity has congenial atmospheric conditions and is homeland for large number of insects. Despite being one of the major biodiversity hotspots several insect families remain poorly studied in the state including, Cicadellidae: Hemiptera. A total of 85 leafhoppers species belonging to 61 genera of 12 subfamilies of Cicadellidae were recorded from all the 12 districts of the state covering 25 locations. Four species, Gurawa monorcephala Pruthi, Leofa pulchellus Distant, Olidiana kirkaldyi (Walker) and Paralimnellus cingulatus (Dlabola) appeared to be new records from Himachal Pradesh and one species, Pseudosubhimalus sp. Nov was new from India. Species richness as well as diversity increased with rising altitude from Sub-mountain low hills zone I (350-650m amsl) with a hump at mid hills zone II (651-1800m amsl) following a declining trend towards high hills wet temperate zone III (1801-2200m amsl) and high hills dry temperate zone IV (above 2200m amsl). This elevational disparity in species richness might be due to variations in the physiological requirements, host preference and changing climate. Abundance of leafhopper species as observed in temperate regions is of serious concern of global warming, due to their job in transmission of plant viruses and phytoplasmas, of which the world has still no control, therefore the future of food security lies in the paradigm of uncertainty.

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Priyanka Thakur[1*], Rajinder Singh Rana[1], Naresh M. Meshram[2], Krishan Chander Sharma[1], Nalini Challa[1] and Mahesh Balaso Gaikwad[1]

[1]Department of Entomology, Dr YS Parmar University of Horticulture and Forestry. Nauni-173230 Himachal Pradesh, India.

[2]Department of Entomology, Indian Agricultural Research Institute (IARI), New Delhi 110 112, India.

***Email:pqu3010@gmail.com**

Abstract: Species richness pattern along the elevation gradient forms precious tools in understanding diversity gradients and their principal mechanisms. Himachal Pradesh, one of the hubs of biological diversity has congenial atmospheric conditions and is homeland for large number of insects. Despite being one of the major biodiversity hotspots several insect families remain poorly studied in the state including, Cicadellidae: Hemiptera. A total of 85 leafhoppers species belonging to 61 genera of 12 subfamilies of Cicadellidae were recorded from all the 12 districts of the state covering 25 locations. Four species, *Gurawa monorcephala* Pruthi, *Leofa pulchellus* Distant, *Olidiana kirkaldyi* (Walker) and *Paralimnellus cingulatus* (Dlabola) appeared to be new records from Himachal Pradesh and one species, *Pseudosubhimalus* sp. Nov was new from India. Species richness as well as diversity increased with rising altitude from Sub-mountain low hills zone I (350-650m amsl) with a hump at mid hills zone II (651-1800m amsl) following a declining trend towards high hills wet temperate zone III (1801-2200m amsl) and high hills dry temperate zone IV (above 2200m amsl). This elevational disparity in species richness might be due to variations in the physiological requirements, host preference and changing climate. Abundance of leafhopper species as observed in temperate regions is of serious concern of global warming, due to their job in transmission of plant viruses and phytoplasmas, of which the world has still no control, therefore the future of food security lies in the paradigm of uncertainty.

Keywords : cicadellidae, species richness, abundance, diversity

1. INTRODUCTION

Biodiversity is the living wealth of earth and is the quintessence of life. Diversity takes into consideration how individuals are distributed amongst the species (Wolda, 1988; Guo *et al* ., 2013; Beck *et al* ., 2017; Kemp *et al* ., 2017). India is second most populous country in the world not just in terms of humans but also stands among the top countries with worlds' rich biological diversity. The Northern hilly region of India is exceptional for its diverse floral and faunal constitution. Himachal Pradesh (Fig I a) with a geographical area of 55673 Km^2 is a hill state of India (30.38°- 33.21° North latitudes and 75.77°-79.07° East longitudes) comprising 12 districts (Statistical Data, 2010). Divided in to four agro-climatic zones with altitudinal range from 350 to 7000 meters above mean sea level (Fig I a &b) and ecosystems temperature from 0° to more than 40° Celsius, the transforming region has low altitude evergreen forests, subtropical fruit trees, lustrous greens and agriculture crops to conifers and vegetables in mid and higher attitudes to smaller shrubs temperate fruits (Singh, 2007) and very few vegetation at extreme altitudes dry temperate zones (CES Technical Report, 2013). The congenial atmospheric conditions favour the luxuriant growth of various plant and animal species as well as support the largest phylum of arthropods. Insects are one of the most significant sections of the biological diversity of any region. These organisms can endure even the acute and harshest of environmental conditions due to their expansive ability of adaptation to wider range of climate (Sala *et al* ., 2000; Beck *et al* ., 2010; Lefebvre *et al* ., 2018; Plant*et al* ., 2018). Therefore, research on the various subjects of their behaviour, environmental impact, survey, geographical distribution and records, etc. constitute very crucial role in any study useful for understanding their diversity alteration and conservation (Mccain, 2005; Watkins *et al* ., 2006; Bässler *et al* ., 2009; Moscol Olivera & Cleef , 2009; Desalegn &Beierkuhnlein, 2010; Jaramillo-Villa*et al* ., 2010; Shimono *et al* ., 2010; Nagaike, 2010).

In view of this, despite being one of the most diverse habitats of India several insect families remain poorly studied in the state. Cicadellidae, one of the largest insect families of order Hemiptera distributed worldwide is one among them, containing at least 20,000 described species (Nielson, 1985). These tiny hemimetabolous insects are generally herbivores that suck sap from the plants, trees, shrubs and grasses etc feeding on wide range of plant fauna. Looking at agricultural aspect, these minute insects cause harmful economical damage to crops either by sucking the sap and making the plant extremely weak or indirectly by transmitting pathogenic viruses and phytoplasmas from plant to plant, which is most difficult to manage and of major serious concern (Nielson, 1968; Klein, 2001; Redak *et al* ., 2004; Weintraub and Beanland, 2006).

Being one of the megadiverse taxon with enormous species richness and distributional limits of such a group of insects that have high economic impact and might be undergoing species drift, extinction or mutation due to rapidly changing environment, plant diversity, rising anthropogenic activities, study of their diversity is of prime importance and is required to be investigated. Therefore, our work focussed on documenting the distribution of leafhoppers in relation to elevation gradient in order to establish the species richness and abundance.

2. MATERIALS AND METHODS

In order to capture maximum species diversity of cicadellids; grasslands, fields, orchards and forests of plains and hilly regions with diverse topographical conditions and distinct climate were selected from 4 agroclimatic zones of Himachal Pradesh (Table 1; Fig Ia) based on different elevational belts. Quantitative as well as qualitative collections (one tour/ survey area) of the cicadellid species were conducted from July, 2017 to May, 2018 in 12 districts covering 25 locations during the seasons when the weather was clear (Table 2; Fig Ib). In various surveys conducted in past years by many researchers (Doran *et al* ., 2003; Ibisca, 2008; Bassler *et al* ., 2009; Axmacher *et al* ., 2004; Fischer *et al* ., 2011; Chatelain*et al* ., 2020) different types of traps have been used for collection, such as light traps, flight-interception traps and malaise traps for invertebrates. Day collection of the leafhoppers were made by sweeping vegetation with a heavy muslin sweep net (catch/10 sweeps) and during night both vertical sheet and portable light trap methods with 250 Watt Mercury Vapour Bulb were installed. With the help of aspirator (Plate 1) maximum number of different morphospecies were collected (Plate 2a) and counted.

2.1. PROCESSING OF MATERIAL FOR STUDY

Selection of leafhoppers was done based on the hind tibial character (two rows spines on the hind tibia). The specimens were mounted (Plate 2b) on a triangular thick white paper mounts on the right side of the mesothorax using the glue. This facilitates the clear examination of head, wings, legs, and abdomen from all desired angles and also useful for easy detaching of the abdomen for the study of male genitalia. Labels (Plate 3a & b) were transfixed to each specimen having information about locality, date of collection, name of the collector and altitude. The photographs of collected specimens were taken with Leica DFC 425C digital camera on the Leica 19205FA stereo zoom automontage microscope and processed using Adobe Photoshop CS5 (Plate 4). From each collected leafhoppers species at least two extra specimens were also preserved indefinitely in 100% ethanol to facilitate later extraction of nucleic acids (DNA and RNA) for further use in phylogenetic and population studies.

2.2. BIODIVERSITY STUDIES

Species assemblages in a particular habitat especially at different elevational gradients can be useful in evaluating the community response to transforming macro and micro environment due to climate change as recorded in the findings of various workers (Rahbek 1995, 2005; McCain & Grytnes 2010; Fischer *et al* ., 2011; Lefebvre *et al* ., 2018; Chatelain *et al* ., 2020). The count on leafhoppers' morphospecies was used to calculate species diversity, diversity distribution patterns using the following indices:

2.2.1. Simpson-Yule Index (D): Simpson diversity index measures the probability that two individuals randomly selected from a sample will belong to the same species. For calculating Simpson Index number of individuals of different species of leafhoppers and a total number of individuals in all the species of leafhoppers were counted and arranged for estimation of Simpson's diversity index. Simpson (1949) index is expressed as:

Sobs

D=1/C D = [?]Pi2

i-1

N_i $(N_i$ - 1)

Where, Pi^2 =

N_T $(N_T$ - 1)

But approximated as, $P_i{}^2 = (N_i / N_T)^{2}$

N_i is the number of individuals in the i^{th} species and N_T the total individuals in the sample

Simpson Inverse= 1/D

2.2.2. Shannon-Wiener Index (H '): is the measurement of the diversity of species in a community or habitat. For calculating Shannon- Wiener index observations on the total number of leafhoppers in a particular species and a total number of individuals of all species of leafhoppers in the whole sample was used for diversity analysis through Wiener index. Thus it is an index applied to biological systems derived by (Shannon 1948) and combined both species richness and evenness. The diversity index was calculated as per the formula is given below:

Shannon Diversity Index (H') = -[?]Pi $\log_e$ Pi

Where;

Pi= S/N (P- the proportional abundance of i^{th} species)

S= Number of individual of one species

N= Total number of all individual in the sample

$\log_e$= logarithm to base e

2.2.3. Measurement of evenness: Species evenness refers to, "how close in numbers each species in an environment is". For studying species evenness; the total number of species collected were counted and used in measuring the evenness along with Shannon's diversity index. The species evenness was calculated as per the following formula.

Species evenness (J) = H/ l_n S

Where;

H= Shannon-Weiner index

S= Total number of species in the sample

l_n= natural logarithm

2.2.4. Measurement of dominance : It is the simple measure of the numerical importance of the most abundant species. Decreasing dominance values indicates diversity. For studying species dominance; the total number of species collected were counted and used in measuring the dominance from Shannon- Winer diversity index. It is calculated as per formula.

Species dominance = 1-J

Where; J= Evenness

2.2.5. Measurement of species richness : This indicates the total number of species in each sample. Species richness is the number of different species represented in an ecological community, landscape or region. To know the species richness, the total number of individuals of different species collected in the sweep net and light traps were counted and also the numbers of different species represented by these individuals were counted. The Margalef diversity index (Margalef, 1958) can be calculated in a spreadsheet by the equation:

Margalef's Index of species richness = (S-1)/ l_n N

Where;

d= Margalef's Index of species richness

S= Total number of species

N= Total number of individual in the sample

l_n= natural logarithm

Calculations of the Shannon-Wiener Diversity Index (H'), Simpson's diversity index (D), Evenness, abundance, and species richness were done using Microsoft Excel.

3. RESULTS

3.1. Distribution pattern of different leafhopper species in different agro-climatic zones of Himachal Pradesh

A total of 85 species of leafhoppers (Plate 5; Plate 6; Plate 7; Plate 8; Plate 9; Plate 10 and Plate 11) belonging to 61 genera of 12 subfamilies were recorded from four agro climatic zones of Himachal Pradesh and the diversity varied with different elevation ranges (Table 3; Fig II). Mid hills zone II was most diverse with recorded 66 leafhopper species followed by High hills wet temperate zone III (49), while, Sub-mountain low hills zone I and High hills dry temperate zone IV were comparatively less diverse with 35 and 39 number of species, respectively (Table 6). Among the collected 85 leafhopper species, 4 species namely *Gurawa monorcephala* Pruthi (Plate 5c),*Olidiana kirkaldyi* (Walker) (Plate 6b), *Leofa*(*Prasutagus*) *pulchellus* Distant (Plate 6d) and*Paralimnellus cingulatus* (Dlabola) (Plate 8f) were recorded for the first time from Himachal Pradesh and 1 species*Pseudosubhimalus* sp. Nov. (Plate 8j) might be the new species from India as to be supported by molecular studies (Fig II).

Both the qualitative and quantitative results obtained from this study indicate that marked difference existed in the leafhopper distribution with respect to altitude. The species composition, stratification, structural attributes such as density and abundance were found to differ between these altitudinal zones. Some leafhopper species displayed a high grade of morphological variation due to altitude and exposure. Leafhopper species (Plate 5; Plate 6; Plate 7; Plate 8; Plate 9; Plate 10 and Plate 11) with habitus darkly stained with evident colourfully patterned forms with higher intensity of red, orange, brown, black and bright tones of reddish yellow, recurred in the mid hills zone II and high hills wet temperate zone III as in case of *Atkinsoniella anabella* Young (reddish black) (Plate 5h), *Chudania axona* Zhang and Yang (white with black pattern) (Plate 11h); *Sohipona sohii*Ghauri & Viraktamath (white with orange pattern); *Nephotettix nigropictus* (Stal) (green with black pattern); *Changwhania* sp. (blackish orange) (Plate 7k) etc. While those recorded in low hills zone I and high hills dry temperate zone IV were mostly black, grey, light green and paler in colour. It was recorded in our study, that few leafhoppers species recorded were distributed only in a particular altitude thereby indicating their certain kind of slight preference and speciation towards that particular habitat (Table 4; Fig. II). A total of 17 leafhopper species (Plate 5; Plate 6; Plate 7; Plate 8; Plate 9; Plate 10 and Plate 11) were commonly recorded in all the four agro-climatic zones of Himachal Pradesh (Table 5) thus, depicting the distribution of these species on wide range of crops preferably feeding on common grasses and weeds.

3.2. Diversity analysis

Collected numbers of leafhopper species (Plate 5; Plate 6; Plate 7; Plate 8; Plate 9; Plate 10 and Plate 11) were analyzed for various diversity parameters to generate spatio-temporal distribution of the group especially based on agroclimatic zonations.

3.2.1. Shannon-Weiner Index value when approaches zero, the composition of the species found in the various zones shows certainty, whereas, higher values indicated that the composition of each species was highly unpredictable. Shannon-Weiner Index of Diversity (H') which takes into account the richness and evenness was more than 1 in all the four zones indicating that the composition of the species in various zones was somewhat unpredictable. The Shannon Diversity Index (Table 6) was 3.5 for the mid hill zone II (651-1800 m amsl) with highest species richness (66) and relative abundance (822). This directs towards more variation in species encountered in mid hills. High hills wet temperate zone III (1801-2200 m amsl) was recorded with second highest Shannon Diversity Index (2.94) with abundance of 749 individuals and 48 species. While in high hills dry temperate zone IV (above 2200m amsl) and low hills zone I (350-650m amsl) the index was 2.74 and 2.63 with 39 and 35 species, respectively (Fig II).

3.2.2. Evenness of leafhopper species for each zone was evaluated using Shannon-Weiner Index. All the zones surveyed had less variation in the evenness value but close to zero, indicating that leafhoppers were unevenly distributed. The evenness value was 0.835 for mid hills zone II (651-1800m amsl) and 0.760 for high hills wet temperate zone IV (above 2200 m amsl), while, 0.742 and 0.749 for low hills zone I (350-650m amsl) and high hills dry temperate zone IV (above 2200m amsl) (Table 6; Fig II).

3.2.3. Dominance is the measure of the numerical importance of the most abundant species. Dominance value (Table 6) was found to be for 0.250 for high hills dry temperate zone IV, 0.239 for hills wet temperate zone III, 0.164 for mid hills zone II and 0.257 for low hills zone I. Decreasing dominance values is the indicative of higher diversity for example, in high hills dry temperate zone IV dominance value of 0.250 indicates that 25 percent of 39 recorded species*i.e.* approximately 10 species were dominant in zone IV (Table 3) that constituted of leafhopper species *viz* ., *Platymetopius fidelis* (Distant) (Plate 8l), *Aconurella erebrus* (Distant) (Plate 10e), *Amrasca biguttula biguttula* (Ishida) (Plate 11d),*Amrasca motti* (Plate 11f), *Empoasca* sp. 1 (Plate 11m),*Austroagallia sinuata* (Mulsant & Rey) (Plate 5a),*Typhlocyba* sp. 1 (Plate 11b), Morphospecies 4 (Plate 11c),*Psammotettix emarginata* Sawai Singh (Plate 8g),*Pseudosubhimalus bicolor* (Pruthi) (Plate 8i),*Pseudosubhimalus* sp. 2. (Plate 8j). In hills wet temperate zone III the value of 0.239 implied 12 dominant species among 49 recorded,*Typhlocyba* sp. 1 (Plate 11b), *Amrasca motti* (Plate 11f), *Amrasca biguttula biguttula* (Ishida) (Plate 11d),*Detocephalus maculates* (Pruthi) (Plate 10d), *Durgades aviana* Viraktamath (Plate 5b), *Empoasca* sp. 1 (Plate 11m), *Pseudosubhimalus bicolor* (Pruthi) (Plate 8i), *Pseudosubhimalus*sp. 2 (Plate 8j), *Jilinga gopi* (Pruthi) (Plate 8e),*Evacanthus* sp. 1 (Plate 5k) and *Exitianus indicus*(Distant) (Plate 6c) and *Mimotettix* sp. 1 (Plate 6e) standing out. In the mid hills zone II, the value of 0.164 stands for 11 dominating species out of 66 comprising of *Exitianus indicus*(Distant) (Plate 6c), *Amrasca motti* (Plate 11f), *Amrasca biguttula biguttula* (Ishida) (Plate 11d), *Austroagallia sinuata*(Mulsant & Rey) (Plate 5a), *Empoasca* sp. 1 (Plate 11m),*Evacanthus convolutus* Viraktamath & Webb (Plate 5l), *Mimotettix* sp. 1 (Plate 6e), Morphospecies 5 (Plate 10l),*Osbornellus confuscus* (Pruthi) (Plate 6h), *Psammotettix emarginata* Sawai Singh (Plate 8g) and *Scaphoidieus* sp. 1 (Plate 6l). Value of 0.257 recorded in low hills zone I implied 9 out of 30 dominating species to be *Exitianus indicus* (Distant) (Plate 6c),*Amrasca motti* (Plate 11f), *Amrasca biguttula biguttula*(Ishida) (Plate 11d), *Cofana spectra* (Distant) (Plate 5j),*Empoasca* sp. 1 (Plate 11m), *Balclutha* sp. 1 (Plate 10k),*Stirellus indra* (Distant) (Plate 9a), Morphospecies 2 (Plate 10h) and *Idioscopus nitidulus* (Walker) (Plate 9f) a well known pest of mango (Fig. II).

3.2.4. Margalef's Index measured the species richness in each of the agro-climatic zones. A perfect linear relationship between the Margalef Index and Shannon-Weiner Diversity Index was observed. The Margalef Index value was found to be 9.684, highest for the mid hills zone II, which showed highest species richness with a maximum species diversity of 3.50 followed by high hills wet temperate zone III with value of 7.252 and Shannon Diversity of 2.956. This indicated that Zone II and Zone III ecosystem were rich with a greater diversity of leafhopper species, followed by richness value of 6.049 in the low hills zone I and 5.954 in the high hills dry temperate zone IV with comparatively less diverse leafhopper fauna (Table 6; Fig II).

3.2.5. Simpson Yule Diversity Indices was measured as the dominance of species, adding the total number of species recorded in an area, along with the relative abundance of each species. Simpson index was found to be the 0.101 for high hills dry temperate zone IV as well as for high hills wet temperate zone III which means that the probability of encountering an individual belonging to the same species among two randomly collected specimens shall be 0.101.In the mid hills zone II the value was 0.043 and in the low hills zone I it was 0.078. Different Simpson Yule Index value in the four agro-climatic zones (Table 6) signals towards variations in leafhopper diversity. Consequently, the higher diversity was attained at mid and low hills zones as compared to the high hills wet and dry temperate zone, thereby, decreasing the chances of encountering a particular species due to the greater relative abundance of different species.

4. Discussion

The intense coloration and patterns seen in leafhopper species collected from mid hills zone II and high hills wet temperate zone III compared to low hills zone I and high hills dry temperate zone IV might be due to more atmospheric humidity, rainfall conditions (Table 1; Fig. Ia & Ib) as well as higher abundance of leafhopper population in those areas. Many workers have found a significant correlation of darker and brighter pigments of insects with high elevational environment, specifically to snow, extreme cold, overcrowding developmental stages and hibernation period, higher light intensity, humidity, and harmful ultraviolet radiations (Sala *et al* ., 2010; Fischer *et al* ., 2011; Guo*et al* ., 2013; Chatelain *et al* ., 2020). In the high species diversity and richness zone, there was diverse vegetation choice constituting forests, grasses, vegetable crops, horticultural crops as well as fruit trees that served for regular supply of food at different times and seasons of the year for their generations and hence, might have affected their physical appearance.

Leafhopper species richness followed a declining trend along the extreme higher and lower elevations in the region. With higher leafhopper abundance as well as species richness, peak rise occurred in mid hills zone II (650-1800m) followed by high hills wet temperate zone III (1801-2200m amsl) which shrinked towards increasing altitude. In the studies conducted by Acharya and Vijayan (2011) while observing the distribution pattern of butterflies' species, similar was the pattern with highest number of species observed below 1800 m highest at 900-1800 m band of elevation. In the western part of Sikkim Himalayas, Chettri*et al* . (2010) recorded lower range of butterflies' species richness with rising altitude. Similar were the results recorded by Fleishman *et al* . (1998) from the Great Basin of the USA; Vu and Yuan (2003) from Vietnam and Leingartner *et al* . (2014). However if the phylogenetic relatedness of the butterfly collections is to be considered, it does not increment with the elevation gradient. The elevational pattern reported for leafhopper in the present study has similarity with the pattern for Himalayan fishes (Bhatt *et al* ., 2012) but differ slightly from plants and other vertebrates groups from the same region (Chettri *et al* ., 2010; Acharya *et al* ., 2011). The distribution pattern reported for leafhopper species at different range of agro climatic zones in the present study might be due to number of reasons governed by various causes that include; specifically & most significantly resources available to the species, distribution pattern & congenial environmental conditions, which are the major factors determining the structure of species in a niche (Table 1; Fig. Ia &b). In general, this study is in line with the findings of most of the previous work on insects but few also attained contrasting results as in the Western Himalayan elevation gradient, Bhardwaj*et al* . (2012) found a negative trend of butterfly diversity. The type and quantity of resources, as well as their distribution patterns, climatic conditions, and disturbance levels, are the major factors that determine the community structure of insects along spatial gradients (Fleishman *et al* ., 1998; Foristera *et al* ., 2010; Fischer*et al* ., 2011). The declining trend at extreme higher elevation in high hills dry temperate zone IV (above 2200m amsl) in the present study might be attributed to low mercury level and lesser humidity in those areas (Table 1; Fig. Ia &b). Temperature is the most essential character that decides and regulates the condition for diversity of plant, animal and any other kind of species of organism. However in the present study, declining trend of leafhopper species was also observed towards the extreme lower elevation in low hills zone I (350-650 m amsl) which might be due to the monocropping pattern followed in terms of cash crops that attracts only certain kind of leafhopper pest species; higher mercury level sometimes going up to 50deg C in summers, unbearable for survival (Table 1; Fig. Ia &b) and higher anthropogenic activity in those areas due to development, etc . Abundance of leafhopper in the warm season was higher than in the hot summers, which might be due to the extreme weather condition which affected the mobility of leafhoppers as reported by Habekuss *et al* . (2009); El-Wakeil *et al* . (2014). Leafhoppers like any other organism require a certain threshold level of temperature and humidity congenial for their survival and continuous lifecycle; hence the extreme hot and extreme cold weather parameters prevailing at these lower and higher elevations, respectively, were the reasons for encountering lesser species diversity in such agro climatic zones. Similar were the causes mentioned by Xu*et al* . (2017) in terms of spatial distributions of plant diversity in his research in the Lvliang Mountains of China.

In the present research work it was observed that the mid hills zone II, as well as high hills wet temperate zone III had maximum plant diversity and a longer period of vegetation as compared to other two zones (Table 1; Fig Ia & Ib) providing complimentary habitat and food for longer duration which might have resulted in the survival of maximum number of generations. The results of the studies carried out by various workers indicated that global warming, increasing temperature and decreasing snow line will cause upward migration of species in Himalayas and mountain system due to climate change (Walther *et al* ., 2005; Pauli *et al* . 2007; Kelly & Goulden, 2008; Lenoir *et al* ., 2008; Fischer *et al* ., 2011; Chatelain *et al* ., 2020). Definitely, the abundance of various species at low altitudes is decreasing and not only insects will become more abundant, but also insects like leafhoppers might migrate from lower to higher elevation as stated by Chmielewski (2007) in his study with Russian wheat aphid (*Diuraphis noxia*). Similar were the results of a study conducted by Sharma (2015) who delivered that changing scenario of climate and alarming effect of global warming initiated the shift in allocation of geographical areas and population dynamics of insect pest species. These transformation and modifications will affect plant diversity and crop production. Niche area of insect's acclimatized to tropical and subtropical areas shall get transferred to colder regions due to increase in mercury level along with alterations in zones of their host plants. Melting glaciers and snow in temperate cold dry zone shall cause the area to become greener with lustrous flora and increase in fauna. Relative abundance of some major insect species and their natural enemies confined to the temperate regions might go extinct in future and in case of leafhoppers the most serious and frightening concern is the rise in plant viruses and phytoplasma transmission, thus, with the rising temperature insect transmitted diseases may also prevail. At present the plant diseases specifically transmitted by leafhoppers have no substantial control, therefore with such hypothesis the coming future of crops and food security lies in the paradigm of uncertainty.

5. Data accessibility statement :

Upon acceptance of manuscript authors are ready to provide their data and all other information (whichever required) in a publicly accessible repository Drayad.

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