Multivariate Analysis of Spider Diversity in Agricultural, Horticultural and Silvicultural Ecosystems and their Relation to Subtropical Climatic Conditions

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Multivariate Analysis of Spider Diversity in Agricultural, Horticultural and Silvicultural Ecosystems and their relation to Subtropical Climatic Conditions

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Abstract

Spiders are the Arthropod and belong to the Phylum: Arthropoda, Class: Arachnida, Order: Araneae. Spiders totally depend on predation of small insects and other animals and have important role in the structure of communities and food webs both as an individual numbers and as an energy consumer.. Hence, documentation of spiders gives information about biodiversity of ecosystem in a particular geographical area. Totally arthropods belonged to 14 orders and 85 Nos. of different families. To study the similarity between two groups in species, family and ordinal level is used Agglomerative Hierarchical Clustering (AHC). Principal Component Analysis (PCA) and Correspondence Analysis (CA) were evaluated to understand the arthropod population dynamics and habitat specific occurrence of spiders in different ecosystem *Viz*., Silvicultural, Horticultural and Agricultural ecosystem. To correlate the weather parameters with spider population we used Pearson correlation, regression line, Redundancy Analysis (RDA) and Canonical Coefficient Analysis (CCA). Correlation analysis showed arthropod population positively correlated to maximum and minimum temperature and evening relative humidity and negatively correlated to morning relative humidity and rainfall. The eigenvectors at generic level was found maximum in horticultural ecosystem (0.591) followed by silvicultural (0.581), maize (0.407), rice (0.329) and potato ecosystem (0.183) in factor (F1). The asymmetric CA row and column plot in generic level suggested that the genus *Tylorida, Cyclosa, Neoga, Phintella, Hamadruas* etc., *Ruborridion, Clubiona, Guizygiella, Callilepis* etc., *Dorassodes, Nihohimea*, *Philodromus, Castineria, Dolomedes, Olios* etc., *Epocilla, Sosticus, Evarcha* etc., *Myrmarache, Larinis, Thaina Mesida, Gasteracantha, Zelotes* etc. showed affinity towards maize, rice, silvicultural, potato and horticultural ecosystems respectively. In case of weather perimeter with relation to arthropod population RDA showed that Arachnids families *viz*., *Lycosidae, Thomisidae, Theridiidae, Tetraganthidae* etc are closely associated with maximum temperature in silvicultural and horticultural ecosystems.

Key words: Principal Component Analysis (PCA), Correspondence Analysis (CA), Biplot, Eigenvalue, Cluster

1 **Introduction**

Biological diversity is the first terminology used by biologist Lovejoy in the year 1890 to describe numbers of species. E. O. Wilson first used the term 'Biodiversity' in written form in the proceedings of U.S. Strategy Conference on Biological Diversity (1981) held on Washington D.C. (Swingland, 2001). According to Delong 1996 "Biodiversity is an attribute of an area and specifically refers to the variety within and among living organisms, assemblages of living organisms, biotic communities, and biotic processes, whether naturally occurring or modified by humans. Muhammad and Ahmed (2014) studied the seasonal abundance of soil arthropods in relation to meteorological and edaphic factors in the agroecosystems *viz.*, sugarcane, cotton, wheat, alfalfa and citrus orchards of Faisalabad, Punjab, Pakistan. They used Bray-Curtis cluster analysis to study the soil arthropod based on similarity of abundance and found 4 different similarity cluster groups: first cluster comprised of Collembola, Hymenoptera, Acarina, and Myriapoda (>10%), second cluster comprised of Orthoptera, Coleoptera, and Araneae (>5%), third cluster those of Hemiptera, Dermaptera, and Diptera (>1%) and fourth cluster comprised of Blattaria, Diplura, Isoptera, and Lepidoptera (≈0%). Schuldt *et al.* (2008) evaluated the spider diversity in 3 different deciduous forest stands *viz.*,one-species stands (Beech, *Fagus sylvatica*), three-species stands (Beech, *F. sylvatica*, Ash, *Fraxinus excelsior* and Lime, *Tilia cordata*) and five-species stands (Beech, Ash, Lime, Hornbeam, *Carpinus betulus* and Maple, *Acer pseudoplatanus*). Mean species richness was found to be significantly low in one-species stands. Shannon-Wiener index and Evenness index were found maximum in one-species stand and minimum in five-species stands. In case of forest floor eigenvalues of Principle component analysis (PCA) and Redundancy analysis (RDA) as well as the distribution of plots within the ordinations differed considerably, even though Monte Carlo testing of axes was significant. RDA for pitfall trap showed negative to community structure, litter depth and amount of beech litter. Pinzon *et al*. (2011) evaluated the spider diversity in boreal white spruce (*Picea glauca*) forest. The species turnover was quantified by Whitaker's beta-diversity (βw) measure between horizontal and vertical turnover. The RDA analysis using Hellinger transformed abundances (λ) showed that spider assembling in mid-over story was maximum than to that of the ground and branch structural features. Bouseksou *et al*. (2015) studied the ecology of spider fauna of two ecosystems of wheat and rape seed from Mitidja plain, Algeria. A total of 2036 nos. of individual were collected comprising of 18 families, 52 genera and 81 species. The habitat preferences of abundant species were evaluated by non-parametric analysis done by Mann-Whitney U-test and Correspondence analysis (CA). Rosa *et al*. (2019) studied the diversity of soil spiders in land use and management systems in Santa Catarina, Brazil and use principal component analysis to evaluate habitat specific occurrence of spider in native forest, eucalyptus reforestation, pasture, crop-livestock integration, and no-tillage crop. They evaluated soil physical, chemical, and microbiological attributes and the abundance and diversity of spider families, collected by soil monolith and soil traps. A total of 448 spiders were captured, 152 in winter and 296 in summer, distributed in 24 families and 52 species/morphospecies. There was a seasonality effect related to the land use systems and the highest Shannon-Wiener diversity index was recorded in the native forest in both sampling periods. Most families of spiders have a direct dependence on soil physical and chemical properties, such as microporosity, exchangeable aluminum, calcium, magnesium, and potassium during the winter. Organic matter, nitrogen, pH in water, weighted average diameter, soil density, and microbial biomass carbon exhibited dependence during the summer. Vegetation type and soil management are the factors that seem to affect most the occurrence of spiders. For clear cut understanding three different ecosystems were selected *viz.*, Silvicultural ecosystem (Pine trees) composed with perennial trees and herbs with no human intervention having stable habitat structure, Horticultural ecosystem (Citrus plantation) composed with perennial crops and herbs but human intervention occurs in a particular periods of time having moderately stable habitat structure and

Agricultural ecosystem (Maize, Potato and Rice plantation) composed with seasonal crops but human intervention occurs frequently in short period of time having unstable habitat structure. For detail evaluation and to correlate between spider population and different ecosystems as mentioned we employ different multivariate analysis techniques such as Agglomerative hierarchical clustering (AHC), Principal component analysis (PCA) and Correspondence analysis (CA). In this paper we also evaluated the effectiveness and efficiency of different multivariate techniques. On the other hand to correlate the weather parameters with spider population we used Redundancy Analysis (RDA) and Canonical Coefficient Analysis (CCA). Correlation analysis showed arthropod population positively correlated to maximum and minimum temperature and evening relative humidity and negatively correlated to morning relative humidity and rainfall.

2 **Materials and methods**

The investigation was carried out at Experimental farm of CPGSAS, CAU, Umiam during the time period 02 July, 2019 to 11 February, 2020. Weekly observation was taken from 1st standard meteorological week (SMW) *i.e.* 27th SMW of July, 2019 onwards till 06th SMW of February, 2020. The sample collection was done in 3 ecosystems and took an area about (10 × 10) m^2, 100m^2 *Viz.*, Agricultural ecosystems (Maize, *Zea mays* L.; Potato, *Solanum tuberosum* L. and Rice, *Oryza sativa* L.), Horticultural (Citrus, *Citrus limon* L. and Turmeric, *Curcuma longa* L. agro ecosystem) and Silvicultural (Native forest dominated by Pine, *Pinus insularis* Endl. trees) ecosystem. Spiders were collected from 3 ecosystems without damaging the crops/plants using hand, aspirators, sweep nets, Inverted umbrella, pitfall trap and rubbish traps. The agricultural and horticultural systems present inside the university campus and permission was taken from college authority to conducting the experiment work. For the collection of silvicolous spider permission taking from the department of Botanical survey of India, Shillong, Meghalaya.

2.1 **Sampling methods**

Collection of arthropods was done through hand picking, using aspirators, sweep nets, Inverted umbrella, pitfall trap and rubbish trap. For carrying out arthropods collection, the plot was divided into 100 quadrats measuring 10 m × 10 m. Spiders and insects from rocks, logs, debris and bark of the trees were collected by hand picking and active searching.

2.2 **Preservation of Arthropods**

Spiders were killed using chloroform and the specimens were preserved in 5 ml glass vials with 70 per cent ethyl alcohol (70 parts of 100 per cent alcohol + 30 parts of distilled water) which was used by Joseph and Premila (2016). Khan (2009) and Khan and Rather (2012) also followed the standard protocol for preserving the very small spider specimens and the juvenile spiders in Oudeman’s fluid.

2.3 **Identification of Arthropods**

The most common and important arthropod species were identified to the lowest possible taxon. Identification was done based on established taxonomic keys and literature (Tikader and Bal, 1980; Tikader, 1987; Barrian and Litsinger, 1995: Khan and Khan, 2011). Cataloguing and documentation was done using images and photographs. Spiders were identified by Dr. Manju Siliwal, Arachnologist at Wildlife Institute of India, Dehradun.

2.3.1 **Multivariate statistics for relationship between arthropods and ecosystems**

2.3.1.1 **Agglomerative hierarchical clustering (AHC)**

Clustering is a function of multidimensional analysis that consists in partitioning a collection of variables. First used by Polish ecologist Kulczynski (1928) quite different from modern clustering known as seriation. AHC is also designated as Hierarchical agglomerative clustering (HAC). To study presence-absence of species, species abundances, similarity and dissimilarity among species and evaluation of indicator species the complete linkage agglomerative hierarchical clustering is widely accepted. Complete linkage AHC also known as furthest neighbour sorting and first proposed by Sorensen (1948). In this clustering method the fusion of two clusters depends on the most distant pair of objects instead of the closest. Thorrington-Smith (1971) used complete linkage AHC to analysis of association among species of phytoplankton and Legendre and Chodorowski (1977) use to analysis of relative abundance of zooplanktons. The linkage between clusters given by relation Gc.

2.3.1.2 **Principal component analysis (PCA)**

Principal Component Analysis (PCA) is a multivariate statistical technique that uses orthogonal transformation to convert a set of correlated variables into a set of orthogonal, uncorrelated axes called principal components. Many times ecologist dealing with a large multivariate ecological dataset dealing with different factors *Viz*., environmental parameters, genetic variability, community structure etc. (Legendre and Chodorowski, 1997).

2.3.1.3 **Correspondence analysis (CA)**

Correspondence analysis (CA) allows ecologist analysed large multivariate dataset into a tow dimensional space with direct comparison of respective variables which is almost similar to Principal component analysis (PCA). CA commonly known as contingency table analysis (Fisher, 1940). CA was developed by several authors independently Hirschfeld (1935), Fisher (1940) etc. and first applied in ecology by Roux and Roux (1967), Hatheway (1971), Ibanez and Seguin (1972) and Hill (1973) to analysed habitat specific occurrence (site × species contingency table) of species. First method of CA was two-way contingency table with rows and columns. Each cells of contingency table represent frequencies. Common application of CA in ecology is to analysis of community composition i.e. presence-absence or abundance of species in sampling sites (Legendre and Chodorowski, 1997).

2.3.2 **Multivariate statistics for relationship between arthropods and environment**

2.3.2.1 **Redundancy analysis (RDA)**

First Canonical redundancy analysis defined by Rao (1964) after that it was rediscovered by Wollenberg (1977) and coined the term Redundancy analysis (RDA). RDA is the direct extension of multiple regressions to the modelling of multivariate response data. The evaluation based on asymmetric response and explanatory variable Y (n χ p) and X (n χ m). RDA ordination axis obtained from PCA data matrix by plotting the Y variables to X through multivariate leaner regression and utilise Euclidian distance among objects. RDA is commonly used to control in leaner effect, separate the outcome of a single explanatory variable, evaluation of related species, construction of MANOVA, construction of Principal response curve (PRC) and screening of explanatory factors. RDA was used by ecologist to analysed structure of arthropod communities and seasonal dynamics by Tim and Roth (2008), Schuldt *et al*. (2008), Samu *et al*. (2014) and Rosa *et al*. (2019).

2.3.2.2 **Canonical correlation analysis (CCA)**

Canonical correlation analysis also designated as CCorA. CCA is asymmetric ordination method first proposed by TerBraak (1986). CCA was utilised to analysed to study spider community and association with environmental factors by Aart and Smeenk-Enserink (1975), TerBraak (1986), De'ath (2002), Maxim *et al.* (2005), Forbanka and Niba (2013) and Muhammad and Ahmed (2014). The Statistic of CCA is derived from RDA but instead of Y, $\bar{Q}$ matrix is used for computation of response matrix and diagonal matrix of row weight D (P_{+i}) is used for computation of regression. The common uses of CCA are study of species spatial distribution with environmental variables (Cadoret *et al*., 1995), Palaeolimnological reconstruction (Birks *et al.,* 1990), Palaeoecology, Limnology and Palaeolimnology (Birks *et al*., 1998).

3 **Results**

3.1 **Arachnida**

Totally 4023 arthropods were collected from silvicultural, horticultural and agricultural ecosystem which belonged to 14 orders and 85 Nos. of different families. In familial level maximum diversity was found in class Insecta composed of 66 Nos. of family and 186 Nos. of genera and class Arachnida composed of 19 Nos. of family and 67 Nos. of genera. In ordinal level maximum diversity was found in class Insecta composed of 13 Nos. of family and class Arachnida composed of 1 Nos. of family. Under Araneae most individuals belonged to the family Araneidae (1456) followed by Tetragnathidae (432), Lycosidae (392), Salticidae (345), Ganophosidae (190), Theridiidae (120), Oxyopidae (111), Linyphiidae (82), Zodariidae (47), Thomisidae (35), Corinnidae (19), Clubionidae (17), Cheiracanthiidae (11), Sparassidae (9), Mimetidae (8), Pisauridae (8), Philodromidae (6) and Pholcidae (1). Majority of individuals under family Araneidae were of the genus *Cyclosa*, *Argiope* and *Neoscona* while under family Lycosidae, Tetragnathidae, Salticidae and Gnaphosidae the genus *Pardosa*, *Mesida*, *Plexippus* and *Haplodrassus* were the most abundant genus found respectively. On the other hand for individual ecosystem maximum diversity were found in silvicultural ecosystem (18 Nos. family) followed by horticultural (13 Nos. family), rice (11 Nos. family), maize (4 Nos. family) and potato (4 Nos. family) ecosystem. In species level maximum diversity found in *Neoscona* (Aranidae) followed by *Cyclosa* (Aranidae), *Argiope* (Aranidae), *Pardosa* (Lycosidae) (Gogoi and Nigthoujam 2021).

3.2 **Multivariate analysis of relationship between arthropods and ecosystems**

3.2.1 **Variation of Arthropods based on Agglomerative hierarchical clustering (AHC)**

Cluster analysis starts with a matrix giving the similarity between each pair of species, families and orders. The similarity between two groups in a matrix is combined to form a single cluster. The analysis proceeds by successively clustering similar groups until all are combined in a single dendrogram. This is not directly evaluating beta diversity but it is generally used to study the presence or absence of different communities. It is used to identify the specific groupings present in a population in a community.

3.2.1.1 **Sivicultural ecosystem**

Analysis based on species, familial and ordinal level of Araneae from silvicultural ecosystem showed a distinct variation in similarity groupings. In silvicultural ecosystem, the Araneae formed 3 clusters comprising of 98 numbers of species which shows variance decomposition for the optimal classification within the class 95.67% and between the classes 4.33% with respect to total class variance 100.00% (**Fig**. 1.1). In silvicultural system, maximum distance between the central objects was seen in species *Drassodes lutiscens* (1.803) followed by *Neoscona vigilans* (1.462) and *Neriene sundaica* (0.00). Analysis showed the species *Drassodes lutiscens* with class object 51, sum of class weight 51, class variance 20.165, minimum class distance to centroid 0.971, average class distance to centroid 3.576 and maximum class distance to centroid 12.553 (**Table** 1).

3.2.1.2 **Horticultural ecosystem**

At species level the araneofauna formed 3 clusters composed of 63 species which showed variance decomposition for the optimal classification within the class 90.49% and between the classes 9.51% with respect to total class variance 100.00% (**Fig**. 1.2). In horticultural system, maximum distance between the central objects was observed in species *Cyclosa insulana* (5.038) followed by *Pardosa sumatrana* (2.650) and *Araneus mitificus* (0.00). Cluster evaluation revealed the species *Cyclosa insulana* with class object 28, sum of class weight 28, class variance 63.587, minimum class distance to centroid 1.957, average class distance to centroid 7.227 and maximum class distance to centroid 14.723 (**Table** 1).

3.2.1.3 **Maize ecosystem**

In maize ecosystem, at species level the araneofauna formed 3 clusters composed of 63 species which showed variance decomposition for the optimal classification within the class 88.98% and between the classes 11.02% with respect to total class variance 100.00% (**Fig**. 1.3). In maize system, maximum distance between the central objects was observed in species *Cyclosa insulana* (4.244) followed by *Oxyopes bimanicus* (2.958) and *Araneus mitificus* (0.00). Cluster evaluation related the species *Cyclosa insulana* with class object 27, sum of class weight 27, class variance 65.430, minimum class distance to centroid 1.953, average class distance to centroid 7.370 and maximum class distance to centroid 14.604 (**Table** 2).

3.2.1.4 **Potato ecosystem**

Analysis based on species level of araneofauna of potato ecosystem showed a distinct variation in similarity groupings represented in the Figure *. In potato ecosystem, the arachnids formed 3 clusters comprising of 14 numbers of species which shows variance decomposition for the optimal classification within the class 71.35% and between the classes 28.65% with respect to total class variance 100.00% (**Fig**. 1.4). In potato system shows maximum distance between the central objects in species *Storena cyanea* (2.236) followed by *Acanthinozodium* sp. (2.000) and *Cheriacanthium* sp. (0.00). Analysis showed the species *Storena cyanea* with class object 7, sum of class weight 7, class variance 3.158, minimum class distance to centroid 0.749, average class distance to centroid 1.543 and maximum class distance to centroid was 2.744 respectively (**Table** 2).

3.2.1.5 **Rice ecosystem**

In rice ecosystem, at species level the araneofauna formed 3 clusters composed of 36 species which showed variance decomposition for the optimal classification within the class 94.59% and between the classes 5.41% with respect to total class variance 100.00% (**Fig**. 1.5). In rice system shows maximum distance between the central objects in species *Neoscona mukerjei* 1 (4.822) followed by *Argiope pulchella* (3.354) and *Argiope* sp. (0.00). Cluster evaluation revealed the species *Neoscona mukerjei* 1 with class object 9, sum of class weight 9, class variance 20.451, minimum class distance to centroid 1.604, average class distance to centroid 3.808 and maximum class distance to centroid 7.996 (**Table** 2).

3.2.2 **Principal component analysis (PCA)**

The principal component analysis showed the variation of collection data set of Arachnids population in 5 different vegetation types *Viz*., silvicultural, horticultural, maize, potato and rice ecosystem (**Fig**. 2.1 & 2.2). The ordination plot explains the occurrence of Arachnids in generic and familial level at observed ecosystems, in generic level PCA biplot explained total 60.89% of variation in which factor F1/PC1 and factor F2/PC2 explained 39.81% and 21.71% and in familial level PCA biplot explained total 83.30% of variation in which factor F1/PC1 and factor F2/PC2 explained 61.82% and 21.48% of variation respectively. The eigenvalues in first and second axis are 1.959 and 1.085 represented in generic level. In familial level eigenvalues are 3.091 and 1.074 in first and second axis (F1/F2) (**Table** 2.2).

The eigenvectors at generic level was found maximum in horticultural ecosystem (0.591) followed by silvicultural (0.581), maize (0.407), rice (0.329) and potato ecosystem (0.183) in factor (F1) (Table 4.2). The eigenvectors at familial level was found maximum in horticultural ecosystem (0.539) followed by silvicultural (0.517), maize (0.464), rice (0.444) and potato ecosystem (0.172) in factor (F1). Spearman correlation between variables (genus) and Factors (Observed ecosystems) was found maximum in horticultural (0.827) and minimum in potato ecosystem (0.256) in first axis factor (F1) (**Table** 2.1). Spearman correlation between variables (family) and Factors (Observed ecosystems) was found maximum in horticultural (0.948) and minimum in potato ecosystem (0.303) in first axis factor (F1).

In correlation circle indicating that Arachnids are closely related in horticultural and silvicultural ecosystems in generic and familial level in case of potato maize and rice ecosystem the arachnids are found to be distantly related. In generic level the genus *Haplodrassus, Pardosa, Plexipus and Epocilla, Evarcha, Ganophosa, Sosticus, Storena, Nephila, Lecauge, Araneus, Tetraganatha, Lycosa, Oxyopes, Neoscona* and *Cyclosa* are found to unique and distinctly positioned in observation by plot and in familial level Zodariidae, Salticidae, Ganophosidae, Lycosidae, Cheriacanrhiidae, Tertragnathidae and Araneidae are found to unique in observation biplot (**Fig**. 2.3 & 2.4). Same results are found in loading vectors in generic and familial level in the Figure 2.3 & 2.4.

3.2.3 **Correspondence analysis (CA)**

The correspondence analysis showed the variation of collection data set of Arachnids population in 5 different vegetation types *Viz*., silvicultural, horticultural, maize, potato and rice ecosystem. The ordination plot explains the occurrence of Arachnids in generic and familial level at observed ecosystems, in generic level CA asymmetric row plot explained total 67.26% of variation in which CA axis 1 and CA axis 2 explained 37.47% and 29.79% and in familial level asymmetric row plot explained total 84.91% of variation in which factor CA axis 1 and CA axis 2 explained 47.80% and 37.11% of variation respectively. The eigenvalues and inertia in first and second axis are 0.381, 37.474% and 0.303, 29.785% represented in generic level. In familial level eigenvalues and percentage inertia are 0.164, 47.797% and 0.127, 37.113% in first and second axis (F1/F2) (**Table** 3.1 & 3.2).

Squired distances from origin in column plot at generic level was found highest in potato ecosystem (7.437) followed by rice (1.473), maize (1.447), horticultural (0.497) and silvicultural ecosystem (0.360). In familial level squired distances from origin in column plot was ranged between 0.063-3.399 in 5 observed ecosystems. The range of standard coordinates was found between -1.534 to 1.845 at generic level and in familial level it was found highest potato ecosystem (4.420) and lowest in maize -1.368 in respects to F1 axis. In case of contribution column at generic level was found highest in horticultural ecosystem in F1 axis (**Table** 3.2).

The asymmetric row and column plot in generic level suggested that the genus *Tylorida, Cyclosa, Neoga, Phintella, Hamadruas* etc., *Ruborridion, Clubiona, Guizygiella, Callilepis* etc., *Dorassodes, Nihohimea, Philodromus, Castineria, Dolomedes, Olios* etc., *Epocilla, Sosticus, Evarcha* etc., *Myrmarache, Larinis, Thaina Mesida, Gasteracantha, Zelotes* etc. showed affinity towards maize, rice, silvicultural, potato and horticultural ecosystems respectively (**Fig**. 3.1 & 3.2). The asymmetric row and column plot in familial level suggested that the family Cheiracanthiidae, Zodariidae, Pasauridae, Philodromidae, Pholcidae, Corinnidae, Salatcidae, Ganophosidae etc., showed a distinctive relation to Silviculture, horticultural and potato ecosystems. The family Linyphiidae, Aranidae, Tetraganthidae, Clubionidae, Mimentidae, Oxyopidae, Uloboridae etc., showed a relation to maize and rice ecosystems respectively (**Fig**. 3.3 & 3.4).

3.3 **Multivariate analysis of relationship between arthropods and environmental parameters**

3.3.1 **Redundancy Analysis (RDA)**:

The Redundancy analysis (RDA) showed the relationship between Arthropod population and environmental parameters in silvicultural, horticultural, maize, potato and rice ecosystem. The RDA ordination plot explains the occurrence of Arthropods in familial and ordinal level at observed ecosystems, in familial level RDA biplot explained total 87.19% of variation in which axis F1 and axis F2 explained 56.46% and 30.73% and in ordinal level RDA biplot explained total 99.27% of variation in which axis F1 and axis F2 explained 87.16% and 12.11% of relation between arthropod population and environmental parameters respectively. The eigenvalues and percentages of inertia in first and second axis are 8.619 and 4.691 represented in familial level (**Table** 4.1). In ordinal level eigenvalues and total percentages of inertia are 8.888 and 1.235 in first and second axis (F1/F2). The canonical coefficient was found maximum in maximum temperature (4.262) followed by minimum temperature (3.132), relative humidity (evening) (3.122), relative humidity (morning) (0.888) and rainfall (-6769) in ordinal level. Redundancy analysis (RDA) indicating that Arachnids families *viz*., Lycosidae, Thomisidae, Theridiidae, Tetraganthidae etc are closely associated with maximum temperature in silvicultural and horticultural ecosystems. In rice ecosytem the families such as Clubionidae, Oxyopidae, Ulboridae and Mimetidae are strongly associated with morning relative humidity (**Fig**. 4.1 & 4.2).

3.3.2 **Canonical Correlation Analysis (CCA)**

3.3.2.1 **Silvicultural ecosystem**

The Canonical Correlation Analysis (CCA) showed the relationship between Arthropod population and environmental parameters in silvicultural ecosystem in familial and ordinal level with 8 Nos. of sampling periods July to February. The CCA ordination plot explains the occurrence of Arthropods in familial and ordinal level in silvicultural ecosystems, in familial level CCA biplot explained total 83.07% of variation in which CCA axis 1 and CCA axis 2 explained 73.07% and 10.00% and in ordinal level CCA biplot explained total 74.43% of variation in which CCA axis 1 and CCA axis 2 explained 56.22% and 18.20% of relation between arthropod population and environmental parameters respectively (**Table** 4.2). Canonical Correlation Analysis (CCA) map indicating that Arachnids families Lycosidae, Pholcidae, Zodariidae and Corinnidae etc. are closely associated with maximum temperature, Araneidae, Theridiidae, Linyphiidae and Salticidae associated with morning RH. The family Cheiracanthiidae, Clubionidae Philodromidae and Sparassidae are associated with evening RH, rainfall and minimum temperature in familial level (**Fig**. 5.1). In ordinal level, orders Isoptera and Lepidoptera strongly associated with maximum temperature and evening RH, Odonata and Hemiptera associated with rainfall. The orders Ephimeroptera and Hymenoptera showed positive relationship towards environmental parameters minimum temperature and morning RH. The orders Dermeptera, Neuroptera, Dictyoptera, Orthoptera, Coleoptera etc. did not show any relationship to environmental parameters (**Fig**. 5.2)

3.3.2.2 **Horticultural ecosystem**

The Canonical Correlation Analysis (CCA) showed the relationship between Arthropod population and environmental parameters in horticultural ecosystem in familial and ordinal level with 8 Nos. of sampling periods July to February. The CCA ordination plot explains the occurrence of Arthropods in familial and ordinal level in horticultural ecosystems, in familial level CCA biplot explained total 92.95% of variation in which axis F1 and axis F2 explained 79.28% and 13.67% and in ordinal level CCA biplot explained total 94.43% of variation in which axis F1 and axis F2 explained 64.02% and 30.41% of relation between arthropod population and environmental parameters respectively (**Table** 4.3). Canocical Correlation Analysis (CCA) map indicating that Arachnids families Lycosidae, Clubionidae and Corinnidae etc. are closely associated with rainfall and evening RH, Salticidae and Thomisidae associated with morning RH and rainfall. The family Cheiracanthiidae and Zodariidae are associated with maximum temperature in familial level. The families Oxyopidae, Theridiidae, Linyphiidae, Araneidae and Tetraganthidae did not showed any relationship towards environmental parameters (**Fig**. 5.3). In ordinal level, orders Isoptera and Araneae are strongly associated with maximum temperature, Hemiptera associated with rainfall. The orders Lepidoptera and Coleoptera showed positive relationship towards environmental parameters maximum temperature (**Fig**. 5.4).

4 **Discussion**

4.1 **Multivariate analysis of relationship between arthropods and ecosystems**

4.1.1 **Variation of Arthropods based on dendrogram analysis**

Muhammad and Ahmed (2014) studied the seasonal abundance of soil arthropods in relation to meteorological and edaphic factors in the agroecosystems *Viz*., sugarcane, cotton, wheat, alfalfa and citrus orchards of Faisalabad, Punjab, Pakistan and used Bray-Curtis cluster analysis to study the soil arthropod based on similarity of abundance and found 4 different similarity cluster groups first cluster comprised of Collembola, Hymenoptera, Acarina, and Myriapoda (>10%), second cluster composed of Orthoptera, Coleoptera, and Araneae (>5%), third cluster Hemiptera, Dermaptera, and Diptera (>1%) and fourth cluster composed of Blattaria, Diplura, Isoptera, and Lepidoptera (≈0%).

Saranya *et al*. (2019) who studied the diversity of predatory spider fauna in maize ecosystem used dendrogram analysis to evaluate similarity index of predatory spider families. The six spider families formed one clusters and genus formed three clusters with 25% similarity. Sidclay *et al*, 2010 used dendrogram analysis to study guilds in Neotropical spiders (Arachnida: Araneae). George *et al*. (1999) used similarity clustering to study guild structure in major crops *Viz*., peanut, alfalfa, soybean, rice, corn, cotton, sugar and sorghum. The six spider families formed one clusters and genus formed three clusters with 25% similarity. Sidclay *et al.* (2010) used dendrogram analysis to study guilds in Neotropical spiders (Arachnida: Araneae). George et al. (1999) used similarity clustering to study guild structure in major crops *viz*., peanut, alfalfa, soybean, rice, corn, cotton, sugar and sorghum.

4.1.2 **Principal component analysis (PCA)**

The ordination plot explains the occurrence of Arachnids in generic and familial level at observed ecosystems, in generic level PCA biplot explained total 60.89% of variation in which factor F1/PC1 and factor F2/PC2 explained 39.81% and 21.71% and in familial level PCA biplot explained total 83.30% of variation in which factor F1/PC1 and factor F2/PC2 explained 61.82% and 21.48% of variation respectively. In correlation circle in generic level the genus *Haplodrassus*, *Pardosa*, *Plexipus* and *Epocilla*, *Evarcha*, *Ganophosa*, *Sosticus*, *Storena*, *Nephila*, *Lecauge*, *Araneus*, *Tetraganatha*, *Lycosa*, *Oxyopes*, *Neoscona* and *Cyclosa* are found unique and distinctly positioned in observation biplot and in familial level Zodariidae, Salticidae, Ganophosidae, Lycosidae, Cheriacanrhiidae, Tertragnathidae and Araneidae were found unique in observation biplot Same results are found in loading vectors in generic and familial level.

Similarly, the Principal component analysis method was used by Rosa *et al*. (2019) to study the diversity of soil spiders in land use and management systems in Santa Catarina, Brazil and evaluate the habitat specific occurrence of spider in native forest, eucalyptus reforestation, pasture, crop-livestock integration, and no-tillage crop. Schuldt *et al*. (2008) also used PCA to analyse ground-living communities of spiders in deciduous forests with relationship between spider diversity and ecosystem function in Thuringia.

4.1.3 **Correspondence analysis (CA)**

The ordination plot explains the occurrence of Arachnids in generic and familial level at observed ecosystems, in generic level CA asymmetric row plot explained total 67.26% of variation in which factor CA axis 1 and factor CA axis 2 explained 37.47% and 29.79% and in familial level asymmetric row plot explained total 84.91% of variation in which factor CA axis 1 and factor CA axis 2 explained 47.80% and 37.11% of variation respectively. The asymmetric row and column plot in generic level suggested that the genus *Tylorida*, *Cyclosa*, *Neoga*, *Phintella*, *Hamadruas* etc., *Ruborridion*, *Clubiona*, *Guizygiella*, *Callilepis* etc., *Dorassodes*, *Nihohimea*, *Philodromus*, *Castineria*, *Dolomedes*, *Olios* etc., *Epocilla*, *Sosticus*, *Evarcha* etc., *Myrmarache*, *Larinis*, *Thaina, Mesida*, *Gasteracantha*, *Zelotes* etc. showed affinity towards maize, rice, silvicultural, potato and horticultural ecosystems respectively. The asymmetric row and column plot in familial level showed that the family Cheiracanthiidae, Zodariidae, Pasauridae, Philodromidae, Pholcidae, Corinnidae, Salatcidae, Ganophosidae etc., showed a distinctive relation to Silviculture, horticultural and potato ecosystems. The family Linyphiidae, Aranidae, Tetraganthidae, Clubionidae, Mimentidae, Oxyopidae, Uloboridae etc., showed a relation to maize and rice ecosystems respectively.

This method was used by Forbanka and Niba (2013) to study the association of invertebrate to different site specific occurrence to habitat variables *Viz*., litter depth, grazing intensity, soil pH, soil phosphorus content and texture in forest ecosystems. Kosulic *et al*. (2016) used these methods to study the spider assembles and it association to canopy openness in forest ecosystems.

4.2 **Multivariate analysis of relationship between arthropods and environmental parameters**

4.2.1 **Redundancy Analysis (RDA)**

In rice ecosystem the families such as Clubionidae, Oxyopidae, Ulboridae and Mimetidae are strongly associated with morning relative humidity. The families Salticidae, Linyphiidae, Cheiracanthiidae and Zodariidae are found to associate with evening relative humidity and rainfall. In familial level the Arachnids population did not show any relationship to minimum temperature in maize and potato ecosystems. In silvicultural and horticultural ecosystems the arthropods orders Araneae, Dermptera, Colioptera, Dictyoptera, Neuroptera, and Isoptera showed a strong relation to maximum temperature. In rice ecosystem the orders Hymenoptera, Orthroptera, Odonata, Lepidoptera and Hemiptera showed strong association to morning relative humidity. In ordinal level the arthropods population did not show any relationship to minimum temperature, rainfall and evening relative humidity in maize and potato ecosystems.

Schuldt *et al.* (2008) used redundancy analysis (RDA) to study spider population and its association to environmental parameters viz., soil pH, lime, litter depth, herb cover and soil moisture in Communities of ground-living spiders in deciduous forests and found no significant correlation of species richness and above environmental variables. Rosa *et al.* (2019) used redundancy analysis (RDA) to study spider population and its association to environmental parameters *viz.*, organic matter, magnesium, resistance to root penetration, weighted mean diameter, microporosity, macroporosity, total organic carbon, aluminium, soil bulk density, calcium, biopores, nitrogen, soil moisture in western Santa Catarina, Mexico in winter and summer seasons.

4.2.2 **Canonical Correlation Analysis (CCA)**

4.2.2.1 **In Silvicultural ecosystem**

Canonical Correlation Analysis (CCA) map indicated that Arachnids families Lycosidae, Pholcidae, Zodariidae and Corinnidae etc. were closely associated with maximum temperature; Araneidae, Theridiidae, Linyphiidae and Salticidae associated with morning RH. The family Cheiracanthiidae, Clubionidae Philodromidae and Sparassidae were associated with evening RH, rainfall and minimum temperature in familial level. The families Oxyopidae, Mimetidae and Tetraganthidae did not showe any relationship to environmental parameters. In ordinal level, orders Isoptera and Lepidoptera were strongly associated with maximum temperature and evening RH; Odonata and Hemiptera were associated with rainfall. The orders Ephimeroptera and Hymenoptera showed positive relationship towards environmental parameters i.e. minimum temperature and morning RH. The orders Dermeptera, Neuroptera, Dictyoptera, Orthoptera, Coleoptera etc. did not show any relationship to environmental parameters.

4.2.2.2 **In Horticultural ecosystem**

The Arachnids families Lycosidae, Clubionidae and Corinnidae etc. were closely associated with rainfall and evening RH; Salticidae and Thomisidae were associated with morning RH and rainfall. The family Cheiracanthiidae and Zodariidae were associated with maximum temperature in familial level. The families Oxyopidae, Theridiidae, Linyphiidae, Araneidae and Tetraganthidae did not show any relationship to environmental parameters. In ordinal level, orders Isoptera and Araneae were strongly associated with maximum temperature and Hemiptera with rainfall. The orders Lepidoptera and Coleoptera showed positive relationship to environmental parameters maximum temperature. The orders which are found in horticultural ecosystem did not show any association with morning and evening RH.

Maxim *et al.* (2005) evaluated the effects of a recent wildfire and clear cuts on ground-dwelling boreal forest spider assemblages and used canocical corrrelation analysis (CCA) to study association of spider assemblages (62 species) to environmental parameters (12 Nos.) in canopy, moss-lichen, Moss-lichen depth, ground vegetation, Litter depth, snags, leaves, bare soil, Heterogeneity index, stumps and tree fall. Forbanka and Niba (2013) studied the distribution and diversity of epigaeic invertebrate assemblages in Silaka Nature Reserve, Eastern Cape, South Africa with environmental variables grazing intensity, litter depth, soil phosphorus, soil pH, percentage sand, percentage clay and percentage silt and found Geophilomorpha, Amphipoda, Isopoda and Opiliones prefers moist and humid habitat, Opiliones, Isopoda and Amphipoda associated with soil texture, pH and phosphorus content. Muhammad and Ahmed

(2014) studied the seasonal abundance of soil arthropods in relation to meteorological and edaphic factors in the agroecosystems viz., sugarcane, cotton, wheat, alfalfa and citrus orchards of Faisalabad, Punjab, Pakistan and used Canocical Corrrelation Analysis (CCA) to study association of spider assemblages to environmental parameters and found Myriapoda correlated with soil temperature and soil organic matter although Collembola, Acarina and Araneae were correlated with relative humidity and soil organic matter composition.

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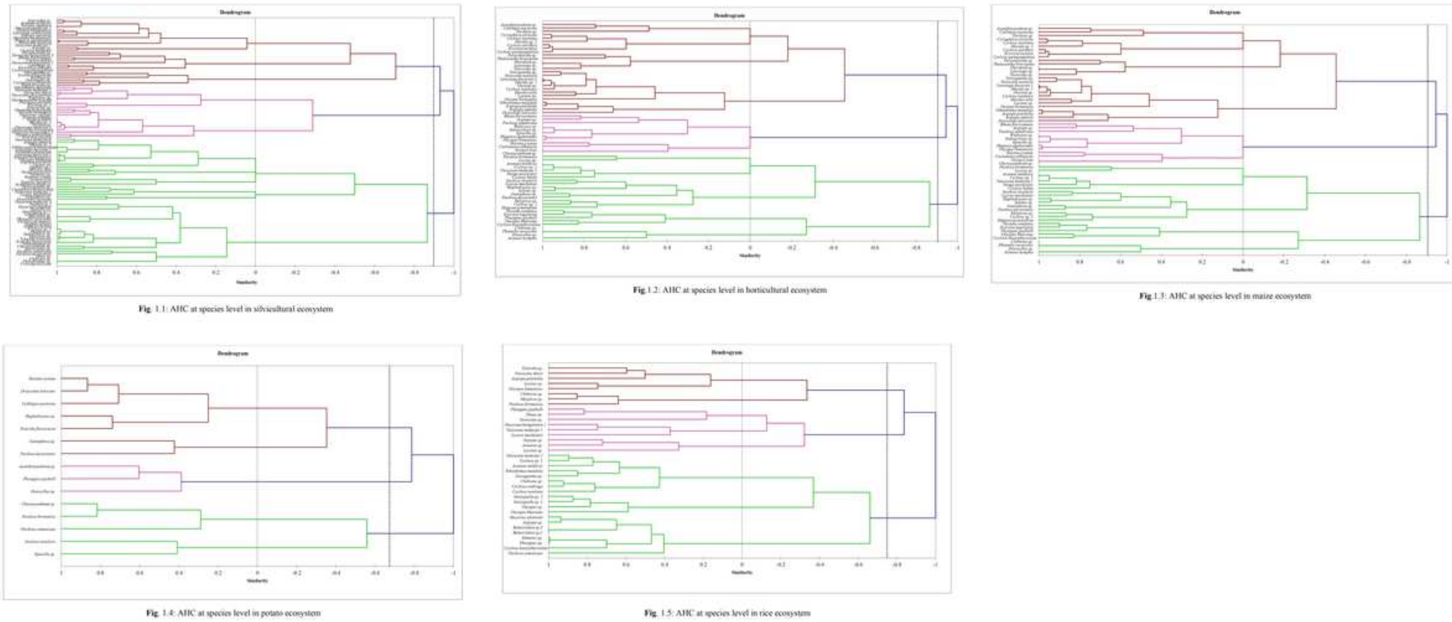

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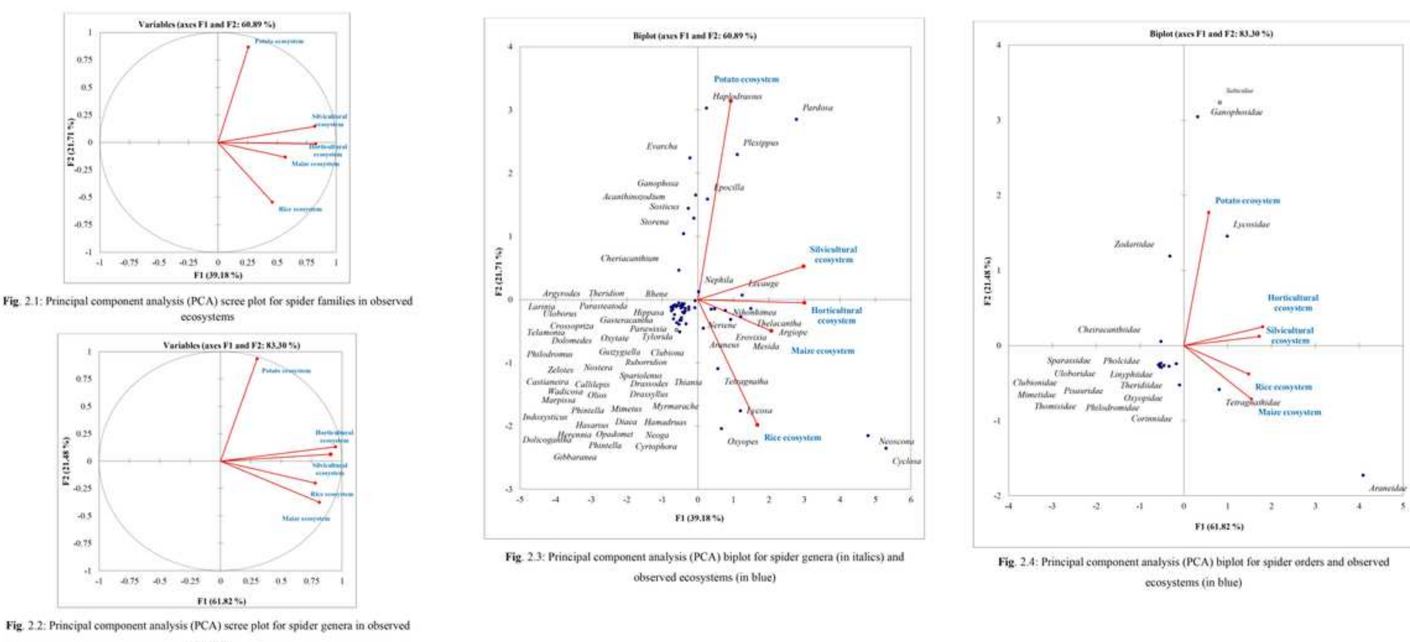

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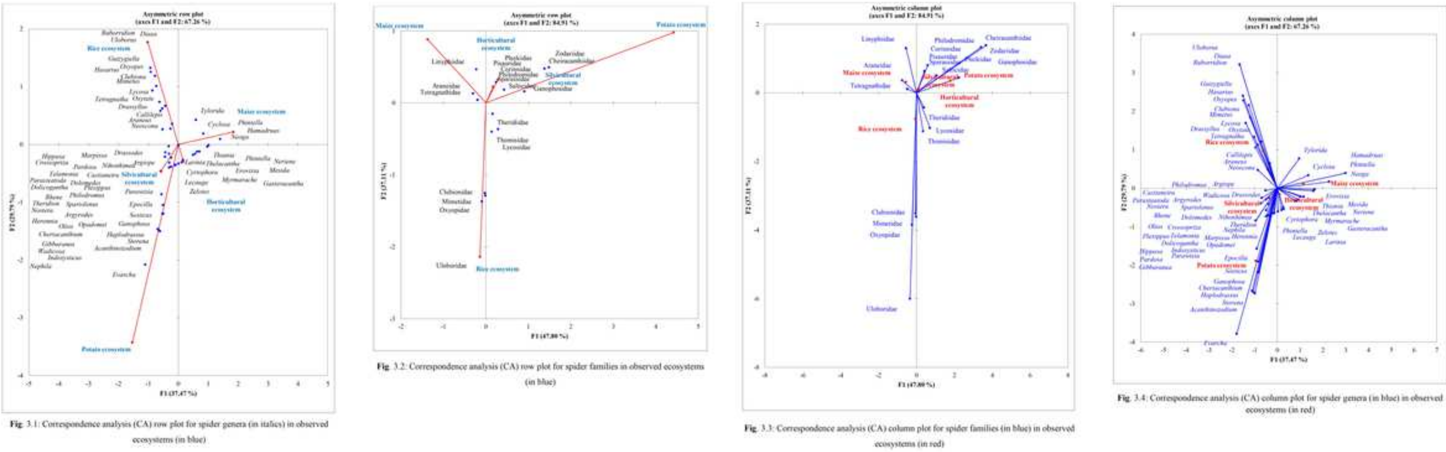

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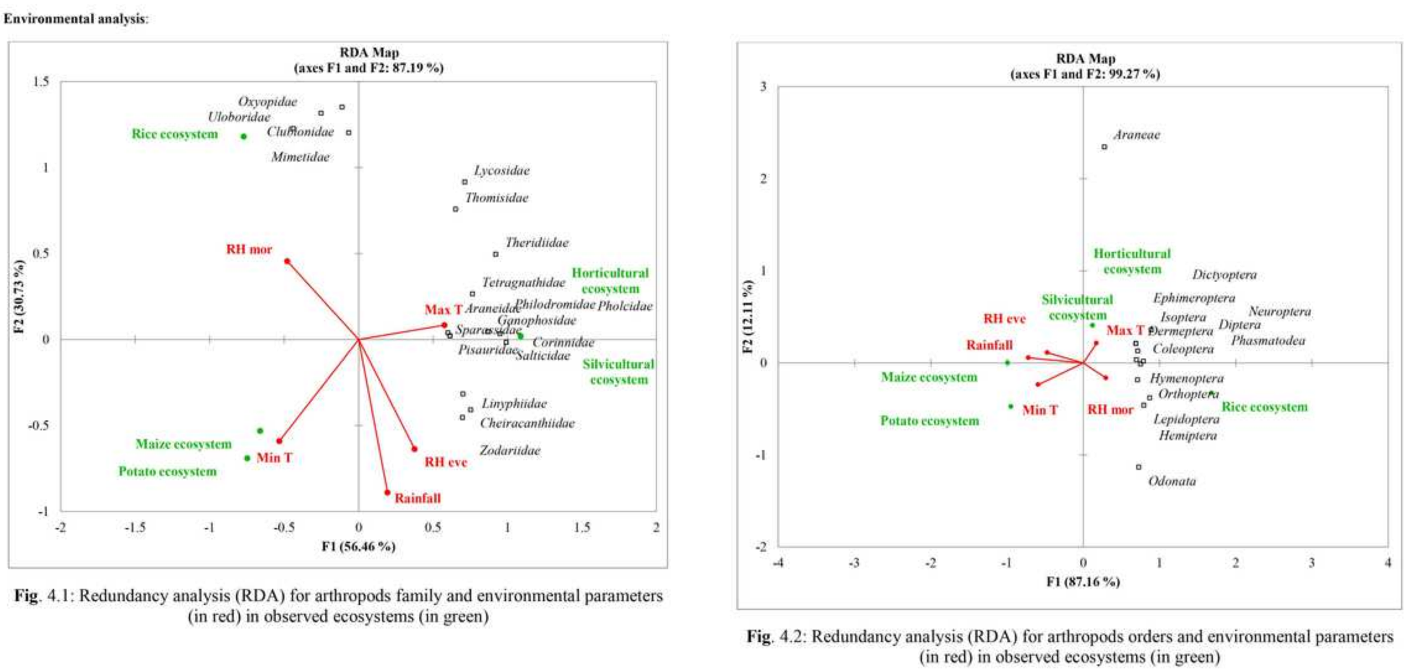

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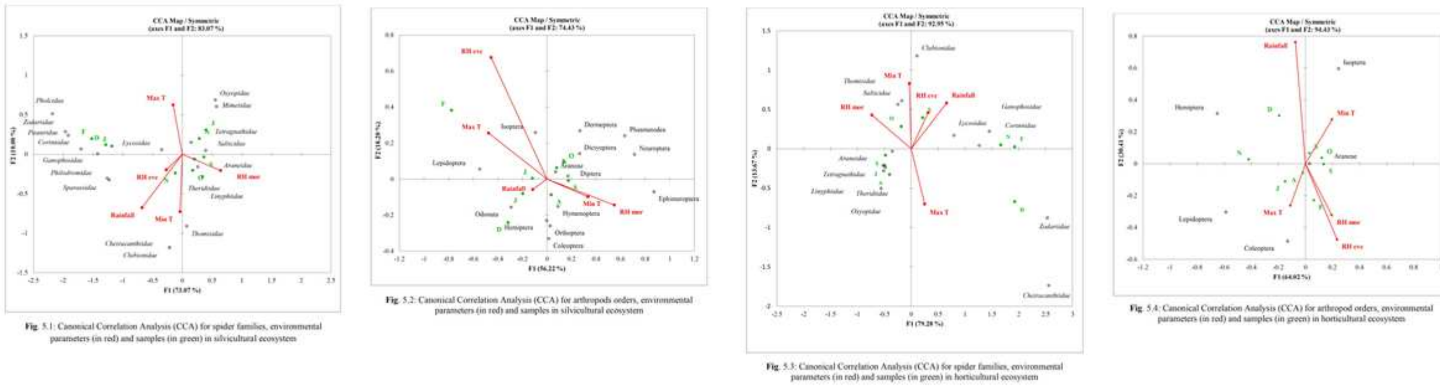

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