ARANEOFAUNA ASSOCIATED WITH SELECTED HORTICULTURAL CROPS OF THRISSUR DISTRICT, KERALA

Thesis submitted in partial fulfilment of

the requirements for the Degree of

DOCTOR OF PHILOSOPHY IN ZOOLOGY

Under the Faculty of Science

University of Calicut

by

PRASAD N. K.

Under the supervision of

Dr. SUDHIKUMAR A.V.
Associate Professor
Department of Zoology
Christ College (Autonomous)
Irinjalakuda, Kerala, India-680125

AUGUST 2024

DECLARATION

I, **PRASAD N. K.**, hereby declare that the work presented in the thesis entitled "**ARANEOFAUNA ASSOCIATED WITH SELECTED HORTICULTURAL CROPS OF THRISSUR DISTRICT, KERALA**" is based on the original work done by me under the guidance of **Dr. Sudhikumar A.V**, Associate Professor, Department of Zoology, Christ College (Autonomous), Irinjalakuda and has not been included in any other thesis submitted previously for the award of any degree. The contents of the thesis are undergone plagiarism check using iThenticate software at C.H.M.K. Library, University of Calicut, and the similarity index found within the permissible limit. I also declare that the thesis is free from AI generated contents.

PRASAD N. K.

Irinjalakuda

August 2024

Dr. SUDHIKUMAR A.V.
Associate Professor

Centre for Animal Taxonomy & Ecology
Department of Zoology
Christ College (Autonomous)
Irinjalakuda, Kerala, INDIA- 680125
Mob: 0091-8547553174
Email: avsudhi@christcollegeijk.edu.in
https://sites.google.com/view/arachnology
http://www.christcollegeijk.edu.in

August 2024

CERTIFICATE

This is to certify that the thesis entitled **"ARANEOFAUNA ASSOCIATED WITH SELECTED HORTICULTURAL CROPS OF THRISSUR DISTRICT, KERALA"** submitted to the University of Calicut in partial fulfilment of the requirements for the Degree of Doctor of Philosophy in Zoology is an authentic record of the work carried out by **Mr. PRASAD N. K.** under my supervision in Centre for Animal Taxonomy and Ecology, Department of Zoology, Christ College (Autonomous), Irinjalakuda, affiliated to University of Calicut and no part of the thesis has formed the basis for the award of any degree, diploma or other similar titles of any University. It is further certified that the corrections/suggestions recommended by the adjudicators have been incorporated in the thesis and that the contents in the thesis and the soft copy are one and the same.

Dr. SUDHIKUMAR A.V.

(Guide)

Dr. SUDHIKUMAR A.V.
ASSISTANT PROFESSOR & RESEARCH SUPERVISOR
CENTRE FOR ANIMAL TAXONOMY & ECOLOGY
DEPARTMENT OF ZOOLOGY
CHRIST COLLEGE, IRINJALAKUDA, KERALA - 680 125

CHRIST COLLEGE (AUTONOMOUS),
IRINJALAKUDA, THRISSUR,
KERALA, INDIA 680125

August 2024

CERTIFICATE

This is to certify that **Mr. PRASAD N. K.** has completed the research work for the full period prescribed under the Ph.D. ordinance of the University of Calicut. This thesis **"ARANEOFAUNA ASSOCIATED WITH SELECTED HORTICULTURAL CROPS OF THRISSUR DISTRICT, KERALA"** embodies the results of his investigations conducted during the period at which he worked as a research scholar. I recommend the thesis to be submitted for the evaluation for the award of the degree of Doctor of Philosophy in Zoology of the University of Calicut.

PRINCIPAL

Associate Professor-
In-charge of Principal
Christ College (Autonomous),
Irinjalakuda

UNIVERSITY OF CALICUT

CERTIFICATE ON PLAGIARISM CHECK

1.	Name of the Research Scholar	PRASAD N K	
2.	Title of thesis / dissertation	Araneofauna associated with selected horticultural crops of Thrissur District, Kerala.	
3.	Name of the Supervisor	Dr. Sudhikumar A.V.	
4.	Department/Institution	Department of Zoology, Christ College (Autonomous), Irinjalakuda	
5.	Similar content (%) identified	Non-Core	Core
		Introduction/ Theoretical overview/Review of literature/ Materials & Methods/ Methodology	**Analysis/Result/Discussion/ Summary/Conclusion/ Recommendations**
		1	3
	Acceptable maximum limit (%)	10	10
6.	Software used	**iThenticate**	
7.	Date of verification	25 - 07 - 24	

**Report on plagiarism check, specifying included/excluded items with % of similarity to be attached.*

Checked by (with name, designation & signature)Name Dr. Nasirudheen. T, Assistant Librarian, University of Calicut, Kerala.

and signature of the Researcher

Name and signature of the Supervisor. Dr. SUDHIKUMAR A.V., ASSISTANT PROFESSOR & RESEARCH SUPERVISOR, CENTRE FOR ANIMAL TAXONOMY & ECOLOGY, DEPARTMENT OF ZOOLOGY, CHRIST COLLEGE, IRINJALAKUDA, KERALA - 680 125

The Doctoral Committee* has verified the report on plagiarism check with the contents of the thesis, as summarized above and appropriate measures have been taken to ensure originality of the Research accomplished herein.

Name & Signature of the HoD/HoI (Chairperson of the Doctoral Committee)

**In case of languages like Malayalam, Tamil etc. on which no software is available for plagiarism check, a manual check shall be made by the Doctoral Committee, for which an additional certificate has to be attached.*

CHRIST COLLEGE (AUTONOMOUS) IRINJALAKUDA

Associate Professor-
In-charge of Principal
Christ College (Autonomous),
Irinjalakuda

Acknowledgements

I am immensely grateful to all those who have helped in the realization of my long-cherished goal. I extend my sincere thanks to Dr. Sudhikumar A.V., Associate Professor in the Department of Zoology at Christ College, Irinjalakuda, and Director of the Centre for Animal Taxonomy and Ecology (CATE). Dr. Sudhikumar A.V. not only sparked my interest in the subject but also provided unwavering support, guidance, encouragement, and invaluable suggestions for my research.

Furthermore, I express my heartfelt appreciation to Dr. Prof. Nasser M., Pro-Vice Chancellor, and Director of Research, University of Calicut for being a constant source of support and motivation throughout my research.

I want to extend my sincere gratitude to Dr. Mathew Paul Ukken, the former Principal, and Rev. Dr. Jolly Andrews CMI, the current Principal-in-Charge of Christ College, Irinjalakuda, for their provision of essential facilities that greatly aided in the completion of my work.

I extend my deepest thanks to the late Fr. Dr. Jose Thekkan CMI, former principal, for his timely assistance and blessings, which I truly appreciate.

Additionally, I am thankful to Dr. Balu T. Kuzhivelil, Dr. V.P. Joseph, and Dr. V.T. Joy, Former and present Research Coordinators at Christ College, Irinjalakuda, for their kind assistance, which played a crucial role in the successful fulfilment of my work.

I wish to convey my deep sense of appreciation to Mr. Shihabudeen A.S., former colleague of mine, for always being there to support and motivate me.

I want to give special recognition to the faculty of the Zoology Department, Christ College, Irinjalakuda for their ongoing cooperation and encouragement during my time as a research scholar.

I am profoundly thankful to the members of the Centre for Animal Taxonomy and Ecology (CATE) for their substantial contributions to my research and for being a continuous source of inspiration and motivation. I am grateful to Dr. Sumesh N.V., Dr. Nafin K.S., Dr. Sudhin P.P., Dr. Kashmeera N.A., Dr. Drisya Mohan O.M., Mrs. Fathima P.A., Ms. Aswathy M. Das, Ms. Shilpa K.R., Mr. Abhijith R.S., Mr. Vishnu Das E.H., and Mr. Rishikesh Tripathi for their insightful comments, suggestions, and timely support throughout my study. I want to convey my deep sense of gratitude to all other research scholars there for their invaluable support and assistance in advancing my research efforts.

I am indebted to the research scholars of various laboratories under the Department of Zoology at Christ College, Irinjalakuda, whose continuous assistance has been much helpful for me. I want to express my thanks to Ms. Madhuri Menon M., Mrs. Jimsy K. Johnson, Mrs. Dhilna Sunny, and Dr. Praveen K. from the Immunology and Toxicology Lab; Ms. Aswathy P.G., Ms. Anju Sara Prakash, Mr. Soorya Narayanan T.B., and Mrs. Thasnim E.S. from the Shadpada Entomology Lab; and Mr. Adharsh P.K. and Aiswarya N. from the Entomo Lab. Also, I am deeply grateful to the scholars from CDRL, including Ms. Lekshmi Jayakrishnan, Dr. Fathibi K., Dr. Asha A.V., Mrs. Lekshmi K.V., Dr. Anoop Kumar A.N., Mr. Sreedev Puthur, and Mrs. Sini, for their support.

Gratitude is also extended to Mrs. Bindu, a part-time research scholar in Physics, and Mr. Ayyappadas, a Research Scholar from the Department of Geology and Environmental Sciences, for their valuable contributions.

I want to give special recognition to the HoD and faculty of Department of Statistics, Christ College Irinjalakuda, for their committed assistance for conducting statistical analysis.

I acknowledge the support of the office staff and library staff at Christ College, Irinjalakuda, throughout my research.

I want to convey my profound gratitude to Dr. Shaji E.M., Mrs. Soumya K.C. and Dr. Seema Menon, my colleagues from KKTM Government College Pullut, Kodungallur.

I am grateful to my family, including my wife, father, brother, daughters, son, cousins and in-laws, for their unwavering support and understanding during my research journey. I want to make a special mention of my beloved mother, who has passed away, but whose continuous efforts and dedication were invaluable in shaping who I am today.

Special appreciation goes to my best friends for their affectionate advice and spontaneous assistance.

My students over the years have played a significant role in fostering my drive for research, and I am deeply indebted to them. Most importantly, I express gratitude to the Divine for granting me the blessings of patience and good health.

Prasad N. K.

ABSTRACT

Horticulture plays a pivotal role in enhancing the food security in our country through increased production of fruits, vegetables and spices. Spiders in the croplands helps in biocontrol of pests in crop fields and there by alleviate the problem of increased use of agrochemicals and health hazards due their residues in crops. This study was conducted or investigating the diversity of spiders within horticultural ecosystems across five different sites in Thrissur district, Kerala, India. The research spanned two years, from 2016 to 2018, focusing on croplands in Kuzhur, Narayanamangalam, Nenmanikkara, Bharata, and Chelakkara, all located in Thrissur district. 116 species of spiders from 75 genera and 21 families were found from the fields of horticultural crops in the Thrissur district. Salticidae and Araneidae were the predominant families, with Salticidae exhibiting the highest richness, comprising 25 genera and 30 species, followed by Araneidae with 10 genera and 24 species. A noticeable difference in diversity, richness and abundance was observed among the habitat surveyed. Nenmanikkara ranked highest in case of richness and Narayanamangalam in case of abundance. An adequate sampling efficiency was reported as the species accumulation curves approached the plateau. On analysis of seasonal fluctuation of diversity, post monsoon season peaked in richness and abundance while in pre-monsoon season it reached to lowest value. Rank abundance curves for various habitats and seasons were plotted for visual comparison of diversity. Out of the seven feeding guilds reported, other hunters turned to be the dominant one. A preliminary analysis on the impact of two commonly used pesticides; quinalphos and lambda cyhalothrin on four dominant species of spiders, was conducted. It was found that both these pesticides adversely affect the feeding efficacy of all the four species of spiders under study. It was also

noteworthy that the impact of lambda cyhalothrin was significantly higher than quinalphos in all the cases.

Key words: Diversity, horticulture, species accumulation curve, Rank abundance curve, feeding guild, feeding efficacy.

സംഗ്രഹം

പുഷ്പ, ഫല, സുഗന്ധവ്യഞ്ജനങ്ങളുടെ ഉൽപാദനത്തിലൂടെ ഭാരതത്തിന്റെ ഭക്ഷ്യസുരക്ഷക്ക് ഹോർട്ടികൾച്ചർ നൽകിയ സംഭാവന വളരെ വലുതാണ്. മറ്റു പരമ്പരാഗത കൃഷി രീതികളെ പോലെത്തന്നെ ഹോർട്ടികൾച്ചറും നേരിടുന്ന വലിയ ഒരു പ്രശ്നം കീടങ്ങളുടെ ആക്രമണവും തദ്വാരാ ഉണ്ടാകുന്ന കൃഷി നഷ്ടവും ആണ്. കീടശല്യം നിയന്ത്രിക്കുന്നതിനായി കീടനാശിനികളുടെ അമിത ഉപയോഗം ഉണ്ടായാൽ അത് ഭീതിദായകമായ ആരോഗ്യപ്രശ്നങ്ങളിലേക്ക് വഴി തെളിയിക്കുകയും ചെയ്യും. ഇവിടെയാണ് ജൈവ കീട നിയന്ത്രണ മാർഗങ്ങളുടെ പ്രാധാന്യം. ഷഡ്പദ കീടങ്ങളെ ആഹരിക്കുന്ന പ്രധാന ജീവിവർഗ്ഗം എന്ന നിലയിൽ ചിലന്തികൾ ജൈവകീട നിയന്ത്രകരിൽ ഗണ്യമായ പരിഗണന അർഹിക്കുന്നുണ്ട്. വൈവിധ്യത്തിൽ ഏഴാം സ്ഥാനത്ത് വരുന്നു എന്നതും ഇക്കാര്യത്തിൽ ചിലന്തികളുടെ പ്രാധാന്യം വർധിപ്പിക്കുന്നുണ്ട്.

ഇപ്പോൾ നടത്തിയിരിക്കുന്ന ഈ ഗവേഷണപഠനത്തിൽ പഠനം പ്രധാനമായും ഊന്നൽ നൽകുന്നത് തൃശ്ശൂർ ജില്ലയിലെ അഞ്ച് ഹോർട്ടികൾച്ചർ കൃഷിയിടങ്ങളിലെ ചിലന്തികളുടെ ജൈവവൈവിധ്യം, കാലാവസ്ഥയിലുണ്ടാവുന്ന മാറ്റങ്ങൾ, കീടനാശിനി പ്രയോഗങ്ങൾ എന്നിവ അതിനെ സ്വാധീനിക്കുന്ന വിധം തുടങ്ങിയവയാണ്. ഭരത, ചേലക്കര, കുഴൂർ, നെന്മണിക്കര, നാരായണമംഗലം എന്നീ അഞ്ച് കൃഷിയിടങ്ങളിലായി 2016 മുതൽ 2018 വരെ നടത്തിയ പ്രസ്തുത പഠനത്തിൽ 21 കുടുംബങ്ങളിൽപെട്ട ചിലന്തികളാണ് ആണ് റിപ്പോർട്ട് ചെയ്യപ്പെട്ടിട്ടുള്ളത്. ഇതിൽ 75 വിവിധ ജീനസുകളിൽ പെട്ട 116 സ്പീഷീസുകൾ ഉൾപ്പെടുന്നു. ഏറ്റവും ഉയർന്ന വൈവിധ്യം പ്രകടിപ്പിക്കുന്നത് സാൾട്ടിസിഡെ, അരാനിഡെ എന്നീ കുടുംബങ്ങളാണ്. 25 ജീനസുകളിൽ ആയി 30 സ്പീഷീസ് സാൾട്ടിസിഡെയിലും 10 ജീനസുകളിലായി 24 സ്പീഷീസുകൾ അരാനിഡെയിലും വരുന്നു. ചിലന്തികളുടെ എണ്ണത്തിൽ നാരായണാമംഗലത്തെ കാർഷിക ആവാസ വ്യവസ്ഥയും സ്പീഷീസ് വൈവിധ്യത്തിൽ നെന്മണിക്കരയിലെ

അവസാവ്യവസ്ഥയും ഒന്നാം സസ്ഥാനത്ത് നിൽക്കുന്നു. സ്പീഷ്യസ് അക്യുമുലേഷൻ കർവുകൾ ഉപയോഗിച്ചുള്ള പഠനത്തിലൂടെ സാംബ്ലിങ്ങ് പ്രക്രിയയിലെ കാര്യക്ഷമതയും ഉറപ്പുവരുത്തിയിരിക്കുന്നു. തെക്കുകിഴക്കേ മൺസൂണിനെ അടിസ്ഥാനപ്പെടുത്തി പഠനകാലയളവിനെ മൺസൂൺ പൂർവ്വകാലം, മൺസൂൺ കാലം, മൺസൂൺ ശേഷകാലം എന്നിങ്ങനെ മൂന്നായി തരം തിരിച്ചിരിക്കുന്നു. ഏറ്റവും ഉയർന്ന വൈവിധ്യം പ്രകടമാക്കുന്നത് മൺസൂൺശേഷകാലഘട്ടത്തിലും ഏറ്റവും കുറവ് വൈവിധ്യം മൺസൂൺ പൂർവ്വ കാലഘട്ടത്തിലുമാണ്. ജൈവവൈവിധ്യ താരതമ്യപഠനത്തിനായി ഷാനോൻ ഡൈവേഴ്സിറ്റി ഇൻഡക്സ്, സിംപ്സൺ ഡൈവേഴ്സിറ്റി ഇന്ഡക്സ്, റാങ്ക് ആബൻഡൻസ് കർവ്, ഡൈവേഴ്സിറ്റി പ്രൊഫൈൽ കർവ് എന്നിവ ഉപയോഗപ്പെടുത്തിയിരിക്കുന്നു. തിരഞ്ഞെടുത്ത നാല് സ്പീഷീസ് ചിലന്തികളിൽ കീടനാശിനികളായ കിനാൽഫോസ്, ലാംഡാസൈഹാലോത്രിൻ എന്നിവയുടെ ആഘാതവും പഠനത്തിൽ ഉൾപ്പെടുത്തിയിരിക്കുന്നു. നാല് സ്പീഷീസ് ചിലന്തികളിലും ലാംഡാസൈഹാലോത്രിൻറെ ആഘാതം കിനാൽഫോസിനെ അപേക്ഷിച്ച് കൂടുതൽ തീവ്രമാണെന്ന് കണ്ടെത്തിയിരിക്കുന്നു.

പ്രധാന പദങ്ങൾ: ഹോർട്ടികൾച്ചർ, ഷാനോൻ ഡൈവേഴ്സിറ്റി ഇൻഡക്സ്, സിംപ്സൺ ഡൈവേഴ്സിറ്റി ഇൻഡക്സ്, റാങ്ക് ആബൻഡൻസ് കർവ്, ഡൈവേഴ്സിറ്റി പ്രൊഫൈൽ കർവ്, സ്പീഷ്യസ് അക്യുമുലേഷൻ കർവ്.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

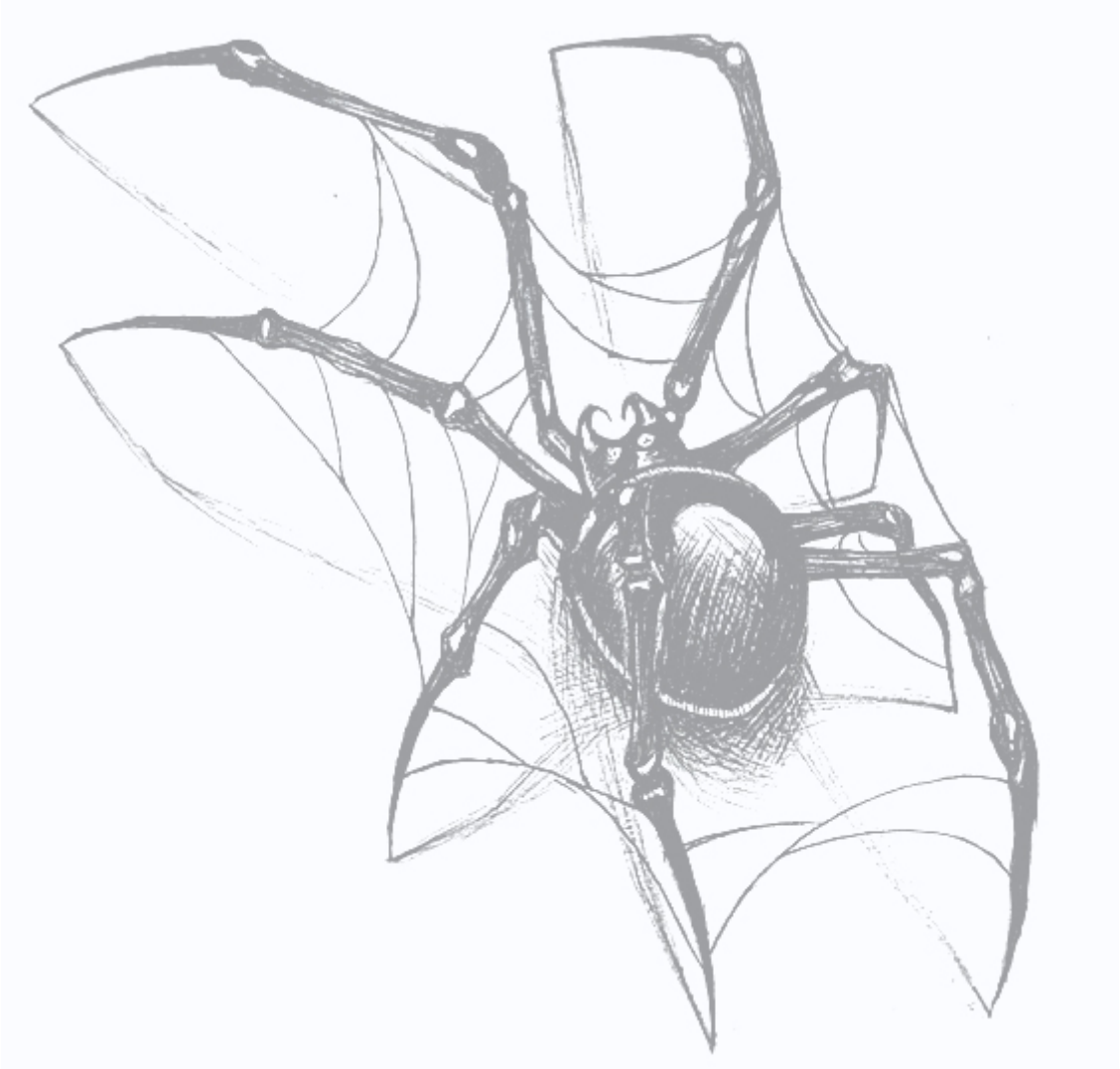
LIST OF PLATES

ACRONYMS AND ABBREVIATIONS

ACE	Abundance-based Coverage Estimator
AIC	Akaike Information Criterion
ANOSIM	Analysis of Similarity
ANOVA	Analysis of Variance
BIC	Bayesian Information Criterion
EC	Effective Concentration
FAO	Food and Agricultural Organization of the United Nations
IDI	Individual Dominance Index
IPM	Integrated Pest Management
nMDS	Non-metric Multidimensional scaling
PERMANOVA	Permutational Analysis of Variance
SD	Standard Deviation
se	Standard Error
SIMPER	Similarity Percentage
WSC	World Spider Catalogue
WWF	World Wildlife Fund

Study sites and Seasons

BTA	Bharata
CRA	Chelakkara
KZR	Kuzhur
NGM	Narayanamangalam
NKR	Nenmanikkara
MON	Monsoon
POM	Post Monsoon
PRM	Pre-Monsoon



CHAPTER 1
INTRODUCTION

INTRODUCTION

1.1. A prelude to the spider world

Spiders (Phylum Arthropoda, Class Arachnida, Order Araneae) are an exceptionally unique group of animals with a remarkably complex niche structure. They are distributed all over the world except in Antarctica (Piel, 2018).Their presence can be traced in every imaginable habitat on earth, including the dwelling places of many other creatures. They play a key role in managing the population size of a large number of other arthropods to a lower level (Nyffeler & Birkhofer, 2017). They exhibit a wide variety of lifestyles, behaviours and adaptations. Being generalist predators, their role in the ecosystem is highly significant. As obligate carnivores, they assume the position of second-order consumers in the ecosystems they live. They also act as the prey of many creatures, including insects, fishes, reptiles, and birds. Even though spiders are considered to be the generalist predators, many exceptions are there, like Bolas spiders which feed only on male moths (Stowe *et al.*, 1987), and some spiderlings that take their nourishment from pollen grains (Smith & Mommsen, 1984; Taylor & Foster, 1996; Taylor & Pfannenstiel, 2008), *Dolomedes triton* (Walckenaer, 1837) subsists on the neustons of water bodies (Zimmermann & Spence, 1989). Nectivory and pollinivory can be seen in many spiders especially in salticids as a mechanism for nutrient supplementation. (Jackson *et al.*, 2001). *Bagheera kiplingi* Peckham & Peckham, 1896 is reported to be herbivorous and feed mainly on selected leaf tips (Meehan *et al.*, 2009).

By playing the role of both predators and prey, spiders facilitate nutrient cycling and energy transfer in their ecosystems. Spiders can function as a top-level consumer in the detritus food chain as the epigeal spiders feed on many detritivorous

insects like collembolans and mites (Wise *et al*., 1999; Shimazaki & Miyashita, 2005). There are several documentations on their interactions such as intraguild competition with other arthropods, particularly ants (Gibb, 2003; Lenior *et al.*, 2003; Sanders & Platner, 2007). Their trophic status in different ecosystems may also vary. Adult spiders are one level higher consumers than their juveniles, according to some research (Sanders & Platner, 2007). All of these suggests that their trophic interactions are complex, and they function as consumers of various levels of the grazing and detritus food chains. So, their impact on the community structure of the habitat that they belong to, is substantial.

Parasitic interactions also can be seen in many spiders. Several micro and macroparasites associated with spiders have been reported so far. Microparasites include Araneopathogenic fungi (Zare & Grams, 2001; Evan, 2013; Shreshtha *et al*., 2019) bacteria (Tanaka & Watanabe, 2003, Gilbert *et al*., 2016), while macroparasites mainly include endoparasitic nematodes (Poinar, 2000; Hanelt *et al*., 2005) as well as ectoparasitic mites (Wunderlich, 2000; Bernardi *et al*., 2017) and wasps (Korenko, 2017; Nyffeler & Brikhofer, 2017). Spiders, being top-level predators in many ecosystems, their parasitic interactions play a crucial role in the population dynamics.

Another important feature that helps spiders to thrive successfully on earth is their capacity to mimic. Different arthropods like ants, scorpions and pseudoscorpions function as the model for mimicry of spiders. The classical example of mimicry by spiders is myrmecomorphy. Several species of spiders, belonging to 13 different families show myrmecomorphy (Cushing, 1997; 2012). They imitate ants morphologically or/and behaviourally. The most striking ant mimics can be seen in the family Salticidae. *Myrmaplata* Prószyński, 2016,

Myrmarachne MacLeay, 1839, *Toxeus* C. L. Koch, 1846 etc. are some of the genera that include ant-mimicking spiders. *Castianeira* Keyserling, 1879 (family Corinnidae) is also a genus with ant-mimicking species. Many myrmecomorphic spiders will have a narrow and long body with long legs. They used to raise their legs and wave while walking to create an 'antennal illusion' (Ceccarelli, 2008). Besides getting protection from predators like wasps (Edmunds, 1993), mantises (Nelson *et al*., 2006) and other spiders (Durkee *et al*., 2011; Nelson, 2012) the association with ants provides them ample availability of food. Many spiders like *Masoncus pogonophilus* Cushing, 1995 (family Linyphiidae) feed on the materials that ants stored in their nest (Cushing, 1998), while some others like *Cosmophasis bitaeniata* (Keyserling, 1882) a spider that shows chemical mimicry of weaver ants (Allan *et al.,* 2002; John, 2020) feeds on its larvae (Allan & Elgar, 2001). *Myrmarachne melanotarsa* Wesołowska & Salm, 2002 lives in aggregations, mimicking an entire ant colony (Nelson & Jackson, 2009).

1.1.1. Morphology of spiders

In spiders, the body may be divided into two tagmata: Prosoma and opisthosoma and are connected by a narrow pedicel. Prosoma bears 4 pairs of legs, 8-10 simple eyes and a pair of chelicerae and pedipalps. The number, position and arrangement of eyes and number of cheliceral teeth are of extremely high taxonomic importance. The terminal region of the pedipalp in male spiders is provided with a complex organ called the palpal organ. It is an intromittent organ and the species-specific structural peculiarities of these organs are also taxonomically important. Opisthosoma corresponds to the abdomen. Except in Mesothelae, the abdomen is externally unsegmented and bears 1-4 pairs of appendages called spinnerets which

are usually used for silk spinning. Each spinneret may have several small, translucent hair-like structures called spigots.

1.1.2. A brief outline of spider taxonomy

Despite their hyper-diverse nature, all spiders have some distinctive characteristics, like the chelicerae associated with venom glands and modified tarsi in the pedipalps which help the male spiders to transfer sperm to the epigyne of females (Wheeler *et al*., 2017; Wang *et al*., 2018)**.** But of all their shared features, spiders are popular for their capability to produce silk and manipulate it according to the needs. The major synapomorphy of this clade is its spinning apparatus (Wheeler *et al.*, 2017; Wang *et al.*, 2018), formed by silk-producing glands that lead to appendages called spinnerets, present in the fourth and fifth opisthosomal (abdominal) segments (Pechmann *et al.*, 2010). Based on synapomorphies, the order Araneae is grouped into two distinct groups, Mesothelae and Opisthothelae. Mesothelae include primitive spiders with many plesiomorphic characters like visible external segmentation of opisthosoma and lack of venom glands. But their existence as a group of spiders is evidenced by certain synapomorphic characters like the presence of sternites and tibial spurs (Haupt, 2003; 2005). Opisthothelae include spiders with no external segmentation of opisthosoma. Apomorphic features like the presence of venom glands and the posterior position of spinnerets are also the characteristic of opisthothelae (Ax, 2000; 2012). Opisthothelae is classified into Mygalomorphae and Araneomorphae. Mygalomorphs are characterized by orthognathous chelicerae and the presence of two pairs of book lungs. The major families under this group include Theraphosidae, Ctenizidae and Atypidae. Araneomorphs, the most diverse group of spiders are characterized by apomorphies like paragnathous chelicerae, presence of cribellum and calamistrum (Ax, 2000; Coddington, 2005). Araneomorphs are further

classified into Haplogynae which lacks sclerotized epigynae and Entelegynae with hard sclerotized epigyne.

1.1.3. Spiders as biological indicators

Organisms, species, or communities that indicate the existence of certain environmental conditions are often termed as biological indicators or bioindicators. They can be grouped into three classes, biodiversity indicators, environmental indicators and ecological indicators (Mc Geoch, 1998). Biodiversity indicators and environmental indicators are descriptive in nature. The former indicates the presence of some other species while the latter indicates the variations in the abiotic components of the ecosystem. The ecological indicators reveal how changes in the environment affect biotic systems. Many invertebrates, especially spiders and beetles can be employed as effective bioindicators (Werner & Raffa, 2000; Heyborne *et al*., 2003). Spiders can be considered to be good ecological indicators as they meet all the four major attributes that are essential for good ecological indicators, viz., feasibility of sampling, easy and reliable identification, consistent response to the disturbances and functional significance (Pearce & Venier, 2006). Spiders can be effectively employed as bioindicators for assessing anthropogenic disturbances in natural as well as semi-natural ecosystems (Maelfait & Hendrickx, 1998; Ossamy *et al*., 2016). There is a variety of spiders that can be used as bioindicators for identifying the presence and extent of disturbances in the ecosystems due to human occupation, agriculture, sand mining, etc. (De *et al*., 2021).

Webs of some spiders belonging to the family Agelenidae (*Eratigena atrica* (C. L. Koch, 1843) and *Agelena labyrinthica* (Clerck, 1757)) can be used as effective bioindicators for detecting heavy metal pollution (Cu, Zn, Ni and Pb) in

various ecosystems (Stojanowska *et al*., 2020). Genetic diversity, dispersal tactics and dispersion of two spiders *Allocosa marindia* Simó, Lise, Pompozzi & Laborda, 2017 and *Allocosa senex* (Mello-Leitão, 1945) belonging to the family Lycosidae turned out to be good ecological indicators for ecosystem health (Batista *et al*., 2017). Some studies suggest that many spiders belonging to the genus *Ariadna* Audouin, 1826 are also good bioindicators of pollution of ecosystems due to heavy metals (Conti *et al*., 2018). Semi aquatic spider *Argyroneta aquatica* (Clerck, 1757) is reported as a bioindicator for assessing the extent of pollution in wetlands (Seyyar *et al*., 2010).

1.1.4. Emergence of spiders as a successful animal lineage

Spiders have been believed to be the predators of arthropods from the middle to late palaeozoic era since their evolution, approximately 400 million years ago. Even 250 million years ago, opisthothelous spiders began to exist. They belong to the subphylum Chelicerata, along with sea spiders and horseshoe crabs, according to phylogenetic classification (Sharma, 2018).It is believed that spiders existed even before the evolution of dinosaurs and remained much unaffected by the mass extinction events which wiped off dinosaurs and many other animal groups from the earth. Many of the recent fossil studies reveal the existence of a large number of extant spider families before the cretaceous tertiary extinction, around 66 billion years ago (Selden & Penney, 2010). Polyphagy, the capacity to remain in reduced metabolic rate at times of food stress, higher diversity, etc. are considered to be some of the reasons for their successful survival (Penney & Selden, 2007).

Even though there are few anatomical modifications that have occurred to spiders since their origin during the carboniferous period, the development of venom glands and silk glands helped them to emerge out as one of the most successful

animal lineages (Luddecke *et al*., 2022). The evolution of chelicerae as the venom injecting organs, is also very peculiar, as it is not common among other chelicerates. Spider evolution has been intimately related to the evolution of insects upon which they mainly prey. This is evidenced by the fact that many of the evolutionary improvements of spiders frequently follow preceding insect developments. For example, the development of aerial foraging webs corresponded with the emergence of insect flight (Bond *et al*., 2014; Garrison *et al*., 2016; Fernández *et al*., 2018). Predation by spiders has been reported as an impetus for the evolution of flight in insects (Vollrath & Selden, 2007). Even though several animal groups are capable of producing venom, the chemical complexity of spider venom is unique in the animal world (Pineda *et al.*, 2020). As per the opinion of some araneologists, the venom of extant spiders has more than 10 million chemical components in total. The existence of sexually dimorphic venoms as an evolutionary adaptation for different lifestyles is also reported in the spider world. For example, in many Mygalomorph spiders, females with a burrow-dwelling lifestyle are less toxic when compared to the actively wandering males of the same species (Santana *et al*., 2017; Herzig *et al*., 2020). Venom composition plasticity in spiders helps them to get adapted to a changing environment more easily and effectively.

The evolution of trophic specialization is clear in the spider world. The majority of spiders feed on other arthropods, but some of them occasionally feed on small vertebrates too (Nyffeler & Gibbons, 2022). Many rare foraging strategies like araneophagy, myrmecophagy, oniscophagy and occasional herbivory are reported in the world of spiders. The feeding specializations also play a significant role in the successful thriving of spiders on almost every part of the earth.

Spiders can occupy every possible terrestrial habitat and microhabitats. They can be seen in natural and semi-natural habitats. The high diversity of spiders has been documented in different habitats like the forest, mangroves, grasslands, riparian ecosystems, etc. The semi-natural ecosystems like cereal croplands, horticultural fields, plantations, fruit orchards, etc. also possess considerably high faunal diversity of spiders.

Seasonality must also be taken into consideration in research on species richness and abundance. Variation in abiotic factors including climatic parameters directly influences the diversity of spiders also. The seasonal variation in the diversity and abundance of ground-dwelling spiders is reported by Mineo *et al.* (2010). Bhat *et al*. (2013) in their study reported that spider diversity was higher in monsoon season in Karnataka state. The fluctuations in species diversity and abundance are related to resource availability and help to reduce competition and stabilize populations (Shimadzu *et al.*, 2013).

1.2. Agroecosystem - an overview

An agroecosystem can be considered as a subset of a natural ecosystem. The core activity in it is agriculture. An agroecosystem can be considered as an ecosystem with its fauna, flora and environment that have undergone anthropogenic manipulations to produce food, fuel and other products for human consumption and processing (Maes *et al.*, 2018). It is comparably less diverse than the natural ecosystems (Karuppuchamy *et al*., 2016). It contains one or more crops and a few pests associated with the crops. The environment of this type of ecosystems are highly manipulated by human beings and have undergone to drastic changes due to ploughing, usage of agrochemicals and other farming practises. Still, we can see that these ecosystems exist as stable units due to the presence of highly interactive food

chains and intricate food webs operating there. As agriculture is the most significant activity there, the crops cultivated, various farming methods adopted, agrochemicals used, etc. greatly influence the biodiversity of the agroecosystems.

1.2.1. Horticulture

Many Palaeo-anthropologists believe that the oldest fossils of modern humans obtained date back to 196000 years back (Trinkaus, 2005). He gathered his food by hunting. A change in his lifestyle from a hunter-gatherer to a cultivator happened around 11000 BCE. He started cultivating crops and rearing animals to meet his food needs. According to many studies, the main reasons for this shift in lifestyle were climatic changes and an increase in population density (Stuart, 2002; Dow *et al*., 2005; Montgomery & David, 2012). Early Holocene climatic conditions favouring the agriculture supported this lifestyle shift (Gupta, 2004). Since then, agriculture has undergone several significant transformations to attain the current status. Now it forms a diverse domain with large number sub-disciplines such as agronomy, horticulture, forestry, animal husbandry, and fisheries.

Agriculture is incredibly significant in the economies of many emerging countries. Even though the contribution of agriculture to GDP is declining, its dominance is still significant in the economic scenario of India. Agriculture contributes around 16 percent of India's GDP and 10% of total exports (Wagh & Dongre, 2016). In India, rice, wheat, vegetables, fruits, spices, sugar cane, cotton, etc. are the major agricultural commodities with high economic value. The major livelihood of 58% of our rural population is agriculture. Globalization and liberalization have led to the modernization of our agriculture. Advancement in technology as well investments in agriculture and agro-based industries resulted in the diversification of our agriculture in an increased pace. Besides, agriculture and

related sectors are one of the high thrust areas of research in India. Production of new GM crops, innovative approaches for pest management and development of stress tolerant crops are a few among the in-vogue areas in agriculture related research in India.

Integrated Pest Management is yet another subject of interest of agricultural researchers in India. IPM is a promising strategy to reduce crop loss and illegitimate pesticide usage (Akilandeswari, 2021). In IPM, a variety of managing approaches were applied, including chemical, biological, and cultural methods for effective regulation of pest.

Horticulture is an important branch of agriculture that involves the cultivation of vegetables, fruits and ornamental plants. It includes branches like olericulture (cultivation of vegetables), floriculture (cultivation of flowering and ornamental plants) and pomiculture (cultivation of plants for fruits). The word ‘horticulture’ has a Latin origin; from the words ‘Hortus' which means ‘garden 'and ‘Colere’ which means ‘to cultivate.’ It involves cropping and sales of fruits, vegetables, flowers, and other ornamental plants. It is believed that horticulture originated in the temple gardens of Egypt approximately in 3000 BC, where fruit plants and grapevines were cultivated as a practice (Von Baeyer & Edwinna, 2010; Peter *et al*., 2015). Theophrastus, the Greek philosopher and a disciple of Aristotle is considered as the first one who practiced horticulture scientifically. Gardens of Versailles of France, and Mughal gardens in various parts of India are good examples of formal horticulture gardens built in the earlier periods (Peter *et al*., 2015). Aztec gardens and farmlands of Mayans were considered as the examples of horticulture practices in ancient south and central America.

Horticulture became popular in India a few decades ago when it was found to be more remunerative than the cultivation of food grains. Currently, India is the second-largest producer of fruits and vegetables and ranks first in the production of fruits like banana, mango, lemon, papaya, and vegetables such as okra, on a global perspective. According to the Horticulture statistics (2018) of the Ministry of Agriculture and Farmers' Welfare, a steady increase is reported in horticulture production in India over the last two decades. Since 2012-13, the production of horticulture crops has outpaced the production of food grain (Figure1.1). Lower requirement of water, flexibility in land use pattern, the possibility of cultivating more crops in the same area, etc. make horticulture a more promising area for the farmers of India. Easiness of storage and post-harvest processing of horticultural products along with increasing demand in the market enhanced the acceptability of horticulture among the farmers.

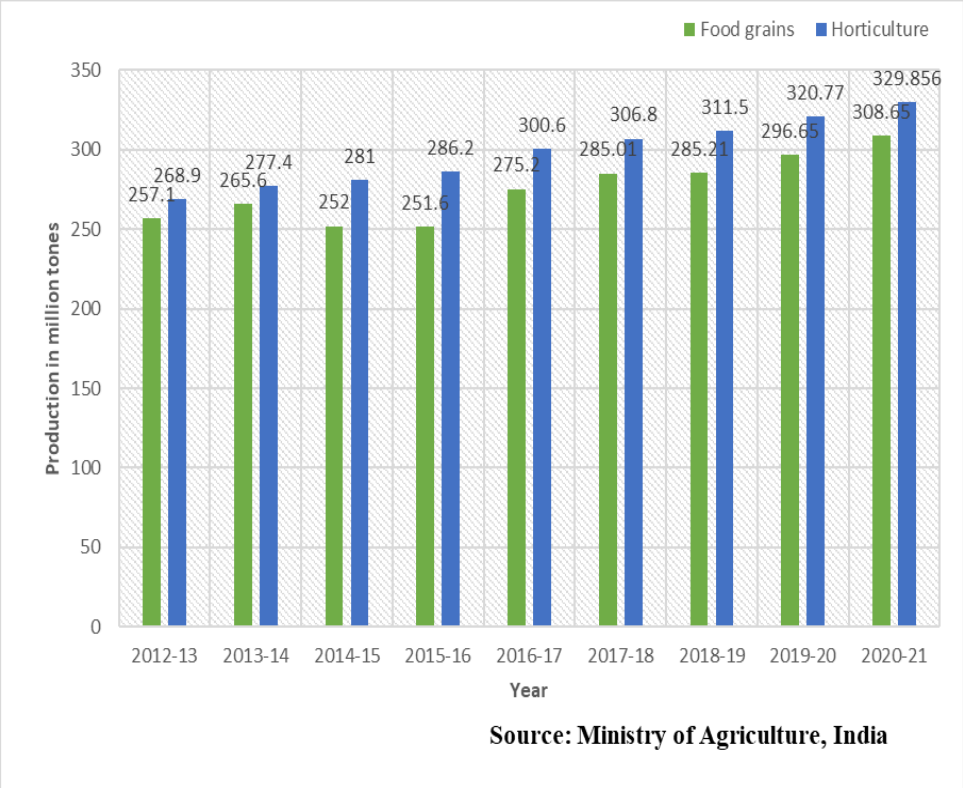


Figure 1.1. Steady increase in horticulture production in India

1.2.2. Pests of major horticultural crops

From a broad point of view, a pest can be defined as any biotic component that is harmful to crop plants and their products (Bos & Parlevliet, 1995). Pest attack is one of the most serious problems that the horticulture field faces. The major pests of horticultural crops include insects belonging to the orders Coleoptera, Diptera, Lepidoptera and Hemiptera (Jayanthi *et al.*, 2015). The green revolution played a significant role in attaining self-sufficiency in food production, but eventually raised many problems that adversely affected the agricultural sector. Change of status of many minor pests to major pests, the resurgence of pests, the development of pesticide-resistant strains, etc. are a few of them (Dhaliwal *et al.*, 2010). Increased monoculture practices, the introduction of exotic varieties of crops, and decrease in natural enemy population due to unscientific usage of pesticides worsen the current global pest problem scenario. The loss in agricultural commodities due to the pest attack is highly significant and may reach up to 40% of total crop production per year (Shivalingaswami *et al.*, 2002). The highest contribution to this loss is caused by insect pests as they cause direct damage by feeding on the crops as well as acting as vectors of different disease-causing pathogens (Muniappan *et al*., 2012). Widened spectrum of host preferences of pests is yet another significant issue that requires immediate attention (Durairaj *et al*., 2006; Patil & Jamadagni, 2008; Mahto & Yadav., 2009).

Kerala, the southernmost state of India was once an agriculture-based state. Changes in the pattern of land usage, increase in the labour costs and fragmentation of croplands have led to a significant decline in the production our agricultural sector. This has led to high food insecurity in the state. Horticulture dominates the traditional agriculture of food grains in Kerala also. Besides the increased labour

costs and insufficient technically skilled labourers, attacks by different pests (Table 1.1) and related crop loss also make agriculture less profitable in Kerala. Chemical control of pests is practically less possible in Kerala, as the majority of our croplands are amidst the human habitations.

Table 1.1. Important pests of selected horticultural crops of Kerala

SL. No.	Host plant	Pest	Damage caused
		Fruit crops	
1	Banana	*Cosmopolites sordidus* (Banana weevil)	Grub feeds on rhizome and pseudo stem
2		*Odoiporus longicollis* (Banana stem weevil)	Grubs burrow tunnel in the pseudo stem
3		*Pentalonia nigronervosa* (Banana aphid)	Nymphs and adults suck the juice of pseudo stem
4		*Spodoptera litura* (Leaf eating caterpillar of banana)	Scrapes and feeds the ventral side of the leaf
5	Mango	*Idioscopus sp.* (Mango leaf hopper)	Sucks sap of tender shoots and leaf)
6		*Orthaga exvinacea* (Mango leaf webber)	Caterpillars make webs and feed the green matter of leaves causing defoliation
7		*Erionota thrax* (Banana skipper)	Causes severe defoliation
8	Papaya	*Paracoccus marginatus* (Papaya mealybug)	Sucks juice from the stem
9	Pineapple	*Dysmicoccus brevipes* (Pineapple mealybug)	Suck the sap from leaves and tender fruits
10		*Holopothrips ananasi* (Pineapple thrips)	Sucks sap from tender leaves
11		*Strymon megarus* (Pineapple fruit borer)	Feed on fruits and inflorescence
		Vegetable crops	
12	Brinjal	*Leucinodes orbonalis* (Shoot and fruit borer)	Larvae bore into tender shoots and cause dead hearts

13		*Epilachna vigintioctopunctata* (Ladybird beetle)	Adults and grubs feed on leaves
14		*Antoba olivacea* (Brinjal leaf roller)	Larva feeds on leaf tissue and rolls the leaf
15	Okra	*Aphis gossypii* (Aphid)	Sucks sap and weakens the plant
16		*Dysdercus cingulatus* (Red cotton stainer)	Adults and nymphs feed on the flower bud
17		*Amrasca biguttula* (Cotton jassid)	Feeds on the green tissue of leaves causing yellowing of leaves
18	Leguminous vegetables	*Aphis craccivora* (Aphid)	Sucks sap from the tender shoot, leaves and premature fruits
19		*Lampides boeticus* (Pod borer)	Bores into tender pods and feed on the seeds
20	Cucurbits	*Aulacophora foveicollis* (Pumpkin beetle)	Adults feed on leaves, fruits and flowers
21		*Diaphania indica* (Leaf eating caterpillar)	Larvae feed on leaves, tender shoots and fruits
22	Spinach	*Cassida circumdata* (Tortoise beetle)	Grubs and adults feed on the upper surface of leaves
23		*Hymenia recurvalis* (Amaranthus leaf webber)	Feeds on leaf tissue and causes defoliation
24	Chilli	*Polyphagotarsonemus latus* (Chilli mites)	Sucks sap from leaves and shoots
25		*Scirtothrips dorsalis* (Chilli thrips)	Sucks saps from leaves and other tender parts

Chemical substances used to control pests are termed as pesticides. They are widely used in agricultural fields, private gardens, and other public areas (Grube *et al.,* 2011). The earliest report of usage of pesticides dates to the period of ancient Romans who used salts and ashes to manage weeds and burn Sulphur to repel and kill pests. Insecticides, nematicides, fungicides, rodenticides and weedicides are different types of pesticides. India ranks third in Asia and twelfth globally in pesticide consumption (Nayak & Solanki, 2021). The most often used pesticides in

India include insecticides, fungicides, and weedicides. Insecticides contribute 56% of the total pesticide consumption (FAO, 2020). Based on chemical nature, the most used pesticides in India are organophosphates, synthetic pyrethroids, neonicotinoids and carbamates (Bera *et al.*, 2022). Pesticide consumption in India is still in an increasing phase (Figure 1.2). But a positive correlation cannot be seen between the increased pesticide consumption and reduction in crop loss (Oerke, 2006). It is noteworthy that the increase in crop production over the last few decades is not due to the adoption of chemical pest management strategies, but due to the utilization of high-yielding varieties of crops, scientific usage of fertilizers, etc.

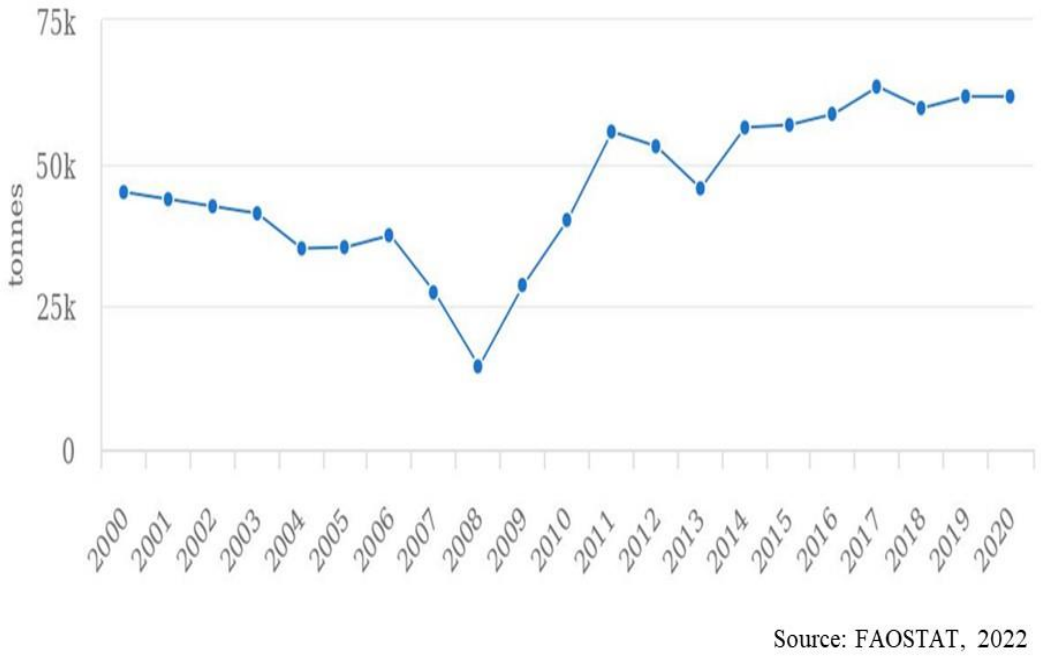


Figure 1.2. Usage of pesticides in India for the last two decades

Chlorpyriphos and cypermethrin are the most abundantly used insecticides in India as per the recent statistical report of the Directorate of plant protection, quarantine and storage, Ministry of Agriculture and welfare of farmers, Govt. of India. When considering the commodity-wise consumption of pesticides, vegetables rank the second just after cotton. Brinjal, cabbage, cauliflower, cucumber, and okra are the vegetables reported with maximum pesticide residues (Bera *et al.*, 2022).

Among the various states of India, Kerala stands in the twelfth position in the consumption of pesticides. Kerala and Karnataka show a decrease in consumption of synthetic pesticides over the last few years as biological control measures are getting increased acceptance in these states.

Among various pesticides, insecticides are causing the most severe problem to the environment as well as organisms. Almost all of synthetic pesticides affect the non-targeted flora and fauna seriously. Their contribution to the pollution of different realms of the environment is extremely high. The pesticides may reach water bodies and adversely affect aquatic flora and fauna. The three major ways of entry of pesticides into water bodies are leaching, runoff from the crop fields and spray drifts. These pesticides impact the groundwater quality remarkably making it not suitable for the optimal growth of flora and fauna (Warra & Prasad, 2020). There are several reports on the decline in the population of animals like fishes and amphibians due to the entry of pesticides into water bodies (Relyea & Hoverman, 2005; Scholz *et al.,* 2012). Many pesticides get amplified through various trophic levels and accumulate in animals of higher trophic levels, especially human beings. This is called biomagnification. Humans, being top-level consumers, will be the serious victims of this phenomenon (Wang *et al*., 2019; Guan *et al*., 2020; Jia *et al.*, 2020).

Prolonged exposure to pesticides causes a multitude of serious health problems in human beings like neurological disorders, diabetes, and several foetal abnormalities (Ntzani *et al*., 2013). The people who are exposed to pesticides relentlessly are more prone to malignancies like non-Hodkin lymphoma, brain tumours, breast cancer, prostate cancer, etc. (Bera *et al*., 2022). Organochlorines are reported to cause endocrine disorders (Mnif *et al.,* 2011) and teratological effects

(Tiemann, 2008). Organophosphates impair cholinesterase function (Jaga & Dharmani, 2003) and insulin secretion (Karami-Mohajeri & Abdollahi, 2011). Synthetic pyrethroids are said to cause endocrine disorders (Pandey & Mohanty, 2015).

Non-judicious usage of agrochemicals adversely affects the non-target organisms like natural enemies in the crop field which may sometimes lead to the emergence of newer pests. Like other natural enemies, spiders are also affected deeply by these chemicals. There is evidence for the effect of chemicals like pyrethroids (Hof *et al*., 1995), organochlorines (Pekar, 2012a) neonicotinoids (Rezac *et al*., 2021) and organophosphates (Niedobova *et al*., 2016) affect spiders adversely. In addition to the direct effect, intensive pesticide application in crop fields may cause spiders to run out of food (Harwood *et al*., 2001). The decline in spider population is reported in several different crop fields like cotton fields (Solanki & Kumar, 2014), apple orchards (Marko *et al.*, 2009), and rice fields (Tahir & Butt, 2009; Prabawati *et al*., 2019) shortly after the application of pesticides. Besides affecting the diversity in agroecosystems, the runoff pesticides reaching freshwater bodies, increase the toxicity of water and affect the riparian fauna adversely (Graf *et al*., 2019).

In recent days, a surprising paradigmatic shift from chemical control to biological control is witnessed all over the world. The concept of biological control involves the utilization of natural enemies for the management of pests of crops. Smith in 1919 used the word 'biological control' for the control of pests using natural enemies. The emergence of biological control as a scientific method for pest management initiated in the second half of the nineteenth century itself. The first successful evidence of biological control was the control of cottony cushion scale

Icerya purchasi by the coccinellid predator *Rhodia cardinalis* in California (Huffaker, 2012). The major advantage of biological control is that they are not adversely affecting the non-target flora and fauna. Several predatory insects and pathogens like bacteria and viruses that affect pests are effectively utilized in biological control. Spiders, being generalist predators, can be effectively employed here.

1.3. Spiders in benefit to agriculture

Man has started his combat with different types of pests since he started the practice of agriculture in the prehistoric period itself. His battle with pests changed from time to time. He adopted various mechanical, physical, chemical and biological methods for the effective management of pests. Soon after the green revolution, chemical methods got greater acceptance for pest control. Global consumption of pesticides has increased severalfold since then. The current global consumption rate of pesticides is 2661124.23 tonnes (FAO, 2020). After the Stockholm convention for particulate organic pollutants came into force on 17.05.2004, the acceptance of chemical methods for pest management started to decrease tremendously. The voices against the indiscriminate use of chemical pesticides started to rise much before that. The book 'Silent Spring' by Rachel Louise Carson published on September 27, 1962, was one among such voices. The use of biological controls has attained unprecedented popularity since then. Research on the employment of natural enemies like predators and parasites for pest management increased. Natural enemies have proved successful in controlling many major agricultural pests.

Biological control may be achieved by the intentional introduction of exotic natural enemies to the crop field or by encouraging the assemblage of native natural enemies. In the former case, the application of a specialist or stenophagous predator

is practical but, in the latter, utilization of an assemblage of generalist predators will be practical and more effective (Symondson *et al.,* 2002). Specialization in predation was of greater concern in biological control till the end of the twentieth century. The contribution of the group of generalist predators by exerting background level control was not given much importance. The research on the multitude of ecological interactions of native natural enemies that are helpful for managing the pests of a crop gained its momentum at the first half of the twenty-first century onwards. Spiders become a good model of biological control in this scenario, due to their predatory polyphagy. Spiders are one of the most abundant predators in agroecosystems (Hanna *et al*., 2003; Schweitz *et al*., 2005). Their diet principally includes insects and other arthropods. Hence, they can be employed to limit the pest populations as well as to stabilize their population at a low level. The following attributes of spiders make them suitable for functioning as effective biocontrol agents:1.The high degree of dispersal. 2. The predatory mode of nutrition throughout all the stages of life. 3. Capacity to resist starvation and desiccation. 4. Density-dependent predation by spider assemblage. Numerous studies proved that spiders or groups of spiders contributed to the successful suppression of pest groups in agroecosystems (Table 1.2).

Table 1.2. List of spiders and the pests controlled by them

Pests controlled	Host plant	Spiders	Reference
Plutella xylostella	Cabbage	*Pardosa astrigera* (Family Lycosidae)	Suenaga& Hamamura, 2015
Myzus persicae	Cabbage	*Pardosa astrigera* (Family Lycosidae)	Suenaga & Hamamura, 2015

Corcyra cephalonica	Rice	*Cyrtophora citricola* (Family Araneidae)	Chauhan *et al*., 2009
Poecilocapsus lineatus	Mint	*Phidippus clarus* (Family Salticidae)	Hoefler *et al.*, 2006
Helopeltis theivora	Tea, Cashew	*Oxyopes javanus* (Family Oxyopidae)	Basnet *et al.*, 2014
Nilaparvata lugens	Rice	*Heteropoda venatoria* (Family Sparassidae)	Karthikeyani & Kannan, 2012
Diaphorina citri	Citrus	*Cheiracanthium insulanum* (Family Cheiracanthiidae)	Vetter *et al.*, 2013
Corcyra cephalonica	Rice	*Telamonia dimidiata* (Family Salticidae)	Chaubey, 2019
Aphis gossypii	Cotton	*Peucetia viridana* (Family Oxyopidae)	Jeyaparvathi *et al.*, 2013
Spodoptera litura	Cotton	*Peucetia viridana* (Family Oxyopidae)	Jeyaparvathi e*t al*., 2013
Bemisia tabaci,	Cotton, Cucurbits, Legumes	*Thyene imperialis* (Family Salticidae)	Ghavami, 2008

1.4. Significance of the study

Kerala is a coastal state located in the southwestern end of India. Due to geographical diversities, the presence of Western Ghats, availability of two major monsoons, rich lush vegetation, etc., Kerala harbours an affluent fauna including spiders which corresponds to more than 70% of the total families of spiders so far recorded in India. The exploration of spider fauna in Kerala is still in its infantile stage. Studies of P.A. Sebastian pioneered arachnology in Kerala. Despite the recent hike in spider research in Kerala, it is still lagging behind those other animal groups

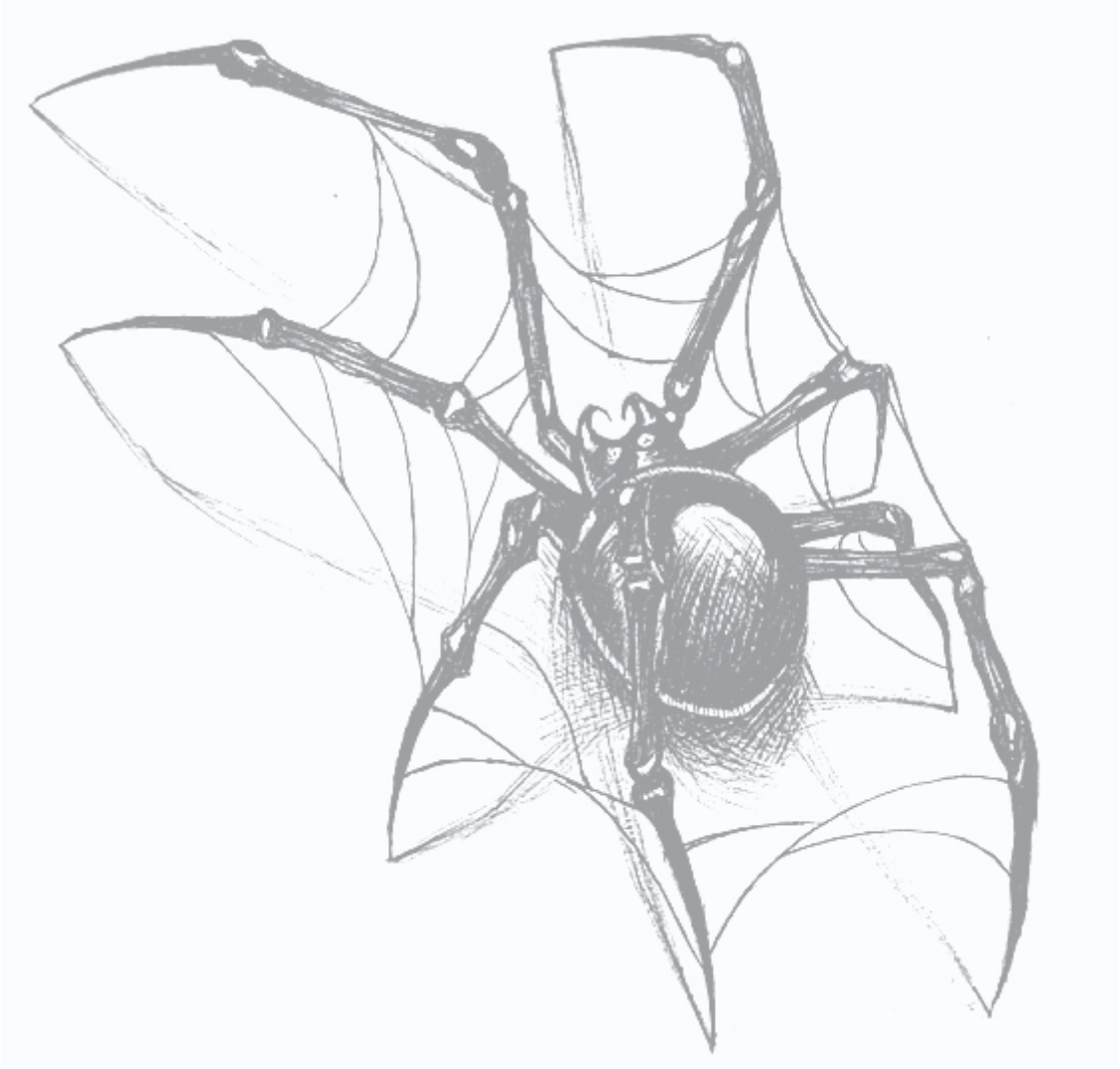
like insects, fishes, birds, etc. Diversity, behaviour, biocontrol potential, toxicology, etc. are some of the fields of interest where the arachnological research in Kerala is focused currently on.

The record on agrobiont spiders in Kerala is a very less explored area so far. The diversity of spider assemblages in our agroecosystem can be considered as an indicator of the health and stability of our crop fields. A better knowledge of their ecological interactions helps us in several ways. It will be useful for the employment of spiders for biocontrol of pests in a more effective way. It also facilitates the conservation of the community. Assessment of the impacts of various pesticides on them will be helpful in the selection of agrochemicals comparatively less hazardous to the non-target organisms in the crop fields.

The present study is an attempt to record the diversity of spider fauna in selected horticultural ecosystems of Thrissur district, Kerala. The study sites include croplands adopting mixed cultivation of various vegetables and fruits, especially bananas. A preliminary assessment of the impact of various pesticides widely used in horticultural fields of Kerala on the dominant spiders, is also done.

1.5. Objectives of the study

1. Assessment of the diversity of spiders in various horticultural ecosystems in Thrissur District, Kerala.
2. Preparation of check list of spiders of different horticultural ecosystems there.
3. Study of various foraging guilds occupied by the spiders there.
4. Study the seasonal fluctuations in the faunal diversity of spiders.
5. Study of influence of pesticides on dominant spiders.



CHAPTER 2

REVIEW OF LITERATURE

REVIEW OF LITERATURE

A review of prior and relevant literature is inevitable for all academic research (Webster & Richard, 2002). It involves analysis, evaluation, and synthesis of existing knowledge relevant to the problem of study. It can be considered as the foundation for the study as subsequent works can be built up on the existing knowledge. It helps to locate the research gaps in study which can be filled by designing and executing new, apt research in the area. It also aids in the development of an acceptable approach by examining the strengths and weaknesses of previous research.

2.1. Horticultural ecosystem

According to the classification of Central Statistical Organization of India, horticulture includes the commercial cultivation of (i) fruits, vegetables, and flowers and (ii) spices and condiments. 30 % of India's agricultural GDP is contributed from the horticultural sector. A diversification of agriculture in our country was turned up in the 1980s and horticulture was one among those diverse areas. Horticulture in India got a real boost in the 1990s (Chand *et al*., 2008) and it contributes a remarkable part of (37%) of our export of agriculture commodities (Sharma, 2015). The number of commodities and varieties produced and traded has drastically shooted up since then. Horticulture supports the economy of several developing nations because of the high export value of agricultural commodities, high yield and returns per unit area. It provides raw materials for several agro-based industries like coir, sago, rubber etc.

According to the recent reports of FAO (2021), India ranks second in the production of fruits and vegetables. Still the productivity of most crops is not up to the mark here, mainly because of the unscientific usage of fertilizers (Malhotra & Srivastava, 2015) and fallacious pest management strategies (Peshin *et al*., 2014; Rathee & Dalal, 2018). In pest management, chemical control was given exceedingly high importance from the period of the green revolution itself. Incautious usage of pesticides is deleterious to the crops, those who consume it and the environment. It creates issues like resistance to pesticides, removal of non-target organisms including natural enemies, resurgence of pests, environmental pollution etc. (Shetty, 2004; Devine & Frurlong, 2007; Hayasaka *et al*., 2012; Shankar & Raju, 2012; Sanchez *et al.*, 2013; Chagnon *et al*., 2015; Dubey & Thakur, 2020). Usage of pesticides in agriculture should be reduced without compromising in the effective management of pests. Studies of several researchers in this direction suggested biological control as an alternative for this.

2.2. Explorations of spider diversity

An analysis of discovery of new species among various groups of animals, since 1758 showed that richness of birds, mammals, bees, and many other animals has almost reached to an asymptote. But it is noteworthy that discovery of spider species has been accelerating for the last 60 years (Agnarsson *et al.*, 2013). This indicates that there does exist an ample scope for exploration in the field of spider diversity. Even though the research on spiders shows an unprecedented growth since the 1990s (Benjamin & Bambaradeniya, 2006) it will not be sufficient to meet the demand of taxonomists in the field of arachnology. Like all other hyper diverse groups, one of the most crucial factors that limits the study of spiders is the number of araneologists available (Cassis *et al*., 2007; Foord *et al*., 2011).

Spiders rank second in contributing to the diversity of arthropods, next to insects (Dey *et al*., 2013). Taxonomic study with standardized techniques is comparatively easy in their case because of their abundance in almost all types of habitats and relative easiness in finding and collecting them (Coddington & Levi,1991; Cardoso *et al*., 2008). Their preservation is also easy when compared to that of many other invertebrates. Despite all these positive factors, the taxonomic study in spiders is still lagging. Presently there are several studies occurring on the diversity of spiders, their foraging guild, and their interactions in the ecosystems where they present, in various parts of the world.

2.2.1. Spiders: Global status

Spiders form one of the most abundant groups of invertebrates. Globally there are 52048 species of spiders belonging to 4377 genera under 135 families. The number of new species of spiders recorded per year is in an exponential phase (WSC, 2024).

Faunistic surveys have been carried out to document the diversity of spiders in all the continents (except Antarctica) of the world vis., Africa (Whitmore *et al*., 2002; Dippenaar- Shoeman & Wassenaar, 2006; Dippenaar-Shoeman *et al*., 2013), Asia (Tong & Li, 2014; Zhao & Li, 2014., Wang *et al*., 2015; Wongprom *et al*., 2016; Palem *et al*., 2017; Mehmood *et al*., 2021), Australia (Harvey *et al*., 2000; Harvey & Edward, 2007), Europe (Scharff *et al*., 2003; Oxbrough *et al.*, 2005; 2007; Kiehorn, 2008; Polchaninova & Prokopenko, 2019; Polchaninova, 2021; Polchaninova *et al*., 2021), South America (Rubio *et al*., 2008; Armendano & Gonzalez, 2011; Lo-Man-Hung *et al*., 2011; Marquez *et al*., 2021), North America (Samu & Szinetar, 2002; Rendon *et al*., 2006a; 2006b; Corcuera *et al*., 2010; Slowik & Blageov, 2012; Ovtcharenko *et al*., 2014; Granados *et al*., 2019).

Incredibly significant contributions have been made in the field of arachnology by several taxonomists by compiling all available publications on region wise spider distribution and preparing checklists, which will be helpful for future studies. Carl Friedrich Roewer won the credit of publishing the first catalogue of spiders, "*Katalog der Araneae von 1758 bis 1940*," in 1942 (Mammola *et al*., 2017). Komnenov (2010) congregated the published records of spiders of Bosnia & Herzegovina to a check list. A checklist of Belasurian spiders was prepared by Ivanov (2013). An annotated checklist of spiders of Turkey was drafted by Demir & Seyyar (2017). Blageov *et al*. (2018) made an updated check list of spiders of Bulgaria pooling together all available literature. Preparations and periodic updations of the check lists of spider fauna of various parts of different countries have contributed a lot to the growth of research of Araneology. Check lists of spider species of Britan (Merrett & Locket, 1985; Merrett & Murphy, 2000; Paquin *et al*., 2010; Lavery, 2019), China (Song *et al*., 2020; Tang *et al*., 2021), North Korea (Marusik, 2009, Namkung *et al*., 2002; 2009; Yoo *et al*., 2015), Iran (Mirshamsi *et al*., 2015; Hosseini & Zamani, 2017) Bhutan (Nepal, 2005) etc. are some of them.

Several studies reveal that spiders can thrive successfully in natural ecosystems with comparatively less human interference as well as in the crop fields, where periodic anthropogenic disturbances are remarkably high. Rubio *et al. (*2008) compared the diversity of spiders in hygrophilous woodland and savannah parkland of the Mburucuya National Park, Humid Chaco ecoregion, Argentina and reported more diversity in hygrophilous wood land. Spider diversity of habitats with varying degree of human disturbances were recorded from Orchid Island, Taiwan by Chen & Tso (2004) and reported more or less similar species richness values even though the spider assemblage of each habitat differed from other. But evenness index was lower

in the habitats with lower human disturbances because of the increased relative abundance of dominant species there.

Clough *et al*. (2005) studied the impacts of region, terrain heterogeneity, management practices (organic and conventional), location within the field of study (edge of the field and centre of the field) on the abundance and species richness of spiders in wheat fields of Central Germany and reported that management practices had very less impact on spider fauna while regional characteristics and heterogeneity of landscape influences the fauna very much. Location within the field also affects the abundance of spiders. Edges of the field were found to be more densely populated by spiders than in the centre. Oberg *et al*. (2007) studied how the habitat type and adjoining landscape influence the diversity of Lycosid and Linyphiid spiders in organically cultivated cereal fields in Sweden. They revealed that activity density of Lycosids with smaller area of dispersal was significantly affected by habitat type while in Linyphiids with a different mode of dispersal, the activity density was much more influenced by the surrounding landscape parameters. Despite the comparable species richness of spider fauna, dominance structure varies significantly between natural and agroecosystems. The most dominant one will have greater impact on the community of agricultural ecosystem(Samu & Szinetar, 2002).

An exploration on spiders of Black Rock Forest of Orange County, USA recorded 27 families, 121 genera, and 279 species of spiders there. Linyphiidae was reported as the dominant family followed by Theridiidae and Salticidae. *Pityohyphantes subarcticus* Chamberlin & Ivie, 1943, *Tenuiphantes tenuis* (Blackwall, 1852), and *Erigone dentosa* O. Pickard-Cambridge, 1894 were found for first time in the New York State region (Ovtcharenko *et al*., 2014). In total, spiders

of 15 families and 94 species were collected from rye fields and fallow strips of land adjoining it in Eastern Poland (Wolak, 2002). Sorenson, (2004) documented 149 species of canopy dwelling spiders belonging to 28 families from the Montaneforest of Tanzania (2004). Campuzano *et al.* (2019) recorded 28 families, 78 genera and 111species of spiders from the tropical mountain cloud forest from El Triunfo Biosphere Reserve, Mexico. Three new species (*Anapistula choojaiae* Rivera-Quiroz, Petcharad & Miller, 2021, *Crassignatha seeliam* Rivera-Quiroz, Petcharad & Miller, 2021., and *Crassignatha seedam* Rivera-Quiroz, Petcharad & Miller, 2021) of Family Symphytognathidae was described by Rivera-Quiroz *et al*. (2021). A new species *Harpactea konradi* Lazarov, 2009 was reported from South Bulgaria by Lazarov, 2009. Two new species, (*P. kovblyuki* Zamani & Marusik,2018 and *P. montana* Zamani & Marusik, 2018) of genus *Ptertricha* Kulczynski, 1903 and Family Gnaphosidae was described for the first time by Zamani *et al*. (2018) from Iran. Zhu & Ono (2007) reported a new species of spider *Talus xiphosus* Zhu & Ono, 2007 from Southern China. Jastrzebski (1997, 2007, 2010) studied salticids of Himalya region of Nepal and Bhutan and described/redescribed three species (*R. falvigera* (c. L. Koch l846), *R. flavicomans* (Simon 1902) and *R. phuntsolingenis* Jastrzebski, 2007) from the Genus *Rhene* Thorell, 1969, two species (E. *chimakothiensis* Jastrzebski, 2007, *E. praetextata Thorell, 1887*) from the genus *Epocilla* Thorell, 1987 and two species (*H. Adansonia* (Audouin,1826), *H. tropicus* Jastrzebski, 2000) from genus *Hasarius* Simon, 1871.

2.2.2. Spider fauna: An Indian perspective

The pioneering research on spiders in India date back to the late 19th century. The works of John Blackwall laid the foundation to arachnology in India. Indian arachnology gathered its momentum through the contributions of Karsch, Simon,

Tikader etc. Presently faunal diversity of spiders in India is rich with 1988 species belonging to 501 genera and 62 families (Caleb & Sankaran., 2024).

Several serious efforts have been so far made to document the spider diversity of natural ecosystems and crop fields in India. Siliwal *et al*. (2005) explored the diversity of spiders in Purna Wildlife Sanctuary, Dangs, Gujarat and documented 116 species of spiders of 25 families. An investigation of the spider fauna in Nawabganj Bird Sanctuary, a large wetland of Unnao district, Uttar Pradesh recorded 55 Spider species belonging to 41 genera & 14 families (Kumar *et al*., 2017a). In one of the explorative studies in Vansda National Park, Gujarat has reported 124 species of spiders belonging to 67 genera and 22 families (Patel, 2003). 37 species of spiders belonging to 12 families were documented from Matia, Goalpara District, Assam through a preliminary exploration of five months duration (Ahmed, 2018). Palem *et al*. (2017) documented the spider fauna of Eastern Ghats region of southern Andhra Pradesh. Pandit & Pai (2017) revealed the existence of 74 species of spiders belonging to 17 families Taleigao Plateau, Goa. Deshpande & Paul (2016) recorded the diversity of spiders in Gulbarga (now known as Kalaburagi), Karnataka. Parmar (2020) recorded 142 species of spiders belonging to 86 genera and 25 families from Dharoi Reservoir, North Gujarat. Malhotra *et al*. (2019) compared the spider assemblage of four different habitats - semi-arid grassland, scrubland, open forest land, and riparian land of upper northern Rajasthan and found that population density is higher in riparian land. 70 species of spiders belonging to 58 genera and 21 families were recorded from Araabath Lake and neighbouring areas (Caleb, 2020a). Spider fauna of Eastern Rajasthan in monsoon was studied by Lawania & Mathur (2018) and recorded 43 species from 35 genera 16 families. Jangid *et al*. (2019) assessed the faunal diversity of spiders in Central

Aravlli ranges of Pali and Ajmer Districts of Rajasthan. Patil *et al.* (2013) documented the diversity and abundance of spiders in Singhori Wildlife Sanctuary, Madhya Pradesh, India.

Kashmeera *et al.* (2020) reported 59 species of spiders from the rocky Thar desert in Kailana, Rajasthan. Kumari *et al*. (2017) studied the diversity of arid and semi-arid regions of Jodhpur and Ajmer Districts of Rajasthan and reported Araneidae and Oxyopidae as the most dominant family there. A survey of spiders in different ecosystems of Nilgiris (grass land, plantations and shola forest), Tamil Nadu revealed that Araneidae was the family with highest species richness in all the types of habitats. Shola Forest was the habitat where maximum number of species was reported, among the three (Dharmaraj *et al*., 2018). Several explorations have so far been conducted to record of faunal diversity of several natural ecosystems of various parts of Tamil Nadu. Survey of the spiders of Mangroves at Adirampattinam coast (Muthukumaravel *et al*., 2013) study on spiders of Sirumalai hills, Dindigul (Krishnaveni & Kandeepan, 2017) are a few among them. Documentation of spider diversity and their microhabitat preference in the forest of Nilgiris, Tamil Nadu was done by Dharmaraj *et al*. (2017). 61 spider species were identified belonging to 45 genera & 16 families were reported from Kukrail Reserve Forest, Lucknow, Uttar Pradesh (Kumar *et al*., 2017b). Deshmukh & Raut (2014) documented 104 species of spiders of 18 families from Salbardi forest, Maharashtra, India. Several studies explored the spider assemblage of various parts of Assam also (Chetia & Kalita, 2012; Anindita *et al.*, 2017; Basumatary & Brahma, 2017; Pandit, 2019). Salticidae was reported as the most abundant family in arid and semi-arid regions of Sirsa, Fatehabad and Hisar districts of Haryana followed by Araneidae and Thomisidae (Malik & Goyal, 2017).

An updated checklist of spiders of Jabalpur district, Madhya Pradesh was prepared by Patil (2012). A check list of spider fauna of various parts Rajasthan was prepared by compiling available literatures (Kaur *et al.*, 2014; Kashmeera & Sudhikumar, 2019). An updated catalogue of spiders of family Philodromidae was made by Singh & Singh (2021) incorporating all the published records on Philodromid spiders of India. Check lists of spiders of families Cheiracanthiidae (Singh *et al*., 2020), Scytodidae (Singh *et al*., 2021) Dictynidae, Dysderidae, Eresidae and Filistatidae (Sharma *et al*., 2021) were prepared and their distribution in various states and union territories of India was traced. Diversity of clades Amycoida and Astioida (Salticidae: Salticinae) in various states of India was also traced recently (Singh *et al*., 2020). Preliminary checklists of spiders of Odisha (Choudhury *et al.,* 2019), Tamil Nadu (Karthikeyani *et al*., 2017) and Gujarat (Yadav *et al*., 2017) were worked out incorporating various publications in the respective fields. 118 species of mygalomorph spiders under 31 genera and 9 families was reported in India by Singh & Singh (2020). The highest number of species of mygalomorph spiders reported in in India belongs to Tamil Nadu (29) followed by Kerala (23) (Dhali *et al*., 2016; Singh & Singh, 2020). Theraphosidae ranks first in India, in the number of species of mygalomorph spiders, followed by Idiopidae (Dhali *et al*., 2016).

Being a biocontrol agent, spiders, and their diversity in croplands, their ecological interactions there etc. have always been a question of curiosity since the burgeoning of research in applied arachnology. In India major part of studies on spiders in agroecosystem is from the cereal fields. Khan (2006) Surveyed rice fields of six districts of Uttar Pradesh and reported 39 species of spiders under 9 families. As per his report Lycosidae and Salticiade ranked first and second in abundance.

Khan (2011) reported 40 species under 29 genera and 13 families of spiders from temperate rice fields of three districts of Kashmir. Diversity and guild structure of spiders was analysed in temperate maize ecosystem of Kashmir by Khan & Rather (2012). In a study of spider assemblage in rice ecosystems of Rajendranagar, Telangana, Tetragnathidae was turned up to be the most abundant family (Anitha & Vijay, 2016). Assessment of diversity of spiders of rice land spiders of four districts of Uttar Pradesh was conducted and Tetragnatidae and Lycosidae came in the first and second rank in abundance (Singh & Singh, 2014). Species composition of spiders of rice fields in Kolasib district of Mizoram was studied and reported that Lycosidae dominated in the ground samples while Tetragnathidae dominated in foliage samples (Chowdhury *et al.*, 2017). Saha *et al.* (2020) conducted an explorative survey on the spider fauna associated with rice fields of South 24 Praganas, west Bengal and reported Salticidae as the most abundant family.

Spiders belonging to 117 species under 63 genera and 18 families were reported from cashew plantations of Puthur and Shanthigodu, Karnataka. Salticidae turned up the most dominant family there (Bhat *et al*., 2013). A survey of spider diversity was conducted in the tea plantations of Darjeeling, West Bengal. (Saha *et al*., 2016). Spiders belonging to 40 species, 23 genera under 11 families were recorded from fruits and vegetable crop fields of Srinagar, Jammu & Kashmir (Khan, 2009). Sugumaran *et al*. (2007) studied the spider diversity of vegetable and fruit orchards of Yercaud hills of Tamil Nadu and recorded 56 species under 18 families. Sugumaran & Duraimurugan (2019) analysed the spider fauna of different horticultural ecosystems of Nagapattinam district, Tamil Nadu and reported that abundance of spiders was highest in fruit crops followed by vegetables and lowest in flowering crops. Pillai *et al.* (2017) in their field investigation for computation of

arthropod diversity in vineyards of Coimbatore, Tamil Nadu, reported spiders as the second most abundant group after insects. Lycosidae and Salticidae were reported as the most abundant families there. Keswani & Vankhede (2014) reported 50 species belonging to 39 genera under 15 families from banana croplands of Purna river basin, Maharashtra. Araneidae was the dominant family there. Mahalakshmi & Jeyaparvathi (2014) documented the diversity of spiders and their seasonal variation in cotton fields of Virudhunagar district, Tamil Nadu. Family Salticidae turned out to be the most abundant family there. Gogoi & Ningthoujam (2021) compared the faunal diversity of spiders in agricultural (rice and other cereals), horticultural (vegetables and fruits) and sylvicultural (trees) ecosystems of mid-hills of Meghalaya and reported that diversity is greater in sylvicultural fields followed by horticultural field and least in agricultural field. Araneidae came out as the most abundant family in all types of ecosystems under the study.

The genus *Scoloderus* Simon 1887 (Araneidae) was reported first by Patel(2003) in Vansada National Park in Gujrat. In a survey of spiders in Manipur, *Myrmarachne kiboschensis* Lassert, 1925, *Latrodectus elegans* Thorell 1898, *Epocilla praetextata* Thorell 1887 were recorded for the first time in India by Kananbala *et al*. (2018). A new species, *Conothele khunthokhanbi* Kananbala, Bhubaneshwari & Siliwal, 2015 (Halonoproctidae) was also described in the same study. In an exploration of spider fauna of Keoladeo National Park, Bharatpur district, Rajasthan *Ptocasius strupifer* Simon, 1901 (Salticidae) was reported first time in India (Kaur *et al*., 2014). *Argyrodes bonadea* (Karsch, 1881) (Theridiidae) was first reported in India, in a survey of spiders in Delhi (Malik *et al*., 2015). *Menemerus nigli* Wesolowska & Freudenschuss, 2012 (Salticidae) and *Psechrus inflatus* Bayer, 2012 (Psechridae) were reported for first time in India by Chatterjee

et al. (2017a & 2017b). *Pagida salticiformis* (O. Pickard- Cambridge, 1883) (Thomisidae) was recorded for the first time in India and *Langona tigrina* (Simon, 1885) was redescribed after 135 years in India by Caleb (2020b). *Pritha nana* (Simon, 1868) (Filistatidae) was recorded for the first time in India from Amaravati district, Maharashtra (Kamble *et al*., 2020).

Several studies reveal that Indian subcontinent is rich of spider fauna and a considerable proportion of the total number of species of spiders reported in India exhibits varying level of endemism. Siliwal *et al*. (2005) reported a total 1002 species of spiders are endemic to Indian mainland and later updated to 1053 (Siliwal & Molur, 2006). Keswani *et al*. (2012) updated the number of species endemic to India to 1238 under 340 genera and 58 families. Extremely high degree of endemism (62.5% of species reported are endemic to India) was reported in the families of spiders, viz. Palpimanidae, Pimoidae, Psechridae, Psilodercidae, Segestriidae, Selenopidae, Sicariidae, Stenochilidae, Symphytognathidae, Tetrablemmidae and Theridiosomatidae (Tiwari *et al*., 2021). Pandit & Pai (2017) reported that 5 out of the 74 species of spiders collected Taleigao Plateau, Goa are endemic to India, 4 species are endemic to South Asia. There are several explorations documenting numerous mygalomorph spiders endemic to India (Dhali *et al*., 2016; Singh & Singh, 2020). Caleb (2020a) reported 7 species of spiders endemic to India and 6 species endemic to India and Sri Lanka during his survey of spiders from the vicinity of Araabath Lake, Chennai, Tamil Nadu. Adarsh & Nameer (2016) had put down that, 34 out of the total 101 species of spiders collected from Chinnar wildlife Sanctuary, Kerala, were endemic to India.

2.2.3. An overview of spider diversity in Kerala

Despite the rich diversity of spider fauna, arachnology in Kerala is still in its infantile stage. Very few works have been done to record the diversity of spiders in Kerala. The study of spiders in Kerala started in the 1990s with the works of P.A. Sebastian.

A diversity of spiders with 72 species, 57 genera and 20 families were recorded from Mannavan Shola forest (Sudhikumar *et al*., 2005a). About 21% species record from there are endemic to Western Ghats, Kerala. An exploratory survey in Mangalavanam mangrove forest yielded 51 species of spiders belonging to 40 genera and 16 families (Sebastian *et al.*, 2005). Sudhikumar *et al*. (2006) studied the diversity of synanthropic spiders in various parts of Kerala. Jose *et al.* (2008) documented the diversity of spiders in Parambikulam Wildlife Sanctuary. Adarsh & Nameer (2016) explored the diversity of spiders in Chinnar Wildlife Sanctuary and recorded 101 species of spiders belonging to 65 genera and 29 families which accounted for 6.98% of Indian spider species. Jose *et al*. (2018) recorded 112 species of spiders belonging to 82 genera under 21 families form Kavvayi river basin. Sumesh & Sudhikumar (2020a) reported 84 species of spiders under 64 genera and 20 families from the sacred groves of Thrissur district Kerala. Araneidae was reported to be the most dominant family there. Peedikayil *et al*. (2021) reported 102 species of spiders belonging to 73 genera and 18 families from various sacred groves of Kannur. An exploration of spider fauna in Poovar mangrove forest recorded 70 species, 45 genera and 14 families of spiders (Vishnudas *et al.,* 2021). Survey of spider fauna in campuses of Kerala Agricultural University, Thrissur (Adarsh & Nameer, 2015), Kerala University, Thiruvananthapuram (Asima *et al*.,

2020) reveals that moderately high faunal diversity of spiders can be seen in the places where anthropogenic disturbances are high.

Mathew *et al*. (2014) studied the distribution of spiders in respect to the vertical strata of in rice agroecosystem of Kuttanad, Kerala. A quantitative survey of araneofauna along the elevation gradient from Nelliyampathy hills by Sudhikumar (2015) revealed that the elevation influences species richness of spiders. Sudhin *et al*. (2020) studied the effect of altitudinal gradient on spider diversity during their explorations in Wayanad Wildlife Sanctuary and reported that the diversity of spiders decreases with elevation. The diversification of arachnological study to behavioural aspects of spiders and their ecological interactions has been started recently in Kerala. Behaviour of social spider *Stegodyphus sarasinorum* Karsch, 1892, impact of kleptoparasitic spiders and ants on their behaviour, relationship between prey size and their cooperative behaviour for prey capture was studied in detail by Drisya-Mohan *et al*. (2019).

A check list of spiders of 257 species belonging to 130 genera under 28 families from sacred groves Northern Kerala was prepared by Sumesh & Sudhikumar (2020). This was one of the pioneering works in this direction in Kerala. 275 species of spiders under 139 genera and 39 family are catalogued from Western Ghats by Sebastian *et al*. (2012).

Jose & Sebastian (2001) reported three species of crab spiders (Thomisidae) *Mitsumune mridulai* Tikader, 1962, *Runcinia insecta* (L. Koch, 1875) (Synonym: *Thomisus cherapunjeus* Tikader, 1968) and *Thomisus lobosus* Tikader, 1965 for the first time in Kerala. Two species - *Oedignatha carli* Reimoser, 1934 (Liocranidae) *Hyllus diardi* (Walckenaer, 1837) (Salticidae), and two genera -*Coleosoma* O. Pickard-Cambridge, 1882 (Theridiidae) and *Neriene* Blackwall, 1833 (Linyphiidae)

were recorded from Mannavan Shola forest first time in India (Sudhikumar *et al.*, 2005b). A new species *Suffasia keralaensis* Sudhikumar, Jocqué & Sebastian, 2009 (Zodariidae) was described from the Western Ghat region of Kerala (Sudhikumar *et al*., 2009). Davis *et al.* (2005) recorded *Thiania bhamoensis* Thorell, 1887 (Salticidae) for the first time in Kerala. A new species *Haploclastus devamatha* Prasanth & Sunil Jose, 2014 (Theraphosidae) was described by Prasanth & Jose (2014). Three new species *Marengo zebra* Sudhin, Nafin, Benjamin & Sudhikumar, 2019, *Marengo batheryensis* Sudhin, Nafin, Benjamin & Sudhikumar, 2019 and *Cocalus lacinia* Sudhin, Nafin, Sumesh & Sudhikumar, 2019 (Salticidae) were reported from Wayanad Wildlife Sanctuary (Sudhin *et al*., 2019). *Dolichognatha longiceps* (Thorell, 1895) (Tetragnathidae) was reported from Western Ghats for the first time in India by Jose (2014). Female of *Micropholcus fauroti* (Simon, 1887), a daddy long leg spider (Pholcidae) was reported for the first time in India from Poovar mangrove forest (Vishnudas & Sudhikumar, 2021).

Mathew *et al*. (2014) recorded 69 species of spiders under 49 genera and 17 families from rice fields of Kuttanad. Diversity of spiders and their variations in different cropping seasons in Kuttanad paddy fields was documented by Sudhikumar *et al*. (2005b). Explorations on the spider diversity of paddy fields of Ernakulam (Sebastian *et al*., 2005; Ambili & Antony, 2016), Idukki (Sebastian *et al*., 2005) and Thrissur (Sudhikumar & Nafin, 2020) districts have been extensively done. A few preliminary studies have been conducted on spider diversity associated with cashew plantations of Thrissur district (Beevi & Mahapatro, 2008; Smitha & Sudhikumar, 2020). Spider fauna associated with vegetables and other horticultural crops of Kerala are remaining a highly unexplored area.

2.3. A compendious account of spider guilds

Earlier the research on spiders in India focused greatly on taxonomic descriptions and inventories. Its diversification to other fundamental (ecology, phylogeny, biogeography, etc.) and applied (agriculture, medicine, conservation, etc.) research started very recently. Spiders being polyphagous predators, their role in the habitats is extraordinarily complex. Feeding guilds of spiders have been an area of interest of arachnologists for a few decades. Ecological guild can be defined as the group of unrelated species that thrive on same resources or make use of different resources in comparable way (Root, 1967). The study of ecological guild is important as it helps to understand the assemblage responses to disturbances in the habitat, climatic changes etc. (Cardoso *et al*., 2011). The major criteria for grouping spiders into different feeding guilds are the foraging patterns in their habitats (Uetz *et al*., 1999).

Bhat *et al*. (2013) had studied the guild structure of spiders of cashew plantations of Puthur, Karnataka. Seven feeding guilds were reported from Chinnar Wildlife Sanctuary (Adarsh & Nameer, 2016). Kashmeera *et al*., (2020) reported stalkers as the dominant guild out of the six feeding guilds recorded from rocky desert in Kailana, Rajasthan. Ambush hunters were reported to be the most abundant type of guild in the sacred groves of northern Kerala (Sumesh & Sudhikumar, 2020). Smitha & Sudhikumar (2020) reported six feeding guilds from cashew plantations of Thrissur District, Kerala.

2.4. Spiders and their role in the agroecosystems

Fritz *et al*. (2011) in their studies on arthropod diversities in rice fields of Brazil describes spiders as one of the most important predators of insect pests there. Jauharlina *et al*. (2019) accounts for four families of spiders (Tetragnathidae, Araneidae, Linyphiidae and Oxyopidae) as the potential natural enemies in the rice

fields of Indonesia. Saengyot & Napompeth (2008) also reported spiders as the significant generalist predator that regulate the pest species in organic paddy fields of Thailand. Bambaradeniya & Edirisinghe (2009) documented the diversity and assemblage of arthropods in rice agroecosystems of Sri Lanka and reported spiders as the most significant predators there followed by beetles. Spiders came out as the most important predator group along with damselflies and dragon flies in an exploration of predators and parasitoids of rice pests in four districts of Manipur (Devi *et al*., 2018). Moses *et al.* (2019) also described spiders as one of the most effective predators in rice ecosystems. According to Maloney *et al.* (2003), spiders can not only lower the pest population, but also stabilize them at low density, by virtue of which spiders can function as good bio control agent. Costello & Daane (1999) reports spiders as the most abundant predator group of insect pests in vineyards of California.

Spiders can be used as good biocontrol agents as they have consumptive and non-consumptive effect on prey populations (Cronin *et al*., 2004; Schmitz, 2005; Bucher *et al*., 2014; Beleznai *et al.,* 2017). Predation causes physiological and behavioural stress in prey which slows down their development, reduces fecundity rate and there by retards the establishment of pest population (Hawlena & Schmitz, 2010). To escape from getting detected by the spiders, a reduction in pest movements occurs which also adversely affect the growth of pest population (Rypstra & Buddle, 2013; Bucher *et al*., 2014; Beleznai *et al*., 2015). Several factors like size and nutritional composition of prey, availability of alternate prey, intraguild predation, predator switching, hunting strategy of spiders etc. also affect biocontrol efficacy of spiders in our agricultural croplands (Michalko *et al.*, 2019). Biocontrol potential of spiders in paddy fields have been studied extensively (Rajeswaran *et al*.,

2005; Tahir & Butt, 2009; Kobayashi *et al.*, 2011). Many efforts have so far been made to document the effect of spiders on horticultural croplands (Hanna *et al.*, 2003; Rajeswaran *et al*., 2005; Liu *et al*., 2015; Michalko & Pekar, 2015). Deploying spiders in combination with specialist natural enemies in the crop field prevents the resurgence of pests besides reducing pest population (Sunderland, 1999). Norma *et al.* (2014) had opined that the spider belonging to the families Araneidae, Lycosidae, Oxyopidae, Tetragnathidae, Thomisidae and Salticidae are the most effective bio control agents in agroecosystems. Suenaga & Hamamura (2015) suggested *Pardosa astrigera* L. Koch, 1878 as an efficacious biocontrol agent against cabbage pests *Plutella xylostella* and *Myzus persicae*. Jeyaparvathi *et al.* (2013) reported *Peucetia viridana* (Stoliczka, 1869) as potent biocontrol agent for cotton pests *Aphis gossypii* and *Spodoptera litura*. *Oxyopes javanus* Thorell, 1887 was reported to be a powerful biocontrol agent against tea mosquito bug *Helopeltis theivora* (Basnet & Mukhopadhyay, 2014). Spiders, especially those who belong to the genus *Philodromus* Walckenaer, 1826 were recorded to be effective in controlling rosy apple aphid *Dysaphis plantaginea* (Lefebvre *et al*., 2017). Kobayashi *et al*. (2011) reported *Pirata subpiraticus* (Bosenberg & Strand, 1906) a fruitful biocontrol agent against *Stenotus rubrovittatus,* a mirid pest of rice. *Telamonia dimidiata* (Simon, 1899) and *Oxyopes shweta* Tikader, 1970 were stated to be effective in managing tea mosquito bug in cashew fields in Karnataka (Bhat *et al*., 2013). *Cyclosa insulana* (Costa, 1834) reported to be powerful biocontrol agent of whiteflies and *Plexippus paykulli* (Audouin, 1826) against thrips, in cotton fields (Mohsin *et al*., 2015). *Evarcha albaria* (L. Koch, 1878) was suggested to be efficient in shrinking down the population size of *Empoasca vitis*, a serious pest of tea. Saqib *et al*. (2021), through molecular gut content analysis revealed that there

are clear prey preferences among spider taxa. Salticids prefer lepidopterans while Pisaurids opt for dipterans and Thomisids for coleopterans. Thorough knowledge of such food preferences, foraging tactics and other trophic interactions of spiders will help in the effective utilization of their feeding potential in biological pest control in a more fruitful manner.

2.5. Impact of man-made disturbances on spiders

Like all other animals on earth, disturbances created by human beings affect spiders also. Most of these anthropogenic disturbances create negative impact to the spider populations in natural as semi natural ecosystems. Deforestation and urbanization had led to modification and fragmentation of habitats. It is noted that interfering noises induce physiological stress in the animals (Brumm & Slabbekoorn, 2005). Wu & Elias (2014) proved that amplitude of man-made vibratory noises affects the sensitivity of prey detection of orb weaver. In many spiders, a decrease in web size and prey capture rate with increasing noise level was observed (Gomes *et al*., 2020). Agroforestry, unscrupulous urbanisation, and environmental defilement are the major man-made threats that spiders have to come across (Branco & Cardoso, 2020). Vergnes *et al*. (2014) reported that urban densification impacts negatively on ground dwelling spiders and other arthropods.

Irrational usage of agrochemicals is another man-made disturbance that affects spider fauna adversely. Graf *et al.* (2019) reported that abundance and species richness of riparian spider fauna decreased with an increase in the toxicity of the river water. A similar decrease is abundance and species richness were reported in terrestrial spider fauna also due to traditional chemical management of agricultural fields (Park *et al*., 2007; Devotto *et al*., 2007).

It is noted that the effect of pesticide on the spider community depends on the community structure, area of the cropland and timing and frequency of the pesticide application (Pekar, 2012a). Generally, all biocides except herbicides affect the canopy dwelling spiders than the epigeic ones. Some pesticides show guild specific impacts while some show negative effect to entire community. Formothion, carbaryl, hexaflumuron, cycloxuron etc. applied in fruit orchards adversely affect entire spider community there (Mansour, 1987; 1988; Pekar, 1998), while phenthoate, deltamethrin, ethofenprox etc. show guild specific effects (Tanaka *et al*., 2000). It is found that the adverse effect of the pesticide is stronger if the application is at the time of immigration of spiders to the field or at the time their reproduction (Volkmar *et al*., 2008). Many biocides, especially herbicides which have comparatively low direct lethal effects, have many indirect effects like reduction in web attachment sites, space for shelter, humidity, and prey availability (Sunderland, 1999). Direct lethal effect of neurotoxic pyrethroids on *Oedothorax apicatus* (Blackwall, 1850) was studied and found that ataxia, tetani, and convulsions were observed before the final paralysis and death (Jager *et al*., 1995). It was noted that *O. apicatus* preferred moist substrate after exposed to deltamethrin which may be for avoiding pesticide induced water loss (Everts *et al*., 1991). The direct lethal effect pesticide application through different routes had been examined using ^{14}C labelled deltamethrin exposure and found that contact to pesticide residue is the most detrimental route of exposure (Mullie & Everts, 1991). The structure of web constructed by spiders also influence the extent to which they are exposed to pesticides as webs act as an effective collector of insecticide sprays (Samu & Vollrath, 1992). Spiders building three-dimensional web with a retreat inside are found to be less exposed to insecticide droplets than the one which makes orb webs

(Pekar, 2012b). The age, sex and nutritional status of spiders also affected the degree of stress created by insecticides on them (Hof *et al*., 1995; Dinter *et al*., 1998; Pedersen, 2002; Van Erp *et al*., 2002).

Besides the direct lethal effects, numerous sublethal effects were recorded in spiders due to exposure to pesticides. These effects lowered the prey capture, reproduction rate, defence, and dispersal of spiders (Pekar, 2012b). The exposure to cypermethrin tropically caused ataxia and paralysis of legs in *Pardosa amentata* (Clerck, 1757) (Shaw *et al*., 2006). Several laboratory studies indicated that different pesticides may affect the stages of reproduction of spiders (Dinter *et al*., 1998; Deng *et al*., 2006; Tietjen, 2006; Benamu *et al*., 2010; Peng *et al*., 2010). Mansour (1987) found that spiders in areas where sublethal doses of pesticides were applied more frequently, were more tolerant to pesticide than those in untreated fields. This indicated that spiders have developed a level of resistance to pesticides. An overall reduction in haemocytes in the lycosid *Schizocosa humilis* (Banks, 1892) was observed after oral azadirachtin administration, indicating a reduction in immunity.

A shift from conventional chemical management to IPM and organic cultivation practices has impacted the spider community positively in several agroecosystems like tea plantations (Bao-Yu, 2005), vegetable croplands (Sengonca & Liu, 2002), wheat fields (Feber *et al.*, 1998), olive groves (Santos *et al.*, 2007), and fruit orchards (Pekar, 1999; Pekar & Kocourek, 2004; Marko *et al.*, 2009).

2.6. Breakthroughs in applied Araneology

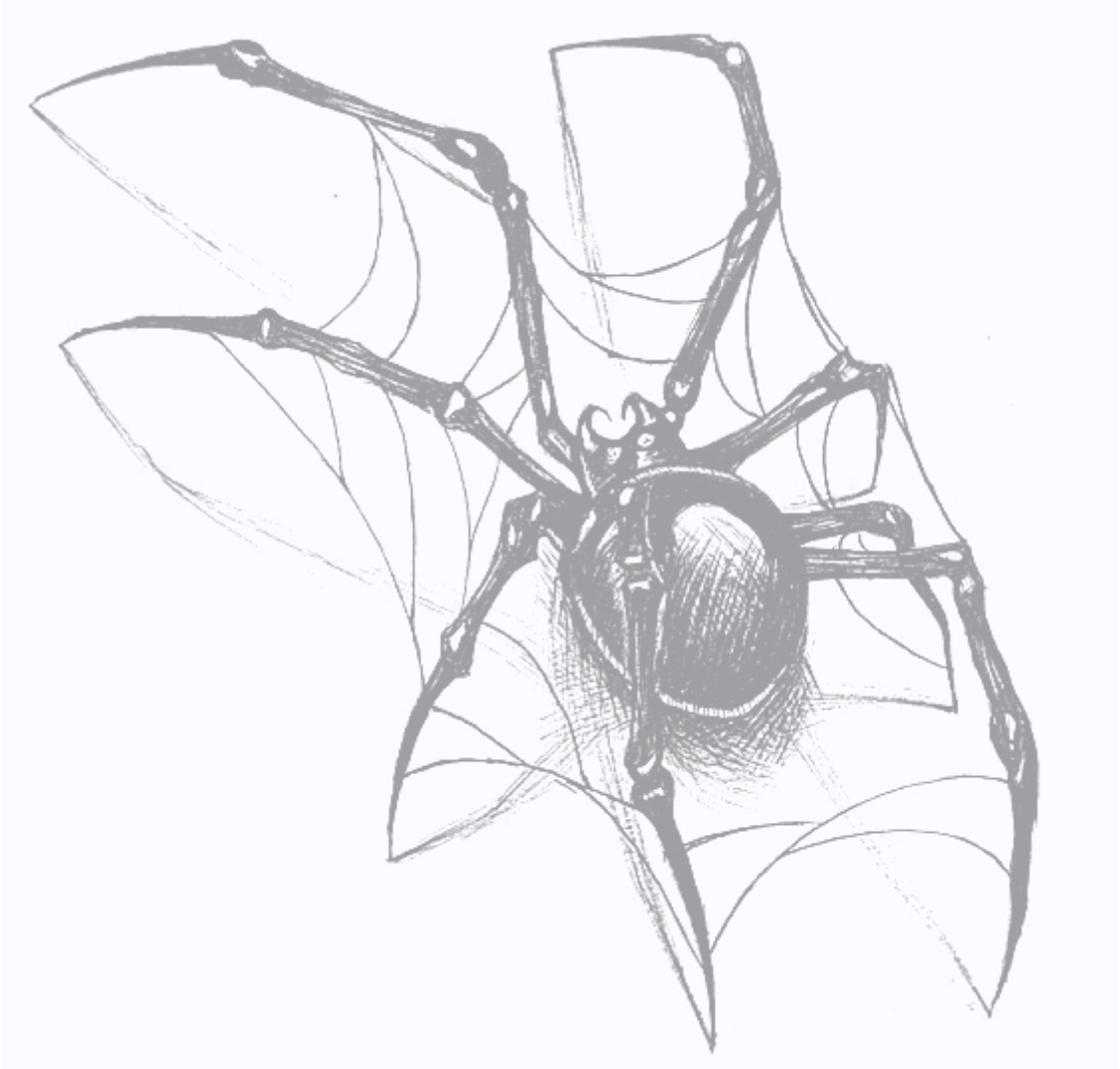
A surge in applied research in arachnology has been seen in the recent decades only. Many studies have been conducted so far on the use of spider venom, spider silk, and other spider-related materials. Spider venom can be utilized to make effective bio pesticides since spiders employ it to catch insect prey. Different voltage gated

ion channels and presynaptic nerve terminals are the most well-known insecticidal targets of spider venom (Vetter, 2011). Polypeptides that target NaV channels are produced by most spiders in their venom. Toxins from spiders affect neural excitability, causing insects to become paralysed and eventually die (Catterall *et al*., 2007). So, spider venom toxins may emerge as potential bio insecticides in near future.

Spider venom can be used in medicine and related studies because it targets certain ion channels or receptors in the body. They can be effectively utilized in the treatment of diseases caused by impaired function of these receptors or ion channels (Saez *et al.*, 2010). Spider venom peptides, like other venom peptides, are renowned for their efficacy and selectivity when compared to typical small molecule medicines, making them attractive for biomedical research (Pennigton *et al*., 2018). Selectivity of spider venom peptide confers it a capacity to minimise off target activity and thereby reduce side effects of drug. Many spider venom peptides are employed in medical research to figure out how ion channels work and how their malfunction leads to ailments (Liu & Bean, 2014; Bishop *et al*., 2015). Novak (2001) reported that polypeptides from spider venom can be used to cure cardiac arrhythmia. Lycosin-I, derived from *Lycosa singoriensis* (Laxmann, 1770) venom, has been shown to inhibit tumour growth in vivo (Liu *et al*., 2012). Lycosin-I is a prospective option for anticancer treatment development, as it can both trigger cancer cell apoptosis and reduce the risk of subsequent metastasis (Gartrell *et al*., 2015; Pascale *et al*., 2017).

Due to its low degradation rate and exceptional mechanical qualities, spider silk can be used as a suture for fixing tendon ruptures (Hennecke *et al.*, 2013). According to Allmeling *et al.* (2006) and Roloff *et al*. (2014) dragline silk fibres

from *Nephila* may be used as a scaffold for human neurons and cell bodies of neurons touched with spider silk scaffold grow into ganglia-like structures. Spider silk has been proposed by Wendt *et al*. (2011) as a new matrix for skin repair in reconstructive surgical procedures. Recombinant spider silk has been reported to be useful for wound healing and regeneration of skin (Baoyong *et al*., 2010; Chouhan *et al*., 2018; 2019) and peripheral nerve (Pawar *et al*., 2019; Aigner *et al*., 2020). Spider silk also has a multitude of uses in optics and photonics (Huby *et al*., 2013).



CHAPTER 3

MATERIALS AND METHODS

MATERIALS AND METHODS

Research methodology is the system of methods adopted to scientifically address the topic of research. It is the way followed by the researcher to solve his research problem. It involves the collection of data, rigorous analysis and drawing reliable conclusions. It also clarifies the reason for adoption of specific methods. The research methodology directs the researcher in the appropriate direction from topic selection to study execution. The methodology of the current study is outlined here**.**

3.1. Study area

Kerala, popular for its coconut groves, is located on the southwest tip of India. It is located between latitudes 8°18' and 12°48' and longitudes 74°52' and 72°22'. The state has a 38,86,300 hectares total land area. Kerala is located between the Western Ghats in the east and the Arabian Sea in the west. Kerala can be classified into three regions topographically - lowlands, midlands, and highlands. High land has an average height of 900 meters and it includes the slope of Western Ghats. Agricultural products there include tea, coffee, rubber, and spices like cardamom.

Midlands lie between highlands and lowlands and constitute around 40 percent of land area of Kerala. Cashew, coconut, banana, vegetables etc. are grown richly in the midlands. Lowlands comprise river deltas, lagoons and coastal shores of Arabian Sea. The major crops in these parts include paddy and coconut. According to Koppen's climatic classification Kerala experiences tropical monsoon (all parts of Kerala except Thiruvananthapuram district) tropical savannah (Thiruvananthapuram district) climates (Nathan, 2000). The state has summer temperatures between 32°C and 36°C, monsoon temperatures between 18°C and 30°C, and average annual rainfall of around 3000 mms.

Crops grown in Kerala include rice, banana, mango, papaya, and a wide variety of vegetables like brinjal, lady's finger, spinach, peas, pumpkins, ash gourds, and many others. Plantation crops such as coconut, rubber, tea, coffee, ginger, etc., as well as spices like pepper, cardamom, cinnamon, and nutmeg, are all farmed here with great success.

Thrissur, popularly known as 'the cultural capital of Kerala' is the anglicised form of the Malayalam phrase 'Thrissivaperur,' which translates as 'town of the sacred Siva'. It is a revenue district of Kerala located in the geographic centre of the state. Thrissur district encompasses around 3,032 km^2 and accommodates nearly 10% of Kerala's population. The district is bounded to the north by Palakkad and Malappuram districts, and to the south by Ernakulam and Idukki districts. The Arabian Sea is to the west, while the Western Ghats are to the east.

The crops cultivated in Thrissur include rice, tapioca, fruits such as mango, banana, papaya, vegetables such as drumstick, brinjal, bitter gourd, cucumber, pumpkin, ash gourd, chilies, and spices such as pepper, nutmeg, turmeric, etc. The average highest summer temperature in the city is 35 degrees Celsius, while the minimum temperature is 22.5 degrees Celsius. The average maximum temperature during winter is 32.3 degrees Celsius, while the average minimum temperature is 20 degrees Celsius. The average annual precipitation in the region is 2037mm. The current study includes the study of the diversity of spiders associated with the horticultural fields of five major vegetable belts of Thrissur district, Kerala (Figure 3.1).

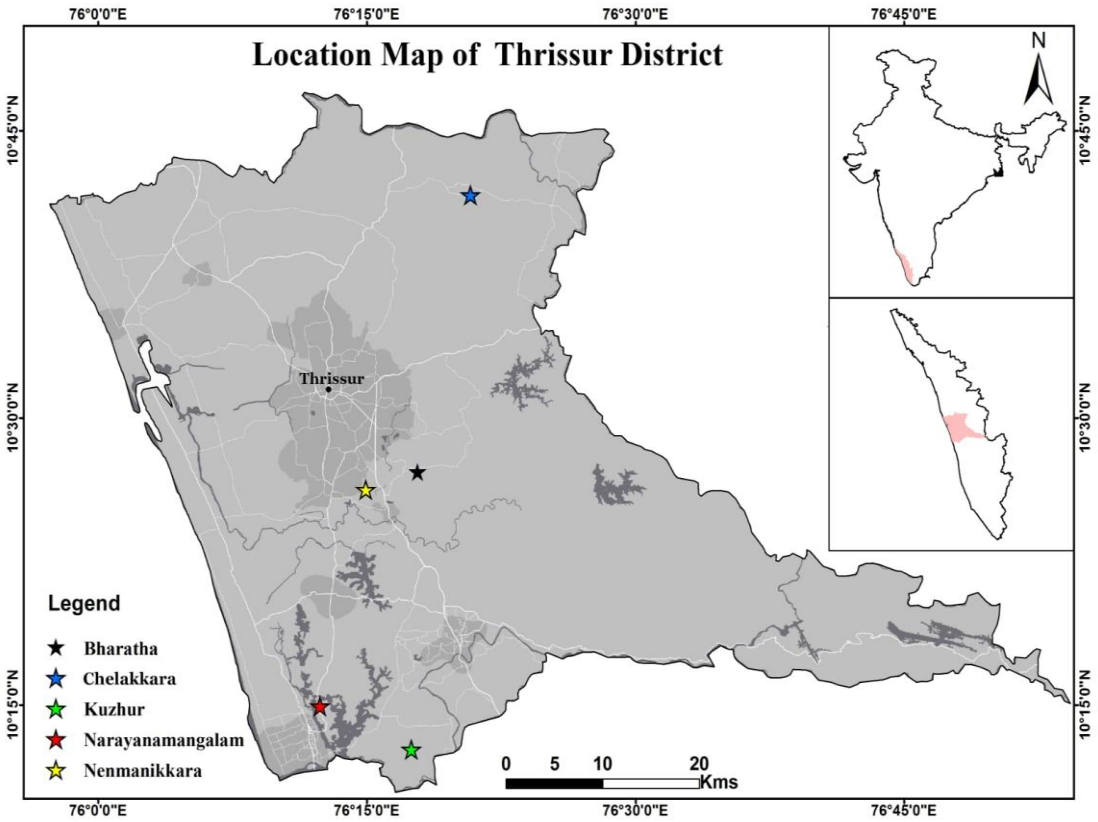


Figure 3.1. Location map of the study sites

3.1.1. Kuzhur (KZR)

Kuzhur is a village of 11.91 square km in the Mala block of the Thrissur district. It is 41km south of the district capital, Thrissur, and 4km from Mala (Table 3.1). Kuzhur is on the southern edge of the district of Thrissur. The study was conducted on an agrofarm in Kuzhur with mixed horticultural crops. Paddy fields, coconut farms, dwelling area, and road bordered the cropland.

3.1.2. Narayanamangalam (NGM)

Narayanamangalam is a village in Kodungallur municipality of Thrissur district. The location of Narayanamangalam is east of Pullut. It is 6km from the town of Kodungallur and 39.5km from the town of Thrissur. The study site selected in the village was a privately owned farm which adopted agriculture as well as animal husbandry practices in the plot. The site is bordered by roads on either side, a low-

lying watershed on one side and housing area on the fourth side. Organic cultivation was practiced there.

3.1.3. Nenmanikkara (NKR)

Nenmanikkara is a village in Kerala. It is part of the Kodakara block panchayath of Thrissur district and has a land area of 11.41km^2. It is closer to NH544 and is near the town of Amballur. The cropland for study is an traditionally cultivated area with a number of various horticultural crops being cultivated. The field was surrounded on all sides by paddy fields, a road, and banana crop lands.

3.1.4. Bharata (BTA)

Bharatha is a tiny village in the Kodakara block panchayath of the Thrissur district. It is governed by Thrikkur panchayath. It is 11km south of the district headquarters in Thrissur and 9km away from Kodakara. Bharatha is bordered to the north by Ollukkara block, to the south by Kodakara block, to the north by Thrissur block, and to the south by Irinjalakuda block. The study in the village was concentrated on banana cropland showing organic farming practice. It was surrounded by vegetable crop fields, roads and housing areas as the borders.

3.1.5. Chelakkara (CRA)

Chelakkara is a village that covers 59.8 square kilometres. It is in the Pazhayannur block of the Thrissur district. It is 27km north of Thrissur, which is the district capital and 6km from Pazhayannur. This place is on the border between the districts of Thrissur and Palakkad. A mixed cropping horticultural field in the village was selected for the study. A cropland with mixed cropping practice was selected for the sample collection. Paddy field, fallow land, housing area and an irrigation canal were located near to the plot under study.

Table 3.1. Characteristics of study sites

Site	Area (m^2)	Geographic coordinates	Major crops cultivated
KZR	4 $x10^4$	10.2115^o N, 76.2914^o E	Banana, Chilli, Tapioca, Pea Yam, Nutmeg, Mangostein, Rambutan
NGM	2.5 $x10^4$	10.2492^o N, 76.2064 ^{o}E	Banana, Plantain, Brinjal, Ladies finger, Yam, pulses, Nutmeg, Tapioca
NKR	3.8 $x10^4$	10.4376 ^{o} N, 76.2490^o E	Banana, Plantain, Brinjal, Pea, Spinach, Yam, Cucurbits, Ladies finger, Tomato.
BTA	2 x 10^4	10.4529^o N, 76.2971^o E	Banana, Plantain
CRA	3.8 x 10^4	10.6941^o N, 76.3464^o E	Banana, Plantain, Yam, Spinach, Pepper, Nutmeg

3.2. Sampling methods

3.2.1. Period of sampling

The time frame covered by the investigation was from 2015 to 2022. The selection of study plots and the pilot study comprised the first phase of the investigation, which took place in 2015-2016. Between 2016 and 2018, samples were taken from each of the study locations at regular intervals. Every season, each field was visited three times for sampling. Between 2018 and 2022, the identification of spiders, data analysis, and laboratory studies to determine the impact of some commonly used pesticides on the dominant spiders were conducted.

3.2.2. Sampling techniques

Sampling procedures and duration for each field are identical. Samples were gathered from each field three times per season. Every day of the collection, samples were taken from 7:00 am to 1:30 pm. Primarily, handpicking and sweep netting were employed for the collection process. Methods such as the beating stick technique and pitfall traps are not used since they are practically unfeasible in the study region, which consists of horticultural croplands. Samples were collected from a fixed number of $5m^2$ quadrats. The key criterion for deciding the number of quadrats per plots for the study is the total area of the croplands selected for the exploration. The quadrats were chosen at random and were placed far enough from each other. All the quadrats were in sufficiently interior regions of the area to prevent the edge effect.

Hand picking

Active searching and hand picking was the most common method adopted for the sampling at all the five sites of study (Mukhtar & Mushtaq, 2005; Sudhikumar *et al*., 2005a; Sial *et al*., 2012; Kashmeera *et al*., 2020). Spiders living in the soil were gathered from the upper layer of the soil after it had been thoroughly inspected. Spiders were collected either by hand picking or by using the kerchief method (Rajeevan *et al*., 2019; Sebastian *et al.*, 2005; Jose & Sebastian, 2001). The foliage of the shrubby vegetables was checked on both the upper and below surfaces. Active searching was performed on the surface of both green as well as on dried leaves, the leaf axil, and the space between the stem and the leaf sheaths of the plantains in the field. Flowers and fruits of vegetable crops were also examined thoroughly. Spiders of a smaller size were collected using a brush dipped in alcohol or by leading them into small specimen vials and closing the lid suddenly. Spiders located on webs were

captured inside the jar by keeping it open below them and rapping the lid of the jar over them. When the spider entered the jar, the jars were closed tightly with the lids.

Sweep netting

Sweep nets are strong nets in the shape of a bag that are attached to a long handle. They are used to collect insects and spiders out of long grasses and other plants. Its benefits are that it is simple, quick, and easy to use, and that it can collect insects that are spread out on top of the plants of moderate heights.

Sweep nets are used to catch aerial spiders on top of plants, which can't be found by visual searching. Standard-sized sweep nets are quickly wiped over the plants to catch the spiders in the net. Carefully, the spiders that are caught in the net are moved to the storage vials. This is the principal method adopted to collect spiders from the top portions of plantain as methods like beating are not possible in the agricultural fields.

3.2.3. Preservation of specimen

Specimens were taken back to the lab where they were photographed with a Nikon DSLR 5200 and a Tamron AF 90mmF/2.8 macro lens. The samples were then placed individually into polypropylene vials for long-term preservation. For specimens of different-sized spiders, different-sized vials are employed. The preservative used was 70% ethanol. The vials are filled with the alcohol in such a way that the specimen was fully immersed in it. Each vial is labelled with the place, date, collector's name, and other relevant taxonomic remarks. Alcohol is refilled to maintain the optimum preservation strength.

3.2.4. Identification

The specimens were observed under the stereo zoom microscope (Leica-M205C) for identification. Identification was mainly based on morphological features. The number, nature, relative size, and distribution of eyes, the number of cheliceral teeth, and the presence or absence of a cribellum are a few of the taxonomically significant characteristics. For correct identification, a microscopic examination of the structure of the male and female genitalia (palp in the case of males and epigyne in females) was done. The genitalia were meticulously dissected using needles with pointed tips, washed with 10% KOH, and viewed using a stereo zoom microscope. The World spider catalogue (2024) was the source of literature for the identification. Some of the collected specimens, particularly juveniles, could not be identified to the species level. They have been identified to the level of genus or family.

3.2.5. Data analysis

Data analysis is a standardised procedure for conducting precise and unbiased assessments of research data. It involves using statistical and logical tools in a planned way to describe and evaluate the data. Data analysis is essential to research since it simplifies and improves the accuracy of data study. It helps the researchers derive inferences from it. All statistical analysis of the present study is done with the help of statistical and computation software R (R Core Team, 2020) and Microsoft Excel 365.

Diversity indices

Diversity indices are the quantitative measures that indicate the number of distinct species in a community. In other words, diversity indices are mathematical measures of species diversity of the community. It represents various aspects of diversity like richness, dominance and evenness in a statistical way.

Shannon-Weiner diversity index (H) is a measure of the diversity of species in a community. It is one of the most used indices for estimating biodiversity in ecological studies. It is affected by both the number of species and evenness. The values might vary from 0 to ln (S) where S is the number of species in the community. Greater values of H indicate increased diversity. It can be calculated as,

$$H = \Sigma\, Pi\, .ln\, Pi$$

Where Pi is the proportion of individuals in a species in the whole community (n/N; n is the number of individuals in the given species and N is the total number of individuals in the community).

Simpson's index (D) (Simpson's Concentration Index) is a measure of dominance. It gives an idea on the chance of two individuals selected randomly from an infinitely sized population belonging to the same species. It is calculated as,

$$D = \frac{(\sum n(n-1)}{N(N-1)}$$

Where n is the number of individuals in a particular species and N is the total number of individuals in the whole community. It can take any value between 0 and 1. If D is 0 then the community is of infinite diversity and if it is 1, it indicates no diversity at all.

The value 1-D is often considered as Simpson's diversity index (Gini Simpson index). It indicates the probability of two randomly selected individuals from a community belonging to two distinct species. If its value is 0, there is no diversity and if its value is 1 it indicates infinite diversity. Both the Shannon and Simpson indices were calculated using the vegan package of R.

Shannon-Wiener and Simpson indices are not themselves diversities. These indices are typically connected with measures of true species diversity, although their properties differ from those of true species diversity. Jost (2006, 2007)

suggested that the effective number of species or Hill Numbers can be employed to circumvent these scaling concerns. True diversity in the community may be expressed as effective numbers. Effective number is the number of equally abundant species in a community (Jost, 2007; Tuomisto, 2010; 2011). For a perfectly even community, it is equal to species richness. For normal communities it is always less than the species richness. The values of effective numbers are less dependent on sampling effort than species richness (Beck & Schwanghart, 2010) and under sampling can be corrected for more easily compared to species richness and indices such as Shannon's H′ and Simpson's D (Chao *et al.,* 2014). These properties of effective numbers should provide more interpretable and comparable assessments of biodiversity (Jost, 2007).

Effective numbers or Hill numbers (^{q}D) can be calculated as follows,

$$^{q}D = (\sum_{i=1}^{s} pi^{q})^{1/(1-q)}$$

Hill numbers for q=0 indicates species richness, for q=1 Shannon diversity (Exponential of H) and for q=2 indicates Simpson diversity (reciprocal of Simpson index).

I.e., $^{0}D=S$, $^{1}D= e^{H}$, $^{2}D= {}^{1}/D$.

Diversity profile curves can be plotted when effective numbers are represented as a function of coefficient q. The shape of the curve gives information on the diversity and evenness of the community (Figure 3.2).

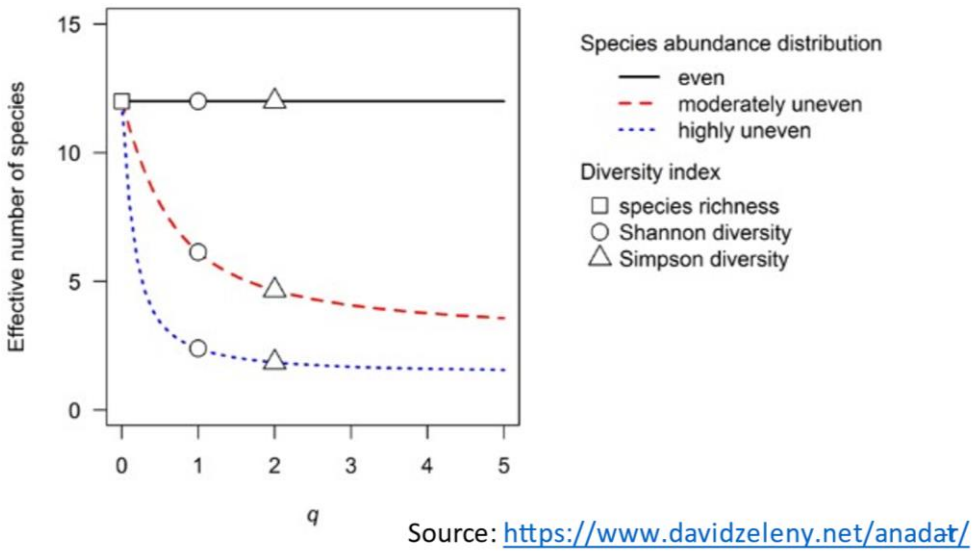


Figure 3.2. Diversity profile curves showing same species richness and different evenness

Kruskal Wallis Test

Kruskal Wallis test is a non-parametric test used to test the difference between multiple samples when the underlying population distributions are non-normal or unknown. It can be used to compare species abundance of different habitats and during different seasons. It is employed to test the null hypothesis, which states that k samples were drawn from the same or identical population with the same median. It confirms whether there exists a statistically significant difference between different samples.

Dunn's Test

The Dunn's test is a nonparametric statistical test that compares two paired groups. The test compares sets of pairs by determining if their differences are statistically significant. In the present study Dunn's test with Bonferroni correction is used for the pair wise comparison of abundance between different habitats. It tests the null

hypothesis that the two samples under investigation have the same median. It is used as a post-hoc test to identify which groups are statistically different from other groups.

Analysis of Beta diversity

Beta diversity quantifies the extent of dissimilarities between the communities in relation to a complex gradient of environments. It can be considered as the ratio between gamma diversity and alpha diversity. The diversity among the units of study (Beta diversity) was studied using Bray Curtis dissimilarity measure. For this Vegdist function of the Vegan package is used (Jost, 2007). A PERMANOVA test was run using the Adonis function of the Vegan package, and the results were interpreted with the help of a nMDS plot based on the BC distance. The SIMPER analysis was carried out with the help of the Simper function in Vegan in order to determine the contribution made by each species to the average Bray Curtis dissimilarity shared by each set of habitats.

Rank Abundance Curve

The Rank Abundance Curve, also called the Whittaker curve, is a two-dimensional chart with the abundance rank on the X-axis and the relative abundance on the Y-axis. It is a method for assessing diversity. It can be used to describe species abundance and species evenness, two elements of biodiversity. In the horizontal direction, the width of the curve corresponds to the abundance of species; the greater the abundance of species, the greater will be the width of the curve. The smoothness of the curve indicates the species evenness; the smoother the curve, the more evenly distributed the species. Rank abundance curve compensates for the inability of the biodiversity indices to illustrate the relative importance of different variables in its calculation.

3.3. Seasonality of spider diversity

The time frame of the study was divided into three seasons. Pre-monsoon, monsoon and post-monsoon are based mainly on the monsoon period in Kerala. The seasonal fluctuations in Kerala are very heavily related to the monsoon fall. Biodiversity, especially invertebrate diversity in Kerala is also highly influenced by these rainfalls. Kerala receives two monsoons: south-west monsoon (Edavappathi) and north-east monsoon (Thulavarsham). Southwest monsoon ranges from June to August and north-east monsoon between mid-October to the end of November. Around 70% of the total rainfall in Kerala is contributed by southwest monsoon, 18% by north-east monsoon contribution and the rest is pre-monsoon falls. So, the division of study period to different seasons mainly depended on the south-west monsoon period. A period of four months (February to May) prior to the onset of Southwest monsoon is considered as pre-monsoon period. Four-month period (June to September) which includes the time of south-west monsoon is considered as monsoon period and the remaining four months (October to January) is selected as post-monsoon.

The abundance of spiders during different seasons was compared by Kruskal Wallis test to find out which pair of seasons contribute maximum to the significant difference.

3.4. Guild structure analysis

A guild is a group of organisms that exploit the same or related category of natural resources in a comparable manner (Root, 1967). It is also considered as a non-phylogenetic assemblage of species that share one or more significant resources. The concept of guild refers to how the resources are shared by different species in an ecosystem. Information regarding the foraging strategy, type of web constructed,

prey range, vertical stratification and circadian activity are used for designating the guild for each family (Cardoso *et al.*, 2011). The guild composition of spiders of various horticultural ecosystems of Thrissur district is done according to the classification of Cardoso *et al.* (2011). According to them different families of spiders are assigned to eight different feeding guilds (Table 3.2). The absence or over-existence of any one or a few of these guilds in habitat throws light on the dominance structure of the community and various external disturbances pertaining there.

Table 3.2. Different guilds of spiders

Guild name	Foraging strategy
Ambush hunters	'Sit and wait' strategy of prey capture
Ground hunters	Capture preys mainly from ground layer
Orb web builders	Construct perfect orb web for prey capture
Sensing web builders	Construct webs with sensing threads for prey capture
Sheet web builders	Construct sheet like web for prey capture
Space web builders	Construct irregular space webs for prey capture
Specialists	Feed on one or very few prey
Other hunters	Captures prey through alternative methods especially chasing and catching

3.5. Study of impact of insecticides on the selected spiders

Effects of persistent pesticides on non-target and beneficial fauna, such as predators, parasites, and pollinators, are triggering the emergence of various small pests in epidemic proportions. Evaluation of the impacts of pesticides on beneficial

arthropods has garnered an increasing amount of interest from experts throughout the globe.

The residual toxicity approach proposed by Rezac *et al. (*2010) was employed to study the impact of pesticides on spiders. The spiders chosen for the study were *Myrmaplata plataleoides* (O. Pickard-Cambridge, 1869), *Indopadilla insularis* (Malamel, Sankaran, & Sebastian, 2015) (Salticidae), *Argiope pulchella* Thorell, 1881 (Araneidae), and *Oxyopes javanus* Thorell, 1881 (Oxyopidae). Ekalux (Quinalphos 25% EC - an organophosphate**)**, and Karate (Lambda cyhalothrin 5-% EC - a pyrethroid) were used for poisoning spiders, as they were widely used on vegetable crops in Kerala. Quinalphos ($C_{12}H_{15}N_2O_3PS$- diethoxy-quinoxalin-2-yloxy-sulfanylidene-5-phosphane) is an agrochemical recommended by the department of agriculture, Kerala, as a substitute for the deadly poisons like carbofuran, endosulfan and parathion in our agricultural and horticultural fields. This organophosphate is a cholinesterase inhibitor. It has a molecular weight of 298.30 and is a colourless crystal. Its exposure can occur through direct contact, ingestion, or inhalation. It is widely used in Kerala against stem borers, leaf rollers, gall midges, *Hispa*, nematodes etc in rice as well as vegetable crop fields. It irreversibly binds with AchE and prevents the breakdown of Ach. It leads to the longer existence of Ach in the synapses which may cause hyper excitation and leads to the death (Siegfried & Scharf, 2001). Lambda cyhalothrin is a colourless and odourless synthetic pyrethroid which disrupts the nervous system functions of arthropods and cause paralysis and death in them. In Kerala, it is commonly employed against stem borer and leaf folder in paddy, shoot and fruit borer in brinjal, fruit borer in okra and tomato.

3.5.1. Rearing of spiders

The spiders which have been caught were kept in a glass jar that was congruent to their webs. The bottom of the jar was filled with clean, sterile, and moist sand, and the top was covered with a thick paper board, which was attached to the mouth of a rectangular jar. The paper lid had a hole in the middle that could be closed or opened as needed. Water was sprayed into the jar occasionally in order to keep the sand moist and keep the humidity at the right level. Small profusely branched twigs were also inserted in the jar so as to provide resting place to the spiders. These twigs also act as the substrate for making web as well as for hiding themselves from the prey given. Since all spiders are carnivores, they consume only living prey. To promote optimal growth, they must consume a variety of insects so that the nutritional requirements might be satisfied. *Drosophila*, odonates, beetle larvae, and small grasshopper nymphs were the most frequently used insects as prey. The live prey was introduced to the glass jar, and every day after the meal, any leftovers were removed. This helped the spiders to get acclimated to the lab condition.

3.5.2. Study of avoidance response

The ecological effects of commercial pesticides on living organisms, particularly non-target species, have been a global concern. To reduce the most severe effects of pesticides, it is very crucial to understand the species-specific responses of organisms to various pesticides. Avoidance response is the ability of organisms to move away from the potential hazards in a free environment. The avoidance response can be used to assess the hazards posed by pesticide-caused pollution (Rosa *et al*., 2012).

Avoidance response of selected spiders (*A. pulchella, I. insularis, M. plataleoides, O. javanus*) against Quinalphos 25% EC and Lambda cyhalothrin 5%

EC was assessed in lab conditions. Twelve filter papers with a 10-centimeter diameter were taken. One end of four papers was dipped in a 1 ml/L concentration of 25% EC Quinalphos. The papers were carefully watched and removed from the pesticide solution when exactly half of them were wet with the solution. The portions of the papers up to where the pesticide solution reached were marked correctly. Then, one half of the strip was with insecticide residue, while the other half was not. A set of four filter papers were made with Lambda cyhalothrin 5-% EC solution also in the similar way. As a control, the identical procedure was performed with distilled water instead of pesticide solution. The filter papers were allowed to dry. Four petri dishes of similar dimensions were prepared for the experiment with each pesticide and four for the control. One each of the above prepared filter papers was inserted to the bottom of the petri dishes. Each acclimatized spider was introduced to all the petri dishes in such a way that one individual of same age, sex and size from each species was introduced to the both the pesticide treated as well as the control petri dishes. The top of each petri dish was closed with a lid allowing the spider to travel easily from one end to the other. Half an hour was devoted to observing the setup. It is recorded how long the spiders remain in the pesticide-treated portion of the filter paper. The Kruskal Wallis test was conducted to find out whether there is a significant difference between time of exposure and avoidance.

3.5.3. Effect of pesticides on the feeding efficacy of spiders

While our knowledge regarding the deadly effects of pollutants on organisms is solid, our knowledge of how these contaminants might impact creatures by modifying their interactions with various other species of their own community is limited. The effects of potent pesticides on prey-predator interactions are complex.

The feeding efficacy of a predator is the rate at which it consumes the prey under a specific set of conditions. The feeding of polyphagous predators plays an incredibly significant role in the management of the pest populations in the croplands. Predatory capacity of sensitive organisms like spiders may be adversely affected by the exposure to commercial pesticides.

The effect of toxicity of sublethal concentrations of organophosphate and pyrethroid pesticides on the feeding efficacy of *A. pulchella, I. insularis, M. plataleoides* and *O. javanus* against fruit fly, *Drosophila melanogaster* was calculated in the laboratory. The residual toxicity method was selected for the study. Twelve filter papers (10 cm in diameter) were taken for exposing the spiders to pesticides. Four filter papers were immersed in a solution of Quinalphos 25% EC with a concentration of 0.5 ml/L, i.e., one fourth of field dosage, four in the solution with the 0.5ml ml/L concentration of Lambda cyhalothrin 5-% EC, (one fourth field dosage). The remaining four papers were selected as control and immersed in distilled water. The filter papers were allowed to dry and then placed one each in a petri dish. One member of each species was introduced to the petri dish containing filter paper impregnated with pyrethroid, one to that with organophosphate. For the control group, the same experiment was performed, but subjects were exposed to filter papers which are dipped in distilled water. All the spiders selected for this study were previously starved for 24 hours. They were allowed to remain there for one hour. They were then transferred to another petri dish containing moist cotton and kept there for 30 minutes.

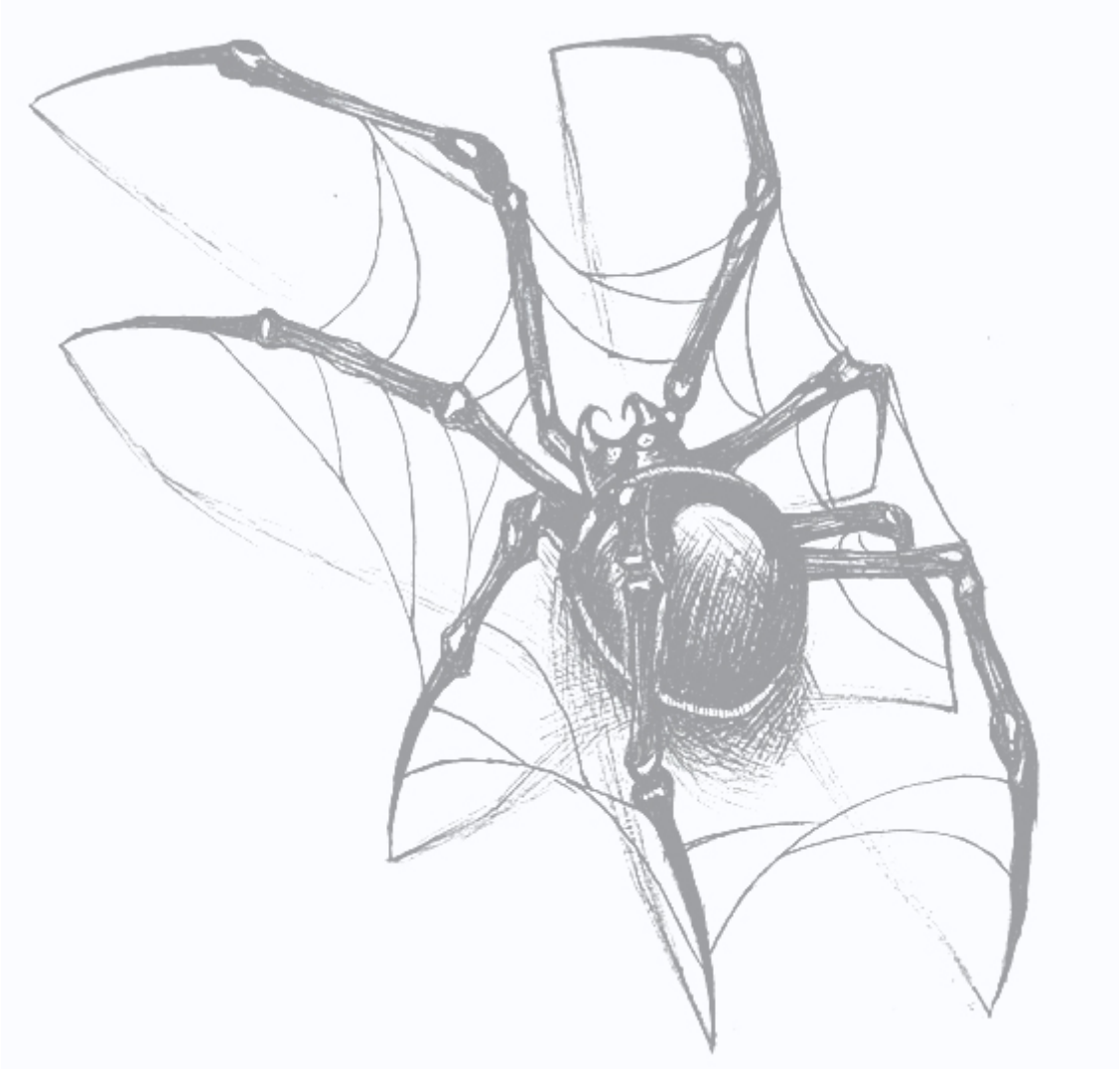
Feeding efficacy was calculated using adult *D. melanogaster* as the prey. For calculation of feeding efficacy the spiders were transferred to rectangular glass jars and a definite number of preys were added to it. The numbers of dead were

recorded every 2 hours and new individuals were added so as to maintain the density of living prey in the glass jar constant. The number of preys consumed per twenty-four-hour period was recorded. The same number of preys introduced to the glass jar with spider which is not exposed to pesticides is taken as control.

To make sure that the difference in the feeding capacity between the pesticide exposed groups and control group is significant, the Kruskal Wallis test was employed.

3.5.4. Assessment of vulnerability of spiders to the pesticides

Susceptibility of spiders to the pesticide was assessed using the protocol of Tahir *et al*. (2019). *A. pulchella, I. insularis, M. plataleoides* and *O. javanus* were selected for the study of vulnerability of spiders to pesticides. The direct lethal effect of Quinalphos 25% EC and Lambda cyhalothrin 5% EC on all the spiders were assessed. Spiders of same age, sex and size were selected and were anesthetized by placing them in refrigerator for five minutes. Four filter papers (10 cm in diameter) were dipped in 1ml/L (half the field dosage) Lambda cyhalothrin 5-% EC, four in same concentration of Quinalphos 25% EC and four in distilled water. The filter papers were allowed to dry at room temperature. Pre-anesthetized spiders of each species was introduced into these filter papers kept in petri dishes so that one member of each species was exposed to both the pesticides and one to the control. After an exposure period of one hour the spiders were transferred to clean glass jars and mortality was recorded every six hours till 24 hours. The Kruskal Wallis test was performed to understand whether the difference in the susceptibility of different spiders to different pesticides was statistically significant.



CHAPTER 4

RESULTS

RESULT

4.1. Araneofauna associated with horticultural crops: a comprehensive study

Understanding the composition and abundance of araneofauna in horticultural crop fields and their interaction with various insects including pests enables the farmers to adopt sustainable agricultural practises. A proper knowledge on different types of foraging guilds of spiders, their feeding preferences and feeding efficacy helps in reducing reliance on chemical pesticides. The complexity of species composition of spiders can be considered as an indicator of health of that agroecosystem.

4.1.1. Overall spider diversity of the horticultural fields

In the present study, 116 species from 75 genera and 21 families were found from the fields of horticultural crops in the Thrissur district (Table 4.1. & 4.2.).Out of the total 116 species 15 species could be identified only up to the genus level. Salticidae and Araneidae were the most abundant families. Salticidae was the most prolific family in terms of richness (with 25 genera & 30 species,), followed by the Araneidae (with 10 genera & 24 species).

Table 4.1. Genus and species, recorded in different families

Sl. No.	Family	No. of Genera	No. of Species
1	Araneidae	9	24
2	Cheiracanthiidae	1	2
3	Clubionidae	1	1
4	Corinnidae	3	3
5	Ctenidae	1	1
6	Gnaphosidae	1	1
7	Hahniidae	1	1
8	Hersiliidae	1	2
9	Lycosidae	4	6
10	Nephilidae	1	1
11	Oxyopidae	2	10
12	Philodromidae	2	2
13	Pholcidae	2	2
14	Pisauridae	1	1
15	Salticidae	25	30
16	Scytodidae	1	2
17	Sparassidae	3	3
18	Tetragnathidae	3	9
19	Theridiidae	5	7
20	Thomisidae	6	6
21	Uloboridae	2	2

A comprehensive inventory of the spiders recorded from the study areas has been meticulously formulated (Table 4.2.). The checklist can be used as a baseline for future studies and as a reference for scientists, conservationists etc.

Table 4.2. Checklist of spiders recorded from the study area

No.	SPECIES
	Araneidae Clerck, 1757
1	*Anepsion maritatum* (O. Pickard-Cambridge, 1877)
2	*Araneus sp.*
3	*Argiope aemula* (Walckenaer, 1842)
4	*Argiope anasuja* Thorell, 1887
5	*Argiope catenulata* (Doleschall, 1859)
6	*Argiope pulchella* Thorell, 1881
7	*Bijoaraneus mitificus* (Simon, 1886)
8	*Cyclosa bifida* (Doleschall, 1859)
9	*Cyclosa confraga* (Thorell, 1893)
10	*Cyclosa hexatuberculata* Tikader, 1982
11	*Cyclosa sp.*
12	*Cyrtophora cicatrosa* (Stoliczka, 1869)
13	*Cyrtophora citricola* (Forsskal, 1775)
14	*Cyrtophora moluccensis* (Doleschall, 1857)
15	*Cyrtophora sp.*
16	*Eriovixia excelsa* (Simon, 1889)
17	*Eriovixia laglaizei* (Simon, 1877)
18	*Gasteracantha geminata* (Fabricius, 1798)
19	*Gea subarmata* Thorell, 1890
20	*Neoscona elliptica* Tikader & Bal, 1981
21	*Neoscona inustua* (L. Koch, 1871)
22	*Neoscona mukerjei* Tikader, 1980
23	*Neoscona sp.*
24	*Neoscona vigilans* (Blackwall, 1865)
	Cheiracanthiidae Wagner, 1887
25	*Cheiracanthium danieli* Tikader, 1975
26	*Cheiracanthium melanostomum* (Thorell, 1895)
	Clubionidae Wagner, 1887
27	*Clubiona drassodes* O.P. Cambridge, 1874
	Corinnidae Karsch, 1880

28 *Apochionomma sp.*

29 *Castianeira zetes* Simon, 1897

30 *Corinnomma sp.*

Ctenidae Keyserling, 1877

31 *Bowie cochinensis* (Gravely, 1931)

Gnaphosidae Banks, 1892

32 *Drassodes sp.*

Hahniidae Bertkau, 1878

33 *Hahnia mridulae* Tikader, 1970

Hersiliidae Thorell, 1869

34 *Hersilia savignyi* Lucas, 1836

35 *Hersilia sumatrana* (Thorell, 1890)

Lycosidae Sundevall, 1833

36 *Hippasa agelenoides* (Simon, 1884)

37 Lycosa mackenziei Gravely, 1924

38 *Lycosa tista* Tikader, 1970

39 *Pardosa pseudoannulata* (Bosenberg& Strand, 1906)

40 *Pardosa sumatrana* (Thorell, 1890)

Nephilidae Simon, 1894

41 *Nephila pilipes* (Fabricius, 1793)

Oxyopidae Thorell, 1869

42 *Hamadruas sikkimensis* (Tikader, 1970)

43 *Oxyopes bharatae* Gajbe, 1999

44 *Oxyopes birmanicus* Thorell, 1887

45 *Oxyopes hindostanicus* Pocock, 1901

46 *Oxyopes javanus* Thorell, 1887

47 *Oxyopes lineatipes* (C L Koch, 1847)

48 *Oxyopes shweta* Tikader, 1970

49 *Oxyopes sunandae* Tikader, 1970

50 *Oxyopes sp.*

51 *Peucetia viridana* (Stolczka, 1869)

52 *Peucetia ananthakrishnani* Murugesan *et al*., 2006

	Philodromidae Thorell, 1869
53	*Psellonus sp.*
54	*Thanatus parangvulgaris* Barrion & Litsinger, 1995
	Pholcidae C. L. Koch, 1850
55	*Crossopriza lyoni* (Blackwall, 1867)
56	*Pholcus phalangioides* (Fuesslin, 1775)
	Pisauridae Simon, 1890
57	*Dendrolycosa gitae* (Tikader, 1970)
	Salticidae Blackwall, 1841
58	*Asemonea tenuipes* (O. Pickard-Cambridge, 1869)
59	*Bianor angulosus* (Karsch, 1879)
60	*Brettus cingulatus* Thorell, 1895
61	*Carrhotus viduus* (C. L. Koch, 1846)
62	*Chalcotropis pennata* Simon, 1902
63	*Chrysilla volupe* (Karsch, 1879)
64	*Epeus indicus* Proszynski,1992
65	*Epeus sp.*
66	*Epeus tener* (Simon, 1877)
67	*Evarcha falcata* (Clerck, 1757)
68	*Evarcha sp.*
69	*Hasarius adansoni* (Audouin, 1826)
70	*Hyllus semicupreus* (Simon, 1885)
71	*Indopadilla insularis* (Malamel et al., 2015)
72	*Menemerus bivittatus*(Dufour, 1831)
73	*Myrmaplata plataleoides* (O. Pickard-Cambridge, 1869)
74	*Myrmarachne melanocephala* MacLeay, 1839
75	*Phaeacius lancearius* (Thorell, 1895)
76	*Phidippus yashodharae* Tikader, 1977
77	*Phintella vittata* C.L. Koch 1846
78	*Plexippus paykulli* (Audouin, 1826)
79	*Plexippus petersi* (Karsch, 1878)
80	*Portia fimbriata* (Doleschall, 1859)
81	*Rhene flavigera* (C. L. Koch, 1846)

82 *Siler semiglaucus* (Simon, 1901)

83 *Stenaelurillus lesserti* Reimoser, 1934

84 *Stenaelurillus sp.*

85 *Telamonia dimidiata* (Simon, 1899)

86 *Thiania bhamoensis* Thorell, 1887

87 *Thyene bivittata* Xie & Peng, 1995

Scytodidae Blackwall, 1864

88 *Scytodes fusca* Walckenaer, 1837

89 *Scytodes sp.*

Sparassidae Bertkau, 1872

90 *Heteropoda venatoria* (Linnaeus, 1767)

91 *Olios milleti* (Pocock, 1901)

92 *Thelcticopis moolampilliensis* Jose & Sebastian, 2007

Tetragnathidae Menge, 1866

93 *Leucauge decorata* (Blackwall, 1864)

94 *Leucauge dorsotuberculata* Tikader, 1982

95 *Tetragnatha cochinensis* Gravely, 1921

96 *Tetragnatha javana* (Thorell, 1890)

97 *Tetragnatha keyserlingi* Simon, 1890

98 *Tetragnatha mandibulata* Walckenaer, 1842

99 *Tetragnatha viridorufa* Gravely, 1921

100 *Tylorida striata* (Thorell, 1877)

101 *Tylorida ventralis* Thorell, 1877

Theridiidae Sundevall, 1833

102 *Argyrodes kumadai* Chida & Tanikawa, 1999

103 *Argyrodes sp.*

104 *Ariamnes flagellum* (Doleschall, 1857)

105 *Meotipa argyrodiformis* (Yaginuma, 1952)

106 *Meotipa sp.*

107 *Phoroncidia septemaculeata* O. Pickard-Cambridge, 1873

108 *Theridion manjithar* Tikader, 1970

Thomisidae Simon, 1881

109 *Thomisus projectus* Tikader, 1960

110	*Amyciaea forticeps* (O. Pickard-Cambridge, 1873)
111	*Indoxysticus minutus* Tikader, 1960
112	*Oxytate virens* (Thorell, 1891)
113	*Runcinia insecta* (L. Koch, 1875)
114	*Strigoplus netravati* Tikader, 1963
	Uloboridae Thorell, 1869
115	*Miagrammopes extensus* Simon, 1889
116	*Uloborus krishnae* Tikader, 1971

4.1.2 Description of families collected from the study area

1. Family: Araneidae Clerck, 1757

Common name: Orb web spiders

Araneidae is one of the largest spider families with 3128 species so far reported under 191 genera. The family includes small to large sized spiders. The members possess eight eyes with medial for arranged in a trapezoid manner and are widely separated from laterals. Labium fully rebordered. Chelicerae strong and vertical. Maxillae are not longer than wide. Strong legs with numerous spines and hairs. Complex partially or fully sclerotised epigyne in females, epigynal plate with transverse furrow. In males, palps with median apophysis and bulbous cymbium. 24 species of spiders belonging to this family were reported from the selected horticultural fields of Thrissur District, Kerala.

The species included:

Anepsion maritatum (O. Pickard-Cambridge, 1877)

Araneus sp.

Argiope aemula (Walckenaer, 1842)

Argiope anasuja Thorell, 1887

Argiope catenulata (Doleschall, 1859)

Argiope pulchella Thorell, 1881

Bijoaraneus mitificus (Simon, 1886)

Cyclosa bifida (Doleschall, 1859)

Cyclosa confraga (Thorell, 1893)

Cyclosa hexatuberculata Tikader, 1982

Cyclosa sp.

Cyrtophora cicatrosa (Stoliczka, 1869)

Cyrtophora citricola (Forsskal, 1775)

Cyrtophora moluccensis (Doleschall, 1857)

Cyrtophora sp.

Eriovixia excelsa (Simon, 1889)

Eriovixia laglaizei (Simon, 1877)

Gasteracantha geminata (Fabricius, 1798)

Gea subarmata Thorell, 1890

Neoscona elliptica Tikader & Bal, 1981

Neoscona inustua (L. Koch, 1871)

Neoscona mukerjei Tikader, 1980

Neoscona sp.

Neoscona vigilans (Blackwall, 1865)

2. Family: Cheiracanthiidae Wagner, 1887

Common name: Yellow sac spiders, Black footed spiders.

Ecrebellate, entelogyne spiders with medium sized body. Legs relatively long and first pair being longer than the rest. Tarsi provided with tufts of darks hairs. Eyes eight in number and nearly similar sized and arranged in two more or less parallel rows. Chelicerae strong and intimidating. They are nocturnal spiders and retain in silken ‘sleep sacs’ build inside the rolled leaves during daytime. There are 371

species of spiders belonging to 14 genera worldwide. Present study reported 2 species of spiders of this family.

The species included:

Cheiracanthhium melanostoma (Thorell, 1895)

Cheiracanthhium danielli Tikader, 1975

3. Family: Clubionidae Wagner, 1887

Common name: Sac spiders

Eight eyed spiders. Eyes arranged in two rows. The posterior row is slightly wider than the anterior. Anterior row is straight or slightly downcurved. Chelicerae oblique and provided with 2-7 promarginal teeth and 2-4 retro marginal teeth. Long legs with spines and two terminal claws. Maxillae longer than wide. Anterior spinnerets are conical and posterior one is small and rounded. Makes sac like silken retreats on foliage. Epigynal plates, in females are convex and scerotised. Retro lateral apophyses, embolus and cymbium are present on male palp. There are 665 species of spiders coming under 18 genera were reported in this family till the date. In the present study this family is represented by a single species.

Species included:

Clubiona drassodes O.P. Cambridge 1874

4. Family: Corinnidae Karsch, 1880

Common name: Ant-mimicking sac spiders

Small to medium sized spiders with slender and elongated body shape in ant-mimicking forms. Eight eyes arranged in two rows. Strong convex chelicerae with curved setae on the upper edge and both rows with teeth. Epigyne is complex. Male palp with bulbus devoid of median apophysis.

Ant mimics shows ant like movements with first pair of legs raised in air to resemble the antennae of ants. They build silken retreats in rolled up leaves. There are 867 species of spiders under 76 genera in this family. The present study reported 3 species of spiders in this family.

Species included:

Apochionomma sp.

Castianeira zetes Simon, 1897

Corinnomma sp.

5. Family: Ctenidae Keyserling, 1877

Common name: False lycosids / wandering spiders.

Medium to large sized body. Eyes eight in number, arranged in three rows (2,4,2). Anterior medians are smaller than laterals. Anterior laterals much closer to posterior laterals than to anterior medians. Strong chelicerae with at least three retro marginal teeth. Maxillae slightly converging and provided with dense setae. Strong two clawed legs with spines. Complex epigyne with laterals horns in females. Palps, in males with dorsal median apophyses which is cup shaped. Spiders of this family is one of the most dangerous because of their aggressive nature and highly toxic venom. Presently this family comprises 612 species of spiders under 49 genera. The family is represented by one species in the current study.

Species included:

Bowie cochinensis (Gravely, 1931)

6. Family: Gnaphosidae Banks, 1892

Common name: Mouse spiders.

Eyes eight in number, heterogenous and situated as two rows. All other eyes are paler than to anterior median eyes, which are the darkest. Posterior median eyes irregularly in shaped. Broad cephalothorax with a clear-cut fovea. Legs short and stout with spines, two claws and

claw tufts. Tarsi I and II with scopulae. Abdomen usually long and narrow behind with cluster of setae at anterior edge. Anterior lateral spinnerets large cylindrical and well separated. In females, epigyne is complex and its margin is prominently cuticular. In males, palps with retro lateral tibial apophyses, large tegulum and slender embolus. Majority are ground dwellers. Many build tubular retreat under stones or rolled up leaves. There are 2474 species belonging to 153 genera in this family worldwide. Present study recorded only one species under this family.

Species included:

Drassodes sp.

7. Family: Hahniidae Bertkau, 1878

Common name: Comb-tailed spiders

Small sized spiders with eight homogenous eyes arranged in two procurved rows. Chelicerae with two teeth at both margins of its furrow. Legs short and stout with three claws. Six spinnerets in single transverse rows. Tracheal spiracles located away from the spinnerets. In females epigyne is complex with strongly coiled ducts. Male palp with long curved tibial apophyses, thin embolus and reduced median apophyses. The family comprise 249 species of spiders under 29 genera. A single species under this family is recorded from selected horticultural crop fields under study.

Species included:

Hahnia mridulae Tikader, 1970

8. Family: Hersiliidae Thorell, 1870

Common name: Two-tailed spiders/ bark spiders.

Small to medium sized. Eyes eight in number and mounted on prominent tubercles. Arranged in two strongly recurved rows. Middle eyes in the anterior row are larger than that in the posterior row. Shape of sternum resembles the shape of heart. The

chelicera is weak, and the fangs are small. Furrow is either devoid of teeth or small teeth are present on the margins. Legs with three claws, the third pair the smallest. Complex epigyne having distinctive septum. Male palp without tibial apophysis, and with tubular, circular or ovoid bulb. The flattened body and apt colouration help them to camouflage on the bark of trees. They are active hunters. There are 188 species coming under 16 genera worldwide. Present study reported 2 species belonging to this family.

Species included:

Hersilia savignyi Lucas, 1836

Hersilia sumatrana (Thorell, 1890)

9. Family: Lycosidae Sundevall, 1833

Common Name: Wolf spiders

Ground dwelling spiders with size varies from small to large. Eyes eight in number arranged in two rows (4,2,2). Anterior row is straight or slightly curved with four small eyes. The middle row consists of two widely separated and large eyes. The posterior row consists of two intermediates sized eyes which are separated wider than that of the second row. Legs three clawed with spines and scopulae. Abdomen covered with dense setae. Strong, stout chelicera with toothed furrow. In females epigyne is complex in structure and have a highly sclerotised septum. Male palp lacks tibial apophyses and have embolus of varying shape. They are active hunters. Females carry egg sacs attached to the spinnerets. There is 2473 species belonging to 134 genera have been reported till date, in this family worldwide. In the present study the family is represented by 5 species.

Species included:

Hippasa agelenoides (Simon, 1884)

Lycosa mackenziei Gravely, 1924

Lycosa tista Tikader, 1970

Pardosa pseudoannulata Bosenberg & Strand, 1906

Pardosa sumatrana (Thorell, 1890)

10. Family: Nephilidae Simon, 1894

Common name: Golden orb weavers

Cephalic region elevated than thoracic region. Eyes eight in number, small and similar. Anterior median eyes separated widely, and anterior laterals are nearly close. Chelicerae long, strong and armed with strong teeth. Maxillae and labium are longer than wide, scopulate anteriorly. Legs long and strong with spines. Epigyne strongly sclerotises with lateral openings. Male palp with terminal apophysis long and pointed, tegulum curved. There included 58 species under 7 genera under this family, worldwide. The present study recorded one species from the family Nephilidae.

Species included:

Nephila pilipes (Fabricius, 1793)

11. Family: Oxyopidae Thorell, 1870

Common name: Lynx spiders

Eight eyes showing hexagonal arrangement with recurved front row and procurved rear row. Anterior median eyes are the smallest. Chelicerae strong, fangs short and furrow without teeth or with one tooth on both sides. Maxillae long and converging. Epigyne is complex and its structure differs among different genera. Male palp with tibial apophysis and paracymbium. There are 443 species under 9 species in this family. The present study recorded 11 species from this family.

Species included:

Hamadruas sikkimensis (Tikader, 1970)

Oxyopes bharatae Gajbe, 1999

Oxyopes birmanicus Thorell, 1887

Oxyopes hindostanicus Pocock, 1901

Oxyopes javanus Thorell, 1887

Oxyopes lineatipes (C L Koch, 1847)

Oxyopes shweta Tikader, 1970

Oxyopes sunandae Tikader, 1970

Oxyopes sp.

Peucetia viridana Stoliczka, 1869

Peucetia ananthakrishnani Murugesan et al., 2006

12. Family: Philodromidae Thorell, 1870

Common name: Running crab spiders.

Small to medium in size. The body is flattened dorsoventrally with fine and soft setae. The legs are laterigrade. Legs I, III and IV are equal sized while legs II are much longer. Eight eyes arranged in two recurved rows. Epigyne complex with median septum and kidney shaped spermatheca. Male palp is small with small tibial apophysis and embolus of varying length. The family comprise 528 species under 29 genera worldwide. Present study reported 2 species from the family.

Species included:

Psellonus sp.

Thanatus parangvulgaris Barrion & Litsinger, 1995

13. Family: Pholcidae C. L. Koch, 1850

Common name: Daddy long leg spiders

Small to medium sized haplogyne spiders. Eyes six to eight. The anterior median being the smallest or even absent. Legs are fragile, slender and long with three claws. Chelicerae chelate and weak. Even though no epigyne, females have a sclerotised area on the underside of the abdomen. Male pedipalp is complex and large. There are 1979 species coming under 97 genera in this family. 2 species from this family have been reported in the current study.

Species included:

Crossopriza lyoni (Blackwall, 1867)

Pholcus phalangioides (Fuesslin, 1775)

14. Family: Pisauridae Simon, 1890

Common name: Nursery web spiders.

Medium to large sized spiders. Eight dark, similar eyes organised as either two or three rows. One or more pairs situated on small nodular protuberances. Posterior laterals are located close to posterior medians. Chelicerae powerful and toothed. Long and slightly laterigrade legs with three claws. In females epigyne is complex. In males palp with tibial apophysis, elongated cymbium and embolus of varying shapes. Females carry egg sac under the sternum and held in position by pedipalp and chelicera. Ther are 359 species belonging to 52 genera in this family. The representation of this family in the present study is a single species.

The species included:

Dendrolycosa gitae (Tikader, 1970)

15. Family: Salticidae Blackwall, 1841

Common name: Jumping spiders.

Small to medium sized hunting spiders with eight eyes arranged in three or four rows. Anterior median eyes are remarkably larger than others and are forwardly

directed. Anterior lateral eyes are just half the size of Anterior median ones. Chelicerae strong with variable number of teeth. Legs long and stout with 2 claws and claw tufts. Epigyne is complex and variable. Complex palp in male, with retrolateral tibial apophysis. Spinnerets in the posterior end. This is the most diverse family with 6697 species belonging to 684 genera. The present study recorded 30 species of salticid spiders.

Species included:

Asemonea tenuipes (O. Pickard-Cambridge, 1869)

Bianor angulosus (Karsch, 1879)

Brettus cingulatus Thorell, 1895

Carrhotus viduus (C. L. Koch, 1846)

Chalcotropis pennata Simon, 1902

Chrysilla volupe (Karsch, 1879)

Epeus indicus Proszynski, 1992

Epeus sp.

Epeus tener (Simon, 1877)

Evarcha falcata (Clerck, 1757)

Evarcha sp.

Hasarius adansoni (Audouin, 1826)

Hyllus semicupreus (Simon, 1885)

Indopadilla insularis (Malamel et al., 2015)

Menemerus bivittatus(Dufour, 1831)

Myrmaplata plataleoides (O. Pickard-Cambridge, 1869)

Myrmarachne melanocephala MacLeay 1839

Phaeacius lancearius (Thorell, 1895)

Phidippus yashodharae Tikader, 1977

Phintella vittata (C. L. Koch, 1846)

Plexippus paykulli (Audouin, 1826)

Plexippus petersi (Karsch, 1878)

Portia fimbriata (Doleschall, 1859)

Rhene flavigera (C. L. Koch, 1846)

Siler semiglaucus (Simon, 1901)

Stenaelurillus lesserti Reimoser, 1934

Stenaelurillus sp.

Telamonia dimidiata (Simon, 1899)

Thiania bhamoensis Thorell, 1887

Thyene bivittata Xie & Peng, 1995

16. Family: Scytodidae Blackwall, 1864

Common name: Spitting spiders.

Glabrous cephalothorax, abdomen oval and slightly smaller than the cephalothorax. Eyes six in number and arranged in three rows (2,2,2). Chelicerae chelate with short fangs. Long slender legs with three claws. Metatarsi longer than tarsi. Epigyne, in females is simple with multiple spermatheca. Male palp with slender embolus. Members of this family possess prosomal glands producing silk. They carry eggs with chelicerae. The family comprise 253 species in 4 genera. The present study reported two species of spiders belonging to this family.

Species included:

Scytodes fusca Walckenaer, 1837

Scytodes sp.

17. Family: Sparassidae Bertkau, 1872

Common name: Giant crab spiders

Oval cephalothorax with narrower eye region. Eyes eight and arranged in two rows. Chelicera strong with fang furrows bearing two rows of teeth. Long laterigrade legs with two claws and claw tufts. Legs I and II are longer than III and IV. Abdomen covered with fine setae. In females the epigyne is highly sclerotised and complex. Male palp with strong tibial apophysis. Females in many species carries egg sac below the body by clasping with their pedipalp. The family include 1488 species belonging to 97 genera. The present study represents this family with three species.

Species included:

Heteropoda venatoria (Linnaeus, 1767)

Olios milleti (Pocock, 1901)

Thelcticopis moolampilliensis Jose & Sebastian, 2007

18. Family: Tetragnathidae Menge, 1866

Common name: Long Jawed spiders.

Elongated cephalothorax. Eight eyes, arranged in two rows. Four median eyes with a trapezoid arrangements and lateral eyes slight away from it. Large, sturdy chelicerae with rows of large teeth and projecting spurs. In females, epigyne is reduced with un sclerotised genital plates. In males pedipalp with large and hairy paracymbium. The family comprise 987 species under 45 genera. The present study reported nine species of spiders from horticultural ecosystems of Thrissur district.

Species included:

Leucauge decorata (Blackwall, 1864)

Leucauge dorsotuberculata Tikader, 1982

Tetragnatha cochinensis Gravely, 1921

Tetragnatha javana (Thorell, 1890)

Tetragnatha keyserlingi Simon, 1890

Tetragnatha mandibulata Walckenaer, 1842

Tetragnatha viridorufa Gravely, 1921

Tylorida striata (Thorell, 1877)

Tylorida ventralis Thorell, 1877

19. Family: Theridiidae Sundevall, 1833

Common name: Comb footed spiders.

Entelegyne, ecribellate spiders. Eight eyes, arranged in two more or less parallel rows. The border of eyes usually encircled by brownish rings. Anterior median eyes darker than other eyes. Legs long with three claws, have tarsal comb on leg IV. Chelicera long without or with a few cheliceral teeth. Epigyne, in females is complex with one or two pairs of spermatheca. Male palp without apophysis and have hook like paracymbium. The family is rich with 2578 species belonging to 129 genera. Present study reported 7 species of spiders from this family.

Species included:

Argyrodes kumadai Chida & Tanikawa, 1999

Argyrodes sp.

Ariamnes flagellum (Doleschall, 1857)

Meotipa argyrodiformis (Yaginuma, 1952)

Meotipa sp.

Phoroncidia septemaculeata O. Pickard-Cambridge, 1873

Theridion manjithar Tikader, 1970

20. Family: Thomisidae Simon, 1881

Common name: Crab spiders.

Eyes eight in number, arranged in two rows. The posterior row slightly recurved. Lateral eyes are usually located on tubercles. Chelicerae without cheliceral teeth. Legs laterigrade with two claws. Legs I and II are longer and stronger than III and IV. In females, epigyne is complex and bears hoods and bordered atrium. Anterior spinnerets are short, conical and the separation between them is narrow. Colulus is present. The family comprise 2165 species belonging to 171 genera worldwide. The present study recorded six species from this family.

Species Included:

Thomisus projectus Tikader, 1960

Amyciaea forticeps (O. Pickard-Cambridge, 1873)

Indoxysticus minutus Tikader, 1960

Oxytate virens (Thorell, 1891)

Runcinia insecta (L. Koch, 1875)

Strigoplus netravati Tikader, 1963

21. Family: Uloboridae Thorell, 1869

Common name: Hackled web spiders

Dark, homogeneous eyes eight in number, may be arranged in two well separated rows with four eyes in each row . Laterals in the rear row may be located above nodular tubercles. Chelicerae with fang furrows having several small teeth to one large tooth on its margins. Legs with three claws. Anterior spinnerets three segmented, middle spinnerets unsegmented and posterior spinnerets two segmented. Epigyne shows caudal projections. Two apical setae on male pedipalp. Only spider group without venom glands and relies on silk snares to capture the prey. There are 285 species under 19 genera over the globe.

The present study recorded two species from this family.

Species included:

Miagrammopes extensus Simon, 1889

Uloborus krishnae Tikader, 1971

4.1.3. Taxonomic key to the spider families recorded

Biologists use taxonomic keys to identify and classify organisms according to their observable characteristics. It is a series of hierarchical questions about characteristics of an organism, with each question leading to a subsequent set of questions that identify the organism to a specific group or species.

Taxonomic keys are essential to the study of biodiversity because they provide a standardised and objective method for identifying and classifying organisms, enabling scientists to precisely describe and comprehend the diversity of life on Earth. A taxonomic key for the identification of various families of spiders associated with horticultural crops of various fields in Thrissur district of Kerala is prepared.

1a. Cribellum and calamistrum present, sometimes absent in males (Section Cribellate) .....**……..ULOBORIDAE**

1b. Cribellum and calamistrum absent (Section Ecribellate) ……..…**2**

2a. With less than eight eyes…….……...…….….**3**

2b. With eight eyes……..…… **4**

3a. Eyes in two well separated triads…….. **PHOLCIDAE**

3b. Eyes arranged otherwise……. **SCYTODIDAE**

4a. Tarsus with two claws…….....……..**5**

4b. Tarsus with three claws……. **13**

5a. Eyes in three rows, anterior median eyes very large……..…. **SALTICIDAE**

5b. Eyes arranged differently……..…. **6**

6a. Legs laterigrade, directed towards side or forwards……..... **7**

6b. Legs prograde, 1 and 2 directed forwards, 3 and 4 backwards……..…. **9**

7a. Tarsi and metatarsi without scopulae, legs I and II usually much longer than legs III and IV ……..... **THOMISIDAE**

7b. Tarsi and sometimes metatarsi with scopulae, legs different……..... **8**

8a. Small to medium-size spiders, chelicerae without teeth or at most one on retromargin, tarsus-metatarsus joint allowing movement in one plane only……..... **PHILODROMIDAE**

8b. Medium-size to large spiders, chelicerae with at least two teeth on retromargin, membranous connection to metatarsus permits free movement of tarsus……..……..... **SPARASSIDAE**

9a. Spinnerets long and cylindrical, far apart……..... **GNAPHOSIDAE**

9b. Spinnerets conical, not wide apart……..……...**10**

10a. Eyes in three rows (2:4:2), epigyne with lateral horns, male palp with dorsally concave median apophysis…..……..... **CTENIDAE**

10b. Eyes in two rows (4:4), epigyne without lateral horns, male palp with different median apophysis …….……. **11**

11a. Male palp pear-shaped with short distal embolus, square-shaped epigyne with spherical spermathecae, median spinnerets of female with three and posterior spinneret with two large cylindrical gland spigots……. **CORINNIDAE**

11b. Genitalia differently shaped, median and posterior spinnerets of female without such spigot ……..…….…….. **12**

12a. Median spinnerets of females laterally flattened, with at least one row of large spigots…….……...…….**CHEIRACANTHIIDAE**

12b. Median spinnerets of females not flattened, without rows of large spigots…….……..…….. **CLUBIONIDAE**

13a. Tarsi with trichobothria, often in a row…….... **14**

13b. Tarsi without trichobothria……...……. ……..**17**

14a. Eyes in two rows…….... **15**

14b. Eyes either in three to four rows or in three groups……...……...**16**

15a. Posterior spinnerets long and two-segmented …..…...…..... **HAHNIIDAE**

15b. Posterior spinnerets not particularly long or with one segment only ……..….**PISAURIDAE**

16a. Clypeus very high, posterior eyes and anterior lateral eyes forming a hexagonal group in front of small anterior median eyes, numerous long spines on tibiae and metatarsi……... **OXYOPIDAE**

16b. Clypeus not as high, eyes in three rows, tibiae and metatarsi only with usual spines…….…… **LYCOSIDAE**

17a. Posterior spinnerets very long, last segment at least three times longer than wide.....**HERSILIIDAE**

17b. Posterior spinnerets not unusually long……. **18**

18a. Tarsi IV with ventral comb of serrated hairs, brownish rings around the eyes…….....**THERIDIIDAE**

18b. Tarsi without ventral comb of serrated hairs, eyes without brownish rings……..……..**19**

19a. Male palp complex, with median apophysis, embolus not wrapped by conductor, paracymbium often hook-shaped…..……..... **ARANEIDAE**

19b. Male palp fairly simple without median apophysis but with conductor wrapping the embolus, paracymbium elongate or short……**……20**

20a. Chelicerae usually long or swollen, modified for courtship in males, epigyne usually indistinct, web not against to substrate ……..**TETRAGNATHIDAE**

20b. Chelicerae not long and swollen, epigyne well developed, web against to substrate……...……. **NEPHILIDAE**

4.2. Diversity, abundance and richness of spiders across the habitats

The assessment of the diversity of spiders in five distinct horticultural croplands in the district of Thrissur was one of the objectives of the study. The diversity and species composition may vary depending up on the crops under cultivation, agricultural practises adopted, geographical location of the cropland, availability of prey groups etc. The two of the five croplands (BTA and NGM) are organically farmed, while the others use agrochemicals such as fertilisers and insecticides. The duration of the study is subdivided into pre-monsoon, monsoon, and post-monsoon seasons for convenience.

4.2.1. Habitat wise abundance of spiders

The term 'abundance' in a habitat indicates the number of individuals of varied species within that habitat. It helps to understand the relative representation of different species in that habitat. It can be quantified as the total number of individuals belonging to different species inhabiting that locality during a defined point of time. The abundance of spiders in five different horticultural croplands in Thrissur district, Kerala shows considerable differences in abundance of spiders. Total number of individuals collected during the study period was highest in NGM (2078 individuals) followed by NKR (2028 individuals). Mean abundance was also the highest in NGM (122±25.68) followed by CRA (114±20.53) and NKR

(113±36.67) respectively (Table 4.3.). NKR showed the highest number of both singletons (8) and doubletons (7) which may be an indication of existence of some rare species there. The lowest number of singletons and doubleton were reported from KZR and CRA respectively (Table 4.3.).

Table 4.3. Habitat wise richness and abundance

Parameter	BTA	CRA	NGM	NKR	KZR
Individuals	1211	1938	2078	2028	1895
Mean abundance ±SD	87±21.88 n=14	114±20.53 n=17	122±25.68 n=17	113±36.67 n=18	105±28.90 n=18
Total no. of species	74	73	86	105	82
Singletons	3	3	4	8	1
Doubletons	3	2	3	7	3

The distribution of the species abundance was slightly skewed positively in all the sites indicating that a slight dominance of a few species over the rest (Fig. 4.1.). The rest of the species were more or less evenly distributed. As agroecosystems undergo continuous human interventions and frequent modifications, the ones with capacity to adapt with these variations can dominate over the other more sensitive ones.

The most abundant family was Salticidae with highest number of individuals collected with a toll of 3986 spiders. Araneidae ranks the second (2119 individuals) followed by Tetragnathidae (770 Individuals) and Oxyopidae (699 individuals) respectively. Clubionidae was the least abundant family (2 Individuals). Hahniidae ranks the second least abundant family with a toll of 3 individuals (Table 4.4.). More than hundred individuals were recorded under eight families and only two families (Salticidae and Araneidae) were reported with more than thousand individuals.

Table 4.4. Family wise representation of abundance of spiders

Sl. No.	Family	No. of individuals collected
1	Araneidae Clerck, 1757	2119
2	Cheiracanthiidae Wagner, 1887	44
3	Clubionidae Wagner, 1887	2
4	Corinnidae Karsch, 1880	37
5	Ctenidae Keyserling, 1877	12
6	Gnaphosidae Banks, *1892*	10
7	Hahniidae Bertkau, 1878	3
8	Hersiliidae Thorell, 1869	60
9	Lycosidae Sundevall, 1833	408
10	Nephilidae Simon, 1894	13
11	Oxyopidae Thorell, 1869	699
12	Philodromidae Thorell, 1869	12
13	Pholcidae C. L. Koch, 1850	27
14	Pisauridae Simon, 1890	45
15	Salticidae Blackwall, 1841	3986
16	Scytodidae Blackwall, 1864	10
17	Sparassidae Bertkau, 1872	167
18	Tetragnathidae Menge, 1866	770
19	Theridiidae Sundevall, 1833	429
20	Thomisidae Simon, 1881	291
21	Uloboridae Thorell, 1869	6

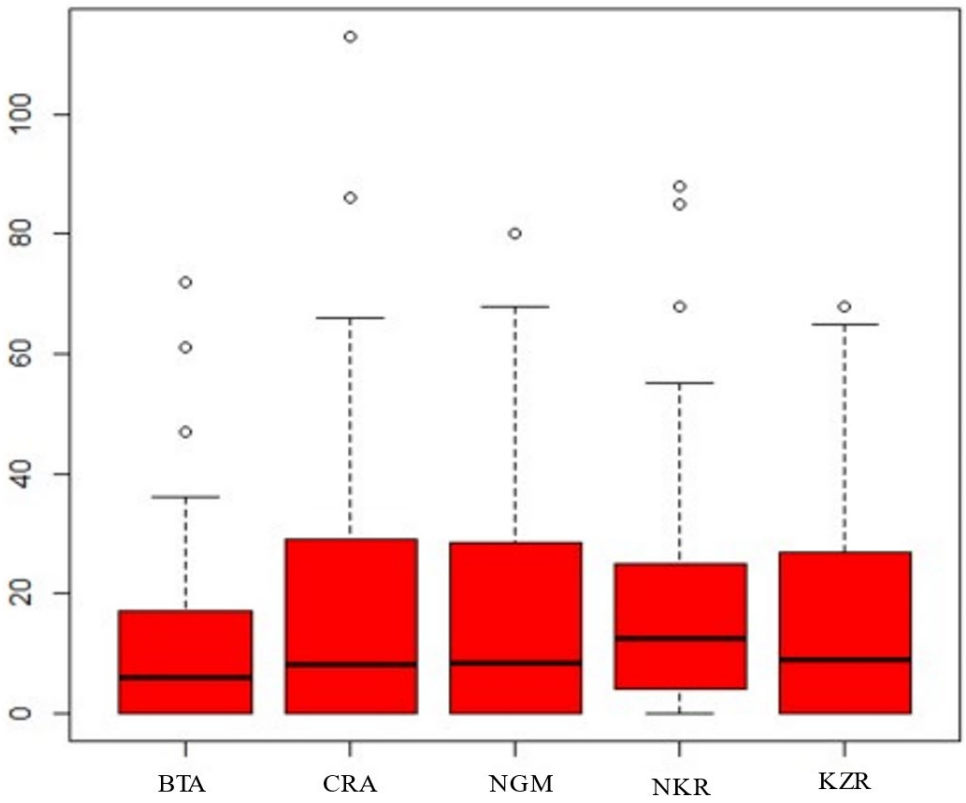


Figure 4.1. Boxplot analysis of abundance of spiders across different habitats

4.2.2. Habitat wise rank abundance distribution of spiders

Among the various methods for plotting species abundance distribution, rank abundance curve is one of the most informative methods in ecological research. It is also known as dominance diversity curve or Whittaker plot. Here the species are ranked according to their numerical abundance, from the most to least. Their abundance was plotted against their ranks. The most abundant species come in the extreme left end and the rare species come at the right end of the plot. Out of the five species abundance models (Null, Pre-emption, Lognormal, Zipf and Mandelbrot) the one with the lowest Akaike's Information Criterion (AIC value) is considered as the best fit model.

Rank abundance curves represent both species richness and evenness. Richness can be assessed as the number of species being ranked and plotted in the curve. Evenness can be viewed from the slope value of the rank abundance curve.

The steeper slopes generally indicate lower level of evenness while a shallower slope represents a community with more evenness.

Table 4.5. Rank abundance models of BTA

Model	Parameter1	Parameter 2	Parameter 3	AIC	BIC
Null				383.430	383.430
Pre-emption	0.036098			378.154	380.458
Lognormal	2.5303	0.73754		346.624	351.232
Zipf	0.077858	-0.57638		438.505	443.113
Mandelbrot	-3.5166e	+0598439e	+06	376.229	383.141

The best fit abundance model for BTA is log normal as the AIC value is lowest for it (346.624) (Table 4.5. & Figure 4.2.). The red circles in the rank abundance curve indicate the actual species abundance while the blue line in the curve indicates the best fit model of species abundance distribution. This model fits for a comparatively larger community with a few species of high abundance and many species that are rare. It is the characteristic of a community with right skewed frequency distribution (Magurran, 1988; Engen *et al*., 2002, Plotkin & Muller-Landu, 2002).

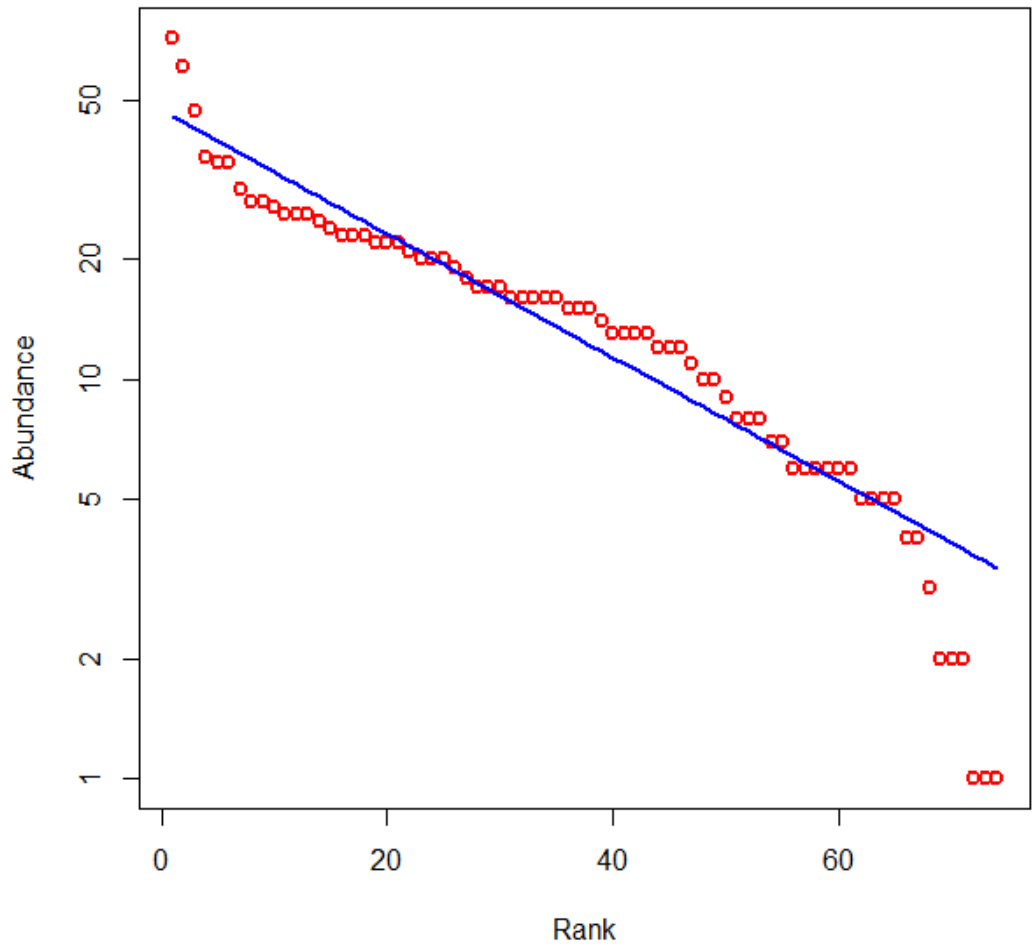


Figure 4.2. Rank abundance distribution of spiders in BTA

In CRA, the lowest value of AIC is for the null model (403.617) of species distribution (Table 4.6. & Figure 4.3.). A null model will be best fit for a community where resources are shared according to their abundance (Tokeshi, 1990). Usually, this model is best fit in communities where the competitive interactions are relatively weak. The resource partitioning in such communities is one dimensional. The colonies where all the species inhabited simultaneously or each sequential invaders encroach a portion of the niche the already inhabited species, will show this model of species abundance distribution as best fit.

Table 4.6. Rank abundance models of CRA

Model	Parameter1	Parameter 2	Parameter 3	AIC	BIC
Null				403.617	403.617
Preemption	0.039825			413.186	415.477
Lognormal	2.9837	0.77931		426.467	431.048
Zipf	0.081073	-0.58927		642.399	646.980
Mandelbrot	-59537e	+081.4897e	+10	411.601	418.472

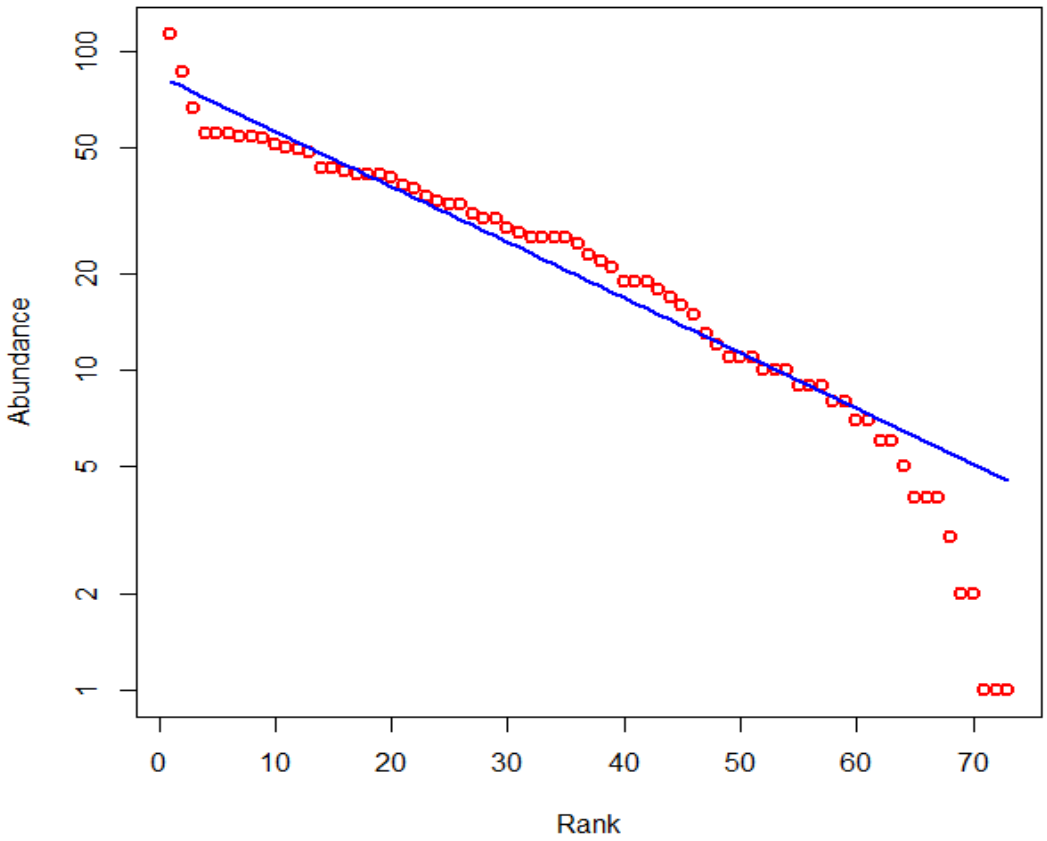


Figure 4.3. Rank abundance distribution of spiders in CRA

The best fit model of species abundance distribution for NGM was Pre-emption model as the AIC value is lowest for that model (Table 4.7. & Figure 4.4.). It is the species abundance model in communities where one or a few environmental factors play significant role in the species distribution or communities in early stage of ecological succession.

In NKR, the best fit model was Null model as AIC value for this model is the lowest (468 .727) (Table 4.8. & Figure 4.5.). While in KZR, the Mandelbrot model fitted the best as the AIC value being the lowest (418.839) (Table 4.9. & Figure 4.6.). The Mandelbrot model will be best fit for a community with a few abundant species and many rare species of comparable abundance. The communities with Mandelbrot model as the best fit will have a well-defined hierarchical structure.

Table 4.7. Rank abundance models in NGM

Model	Parameter1	Parameter 2	Parameter 3	AIC	BIC
Null				444.043	444.043
Pre-emption	0.036552			424.893	427.347
Lognormal	2.8648	0.81023		517.117	522.026
Zipf	0.075452	-0.59105		798.299	803.208
Mandelbrot	-1.4435e	+093.9158e	+10	425.244	432.607

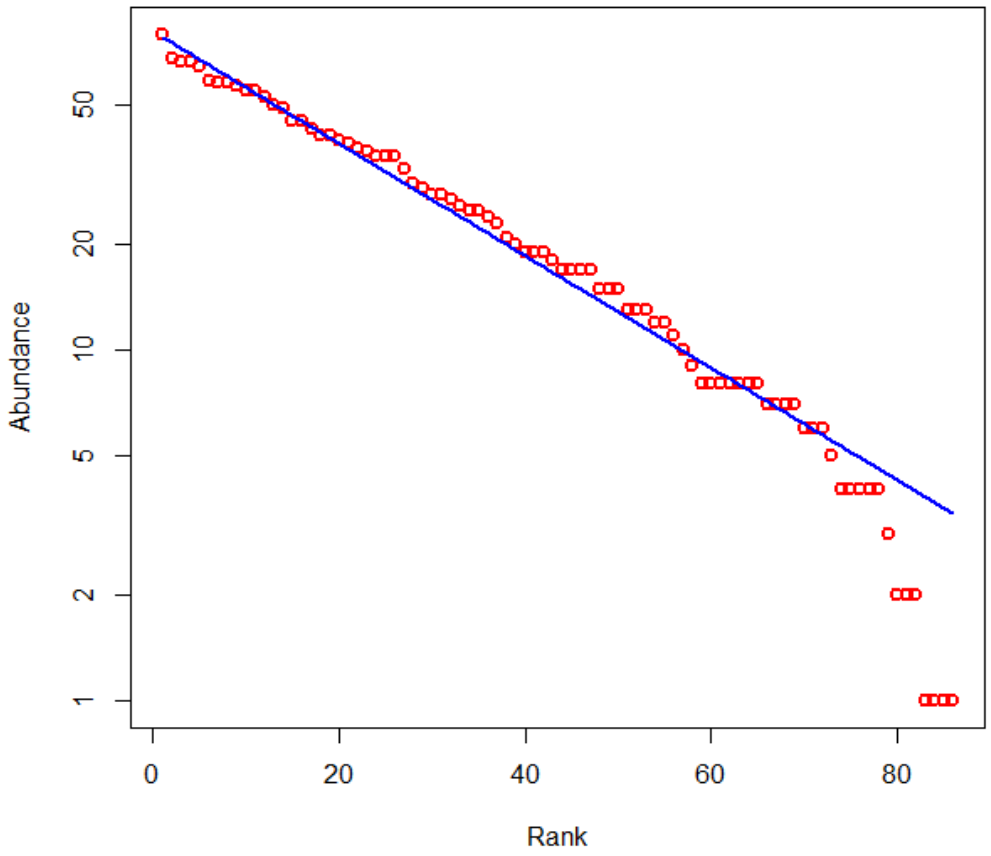


Figure 4.4. Rank abundance distribution of spiders in NGM

Table 4.8. Rank abundance models in NKR

Model	Parameter 1	Parameter 2	Parameter 3	AIC	BIC
Null				468.727	468.727
Pre-emption	0.031762			508.156	510.810
Lognormal	2.589	0.87234		531.351	536.659
Zipf	0.076384	-0.62743		790.839	796.147
Mandelbrot	-1.2697e	+073.9608e	+08	509.739	517.701

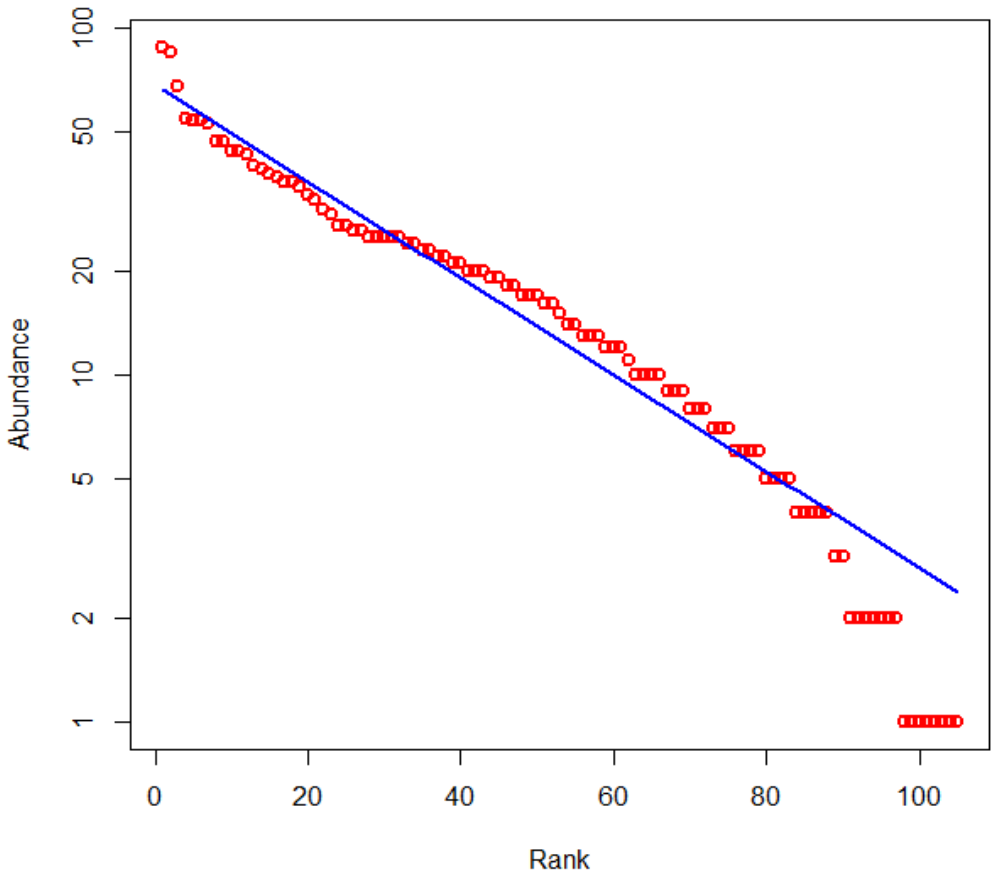


Figure 4.5. Rank abundance distribution of spiders in NKR

Table 4.9. Rank abundance models in KZR

Model	Parameter1	Parameter 2	Parameter 3	AIC	BIC
Null				461.277	461.277
Pre-emption	0.034853			421.015	423.422
Lognormal	2.8706	0.74343		484.948	489.761
Zipf	0.068877	-0.54977		717.401	722.215
Mandelbrot	-2.2687e	+066.5178e	+07	418.839	426.060

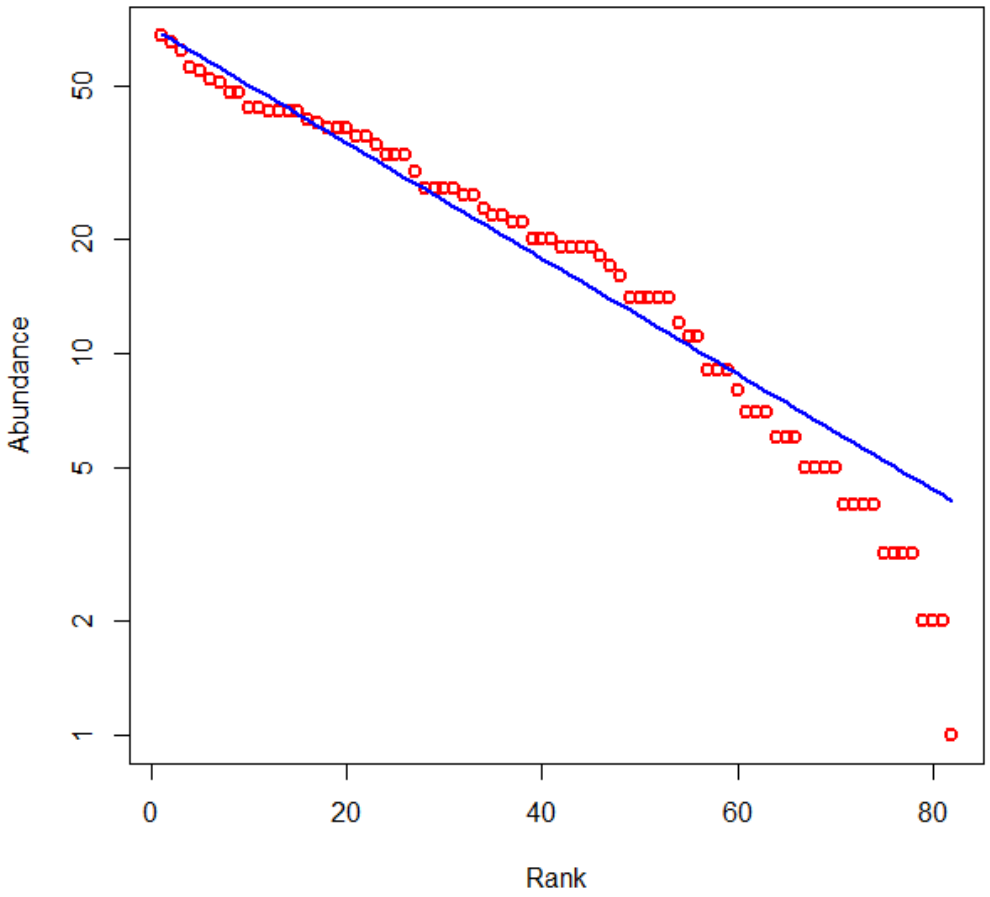


Figure 4.6. Rank abundance distribution of spiders in KZR

4.2.3. Spider dominance across the habitats

Ecological dominance is the phenomenon by which one or a few species exerts a controlling effect on the other species in their community. Usually most numerous groups in the community with highest ecological impact is considered to be the dominant ones. The dominance of individual species is calculated using the formula,

Individual dominance Index, D_i = (ni/N) x 100; n_i is the number of individuals of a particular species and N is the total number of individuals (Khofar *et al*., 2019; Kashmeera & Sharma, 2023). Tischler's scale for species dominance was used for assigning various level levels of dominance to each of the species (Tischler, 1949). According to this scale five diverse levels of dominance are described based on D_i value. Species with D_i value ranging between 10%-100% are considered as eudominant. If the D_i value is between 5%- 10%, they are dominant, if it is 2-5% they are subdominants. Recedents will have D_i value ranging between 1%- 2% and subrecedents will have a D_i value <1%.

Numerically most dominant species in BTA is *Indopadilla insularis (Malamel et al., 2015)* (72 individuals) followed by *Myrmaplata plataleoides* (O. Pickard-Cambridge, 1869) with 61 individuals and *Anepsion maritatum* (O. Pickard-Cambridge, 1877) with 47 individuals. Two species (*I. insularis* & *M. plataleoides*) were reported as dominant. 12 species came under the category of subdominant, 29 species under recedent and 31 under subrecedent categories (Table 4.10.).

Table 4.10. Individual dominance index of spiders of BTA

Sl.No.	*Species*	IDI	Category
1	*Anepsion maritatum* (O. Pickard-Cambridge, 1877)	3.9	Subdominant
2	*Araneus sp.*	0.7	Subrecedent
3	*Argiope anasuja* Thorell, 1887	1.1	Recedent
4	*Argiope pulchella* Thorell, 1881	2.2	Subdominant
5	*Cyclosa bifida* (Doleschall, 1859)	0.8	Subrecedent
6	*Cyclosa hexatuberculata* Tikader, 1982	1.4	Recedent
7	*Cyrtophora cicatrosa* (Stoliczka, 1869)	1.9	Recedent
8	*Cyrtophora citricola* (Forsskal, 1775)	1.8	Recedent
9	*Eriovixia laglaizei* (Simon, 1877)	0.9	Subrecedent
10	*Gasteracantha geminata* (Fabricius, 1798)	1.3	Recedent
11	*Gea subarmata* Thorell, 1890	0.3	Subrecedent

12	*Neoscona inustua (*L. Koch, 1871)	1.9	Recedent
13	*Neoscona mukerjei Tikader*, 1980	1.8	Recedent
14	*Neoscona vigilans* (Blackwall, 1865)	1.2	Recedent
15	*Hersilia savignyi* Lucas, 1836	0.2	Subrecedent
16	*Hippasa agelenoides* (Simon, 1884)	3.0	Subdominant
17	*Pardosa pseudoannulata* Bosenberg & Strand, 1906	2.1	Subdominant
18	*Pardosa sumatrana* (Thorell, 1890)	1.1	Recedent
19	*Oxyopes bharatae* Gajbe, 1999	0.5	Subrecedent
20	*Oxyopes birmanicus* Thorell, 1887	2.1	Subdominant
21	*Oxyopes hindostanicus* Pocock, 1901	2.3	Subdominant
22	*Oxyopes javanus* Thorell, 1887	0.7	Subrecedent
23	*Oxyopes lineatipes* (C L Koch, 1847)	0.3	Subrecedent
24	*Oxyopes shweta* Tikader, 1970	0.7	Subrecedent
25	*Oxyopes sunandae* Tikader, 1970	1.0	Subrecedent
26	*Oxyopes sp.*	0.5	Subrecedent
27	*Peucetia viridana* (Stoliczka, 1869)	1.2	Recedent
28	*Crossopriza lyoni* (Blackwall, 1867)	0.1	Subrecedent
29	*Dendrolycosa gitae* (Tikader, 1970)	1.0	Subrecedent
30	*Asemonea tenuipes* (O. Pickard-Cambridge, 1869)	1.3	Recedent
31	*Bianor angulosus* (Karsch, 1879)	0.1	Subrecedent
32	*Brettus cingulatus* Thorell, 1895	1.7	Recedent
33	*Carrhotus viduus* (C. L. Koch, 1846)	2.1	Subdominant
34	*Chalcotropis pennata* Simon, 1902	0.6	Subrecedent
35	*Chrysilla volupe* (Karsch, 1879)	1.4	Recedent
36	*Epeus indicus* Proszynski,1992	0.5	Subrecedent
37	*Epeus sp.*	0.4	Subrecedent
38	*Epeus tener* (Simon, 1877)	1.6	Recedent
39	*Evarcha falcata* (Clerck, 1757)	0.4	Subrecedent
40	*Evarcha sp.*	0.2	Subrecedent
41	*Hasarius adansoni* (Audouin, 1826)	1.4	Recedent
42	*Hyllus semicupreus* (Simon, 1885)	1.8	Recedent
43	*Indopadilla insularis* (Malamel *et al., 2015)*	5.9	Dominant

44	*Menemerus bivittatus* (Dufour, 1831)	1.9	Recedent
45	*Myrmaplata plataleoides* (O. Pickard-Cambridge, 1869)	5.0	Dominant
46	*Myrmarachne melanocephala* MacLeay, 1839	1.5	Recedent
47	*Phidippus yashodharae* Tikader, 1977	1.1	Recedent
48	*Phintella vittata* (C. L. Koch, 1846)	2.3	Subdominant
49	*Plexippus paykulli* (Audouin, 1826)	2.5	Subdominant
50	*Plexippus petersi* (Karsch, 1878)	2.9	Subdominant
51	*Portia fimbriata* (Doleschall, 1859)	1.2	Recedent
52	*Rhene flavigera* (C. L. Koch, 1846)	1.7	Recedent
53	*Siler semiglaucus* (Simon, 1901)	2.9	Subdominant
54	*Stenaelurillus lesserti* Reimoser, 1934	0.5	Subrecedent
55	*Stenaelurillus sp.*	0.7	Subrecedent
56	*Telamonia dimidiata* (Simon, 1899)	2.0	Recedent
57	*Thiania bhamoensis* Thorell, 1887	0.8	Subrecedent
58	*Thyene bivittata* Xie & Peng, 1995	0.6	Subrecedent
59	*Scytodes fusca* Walckenaer, 1837	0.1	Subrecedent
60	*Heteropoda venatoria* (Linnaeus, 1767)	1.3	Recedent
61	*Olios milleti* (Pocock, 1901)	0.4	Subrecedent
62	*Leucauge decorata* (Blackwall, 1864)	0.2	Subrecedent
63	*Leucauge dorsotuberculata* Tikader, 1982	1.7	Recedent
64	*Tetragnatha cochinensis* Gravely, 1921	0.5	Subrecedent
65	*Tetragnatha javana* (Thorell, 1890)	2.1	Subdominant
66	*Tetragnatha mandibulata* Walckenaer, 1842	1.7	Recedent
67	*Tylorida ventralis* Thorell, 1877	1.2	Recedent
68	*Argyrodes kumadai* Chida & Tanikawa, 1999	0.5	Subrecedent
69	*Ariamnes flagellum* (Doleschall, 1857)	1.3	Recedent
70	*Meotipa argyrodiformis* (Yaginuma, 1952)	1.3	Recedent
71	*Theridion manjithar* Tikader, 1970	1.1	Recedent
72	*Thomisus projectus* Tikader, 1960	1.0	Subrecedent
73	*Indoxysticus minutus* Tikader, 1960	0.4	Subrecedent
74	*Strigoplus netravati* Tikader, 1963	0.2	Subrecedent

In CRA most abundant species was *I. insularis* (113 individuals) followed by *M. plataleoides* (86 individuals) and *C. viduus* (66 individuals). Only one species was reported as dominant while 19 subdominants, 19 recedents and 34 subrecedents were reported from CRA (Table 4.11.).

Table 4.11. Individual Dominance index of CRA

SL. No.	Species	IDI	Category
1	*Anepsion maritatum* (O. Pickard-Cambridge, 1877)	2.6	Subdominant
2	*Bijoaraneus mitificus* (Simon, 1886)	0.4	Subrecedent
3	*Argiope aemula* (Walckenaer, 1842)	0.5	Subrecedent
4	*Argiope anasuja* Thorell, 1887	0.6	Subrecedent
5	*Argiope pulchella* Thorell, 1881	1.8	Recedent
6	*Cyclosa confraga* (Thorell, 1893)	0.9	Subrecedent
7	*Cyclosa hexatuberculata* Tikader, 1982	1.3	Recedent
8	*Cyrtophora cicatrosa* (Stoliczka, 1869)	2.8	Subdominant
9	*Cyrtophora citricola* (Forsskal, 1775)	1.9	Recedent
10	*Cyrtophora moluccensis* (Doleschall, 1857)	1.5	Recedent
11	*Eriovixia laglaizei* (Simon, 1877)	0.4	Subrecedent
12	*Gasteracantha geminata* (Fabricius, 1798)	1.1	Recedent
13	*Gea subarmata* Thorell, 1890	0.3	Subrecedent
14	*Neoscona inustua (*L. Koch, 1871)	2.1	Subdominant
15	*Neoscona mukerjei Tikader*, 1980	2.1	Subdominant
16	*Neoscona vigilans* (Blackwall, 1865)	0.1	Subrecedent
17	*Nephila pilipes (Fabricius, 1793)*	0.2	Subrecedent
18	*Clubiona drassodes* O.P. Cambridge, 1874	0.1	Subrecedent
19	*Castianeira zetes* Simon, 1897	0.6	Subrecedent
20	*Corinnomma sp.*	0.1	Subrecedent
21	*Hersilia sumatrana* (Thorell, 1890)	0.4	Subrecedent
22	*Hippasa agelenoides* (Simon, 1884)	2.0	Recedent
23	Lycosa mackenziei Gravely, 1924	0.2	Subrecedent
24	*Pardosa pseudoannulata* Bosenberg & Strand, 1906	1.4	Recedent

25	*Oxyopes birmanicus* Thorell, 1887	2.1	Subdominant
26	*Oxyopes hindostanicus* Pocock, 1901	2.8	Subdominant
27	*Oxyopes javanus* Thorell, 1887	0.9	Subrecedent
28	*Oxyopes lineatipes* (C L Koch, 1847)	0.3	Subrecedent
29	*Oxyopes shweta* Tikader, 1970	1.0	Subrecedent
30	*Oxyopes sunandae* Tikader, 1970	0.5	Subrecedent
31	*Peucetia viridana* (Stoliczka, 1869)	1.5	Recedent
32	*Psellonus sp.*	0.2	Subrecedent
33	*Asemonea tenuipes* (O. Pickard-Cambridge, 1869)	2.8	Subdominant
34	*Bianor angulosus* (Karsch, 1879)	0.6	Subrecedent
35	*Brettus cingulatus* Thorell, 1895	2.6	Subdominant
36	*Carrhotus viduus* (C. L. Koch, 1846)	3.4	Subdominant
37	*Chalcotropis pennata* Simon, 1902	1.3	Recedent
38	*Chrysilla volupe* (Karsch, 1879)	2.5	Subdominant
39	*Epeus tener* (Simon, 1877)	0.8	Subrecedent
40	*Evarcha falcata* (Clerck, 1757)	0.4	Subrecedent
41	*Evarcha sp.*	0.1	Subrecedent
42	*Hasarius adansoni* (Audouin, 1826)	2.8	Subdominant
43	*Hyllus semicupreus* (Simon, 1885)	2.8	Subdominant
44	*Indopadilla insularis* (Malamel et al., 2015)	5.8	Dominant
45	*Menemerus bivittatus* (Dufour, 1831)	0.8	Subrecedent
46	*Myrmaplata plataleoides* (O. Pickard-Cambridge, 1869)	4.4	Subdominant
47	*Myrmarachne melanocephala* MacLeay, 1839	2.5	Subdominant
48	*Phidippus yashodharae* Tikader, 1977	0.6	Subrecedent
49	*Phintella vittata* (C. L. Koch, 1846)	2.7	Subdominant
50	*Plexippus paykulli* (Audouin, 1826)	2.2	Subdominant
51	*Plexippus petersi* (Karsch, 1878)	2.2	Subdominant
52	*Rhene flavigera* (C. L. Koch, 1846)	0.5	Subrecedent
53	*Siler semiglaucus* (Simon, 1901)	1.7	Recedent
54	*Stenaelurillus lesserti* Reimoser, 1934	0.3	Subrecedent
55	*Telamonia dimidiata* (Simon, 1899)	1.8	Recedent
56	*Thiania bhamoensis* Thorell, 1887	0.7	Subrecedent

57	*Heteropoda venatoria* (Linnaeus, 1767)	1.4	Recedent
58	*Olios milleti* (Pocock, 1901)	1.0	Subrecedent
59	*Leucauge dorsotuberculata* Tikader, 1982	1.1	Recedent
60	*Tetragnatha cochinensis* Gravely, 1921	0.2	Subrecedent
61	*Tetragnatha javana* (Thorell, 1890)	2.1	Subdominant
62	*Tetragnatha mandibulata* Walckenaer, 1842	2.2	Subdominant
63	*Tetragnatha viridorufa* Gravely, 1921	0.5	Subrecedent
64	*Tylorida ventralis* Thorell, 1877	1.3	Recedent
65	*Argyrodes kumadai* Chida & Tanikawa, 1999	0.5	Subrecedent
66	*Ariamnes flagellum* (Doleschall, 1857)	1.3	Recedent
67	*Meotipa argyrodiformis* (Yaginuma, 1952)	1.7	Recedent
68	*Phoroncidia septemaculeata* O. Pickard-Cambridge, 1873	0.1	Subrecedent
69	*Theridion manjithar* Tikader, 1970	1.2	Recedent
70	*Thomisus projectus* Tikader, 1960	1.6	Recedent
71	*Indoxysticus minutus* Tikader, 1960	1.3	Recedent
72	*Oxytate virens* (Thorell, 1891)	1.0	Subrecedent
73	*Strigoplus netravati* Tikader, 1963	0.5	Subrecedent

In NGM, *Anepsion maritatum* (O. Pickard-Cambridge, 1877) came to be numerically most dominant group (80 individuals) followed by *M. plataleoides* (68 individuals) and *I. insularis* (67 individuals). The number of subdominants, recedent and subrecedent species were 17, 21 and 48 respectively (Table 4.12.)

Table 4.12. Individual dominance index of NGM

Sl. No.	Species	IDI	Category
1	*Anepsion maritatum* (O. Pickard-Cambridge, 1877)	3.8	Subdominant
2	*Bijoaraneus mitificus* (Simon, 1886)	0.7	Subrecedent
3	*Araneus sp.*	0.3	Subrecedent
4	*Argiope aemula* (Walckenaer, 1842)	0.6	Subrecedent
5	*Argiope anasuja* Thorell, 1887	0.9	Subrecedent

6	*Argiope pulchella* Thorell, 1881	1.4	Recedent
7	*Cyclosa confraga* (Thorell, 1893)	0.3	Subrecedent
8	*Cyclosa hexatuberculata* Tikader, 1982	2.8	Subdominant
9	*Cyrtophora cicatrosa* (Stoliczka, 1869)	3.2	Subdominant
10	*Cyrtophora citricola* (Forsskal, 1775)	2.1	Subdominant
11	*Cyrtophora moluccensis* (Doleschall, 1857)	0.8	Subrecedent
12	*Cyrtophora sp.*	0.1	Subrecedent
13	*Eriovixia excelsa* (Simon, 1889)	0.4	Subrecedent
14	*Eriovixia laglaizei* (Simon, 1877)	0.7	Subrecedent
15	*Gasteracantha geminata* (Fabricius, 1798)	0.9	Subrecedent
16	*Neoscona elliptica* Tikader & Bal, 1981	0.2	Subrecedent
17	*Neoscona inustua (*L. Koch, 1871)	2.6	Subdominant
18	*Neoscona mukerjei Tikader*, 1980	1.2	Recedent
19	*Neoscona vigilans* (Blackwall, 1865)	0.4	Subrecedent
20	*Nephila pilipes (Fabricius, 1793)*	0.1	Subrecedent
21	*Cheiracanthium melanostomum* (Thorell, 1895)	0.4	Subrecedent
22	*Cheiracanthium danieli* Tikader, 1975	1.2	Recedent
23	*Apochionomma sp.*1	0.1	Subrecedent
24	*Castianeira zetes* Simon, 1897	0.2	Subrecedent
25	*Corinnomma sp.*	0.1	Subrecedent
26	*Bowie cochinensis* (Gravely, 1931)	0.3	Subrecedent
27	*Drassodes sp.*	0.4	Subrecedent
28	*Hahnia mridulae* Tikader, 1970	0.1	Subrecedent
29	*Hersilia savignyi* Lucas, 1836	0.8	Subrecedent
30	*Hippasa agelenoides* (Simon, 1884)	1.8	Recedent
31	*Pardosa pseudoannulata* Bosenberg & Strand, 1906	1.3	Recedent
32	*Pardosa sumatrana* (Thorell, 1890)	0.3	Subrecedent
33	*Oxyopes bharatae* Gajbe, 1999	0.4	Subrecedent
34	*Oxyopes birmanicus* Thorell, 1887	2.6	Subdominant
35	*Oxyopes hindostanicus* Pocock, 1901	2.4	Subdominant
36	*Oxyopes javanus* Thorell, 1887	0.2	Subrecedent
37	*Oxyopes lineatipes* (C L Koch, 1847)	0.5	Subrecedent

38	*Oxyopes shweta* Tikader, 1970	0.3	Subrecedent
39	*Oxyopes sunandae* Tikader, 1970	0.6	Subrecedent
40	*Peucetia viridana* (Stoliczka, 1869)	0.8	Subrecedent
41	*Thanatus parangvulgaris* Barrion & Litsinger, 1995	0.2	Subrecedent
42	*Pholcus phalangioides* (Fuesslin, 1775)	0.5	Subrecedent
43	*Dendrolycosa gitae* (Tikader, 1970)	1.6	Recedent
44	*Asemonea tenuipes* (O. Pickard-Cambridge, 1869)	2.7	Subdominant
45	*Brettus cingulatus* Thorell, 1895	1.2	Recedent
46	*Carrhotus viduus* (C. L. Koch, 1846)	2.8	Subdominant
47	*Chalcotropis pennata* Simon, 1902	0.3	Subrecedent
48	*Chrysilla volupe* (Karsch, 1879)	1.9	Recedent
49	*Epeus indicus* Proszynski,1992	0.6	Subrecedent
50	*Epeus tener* (Simon, 1877)	1.7	Recedent
51	*Evarcha falcata* (Clerck, 1757)	0.6	Subrecedent
52	*Hasarius adansoni* (Audouin, 1826)	2.8	Subdominant
53	*Hyllus semicupreus* (Simon, 1885)	3.1	Subdominant
54	*Indopadilla insularis* (Malamel et al., 2015)	3.2	Subdominant
55	*Menemerus bivitatus Dufour*, 1831	1.0	Recedent
56	*Myrmaplata plataleoides* (O. Pickard-Cambridge, 1869)	3.3	Subdominant
57	*Myrmarachne melanocephala* MacLeay, 1839	1.7	Recedent
58	*Phaeacius lancearius* (Thorell, 1895)	0.4	Subrecedent
59	*Phidippus yashodharae* Tikader, 1977	1.1	Recedent
60	*Phintella vittata* (C. L. Koch, 1846)	1.8	Recedent
61	*Plexippus paykulli* (Audouin, 1826)	2.6	Subdominant
62	*Plexippus petersi* (Karsch, 1878)	2.2	Subdominant
63	*Rhene flavigera* (C. L. Koch, 1846)	1.3	Recedent
64	*Siler semiglaucus* (Simon, 1901)	2.2	Subdominant
65	*Stenaelurillus lesserti* Reimoser, 1934	0.4	Subrecedent
66	*Telamonia dimidiata* (Simon, 1899)	2.0	Recedent
67	*Thiania bhamoensis* Thorell, 1887	0.3	Subrecedent

68	*Thyene bivittata* Xie & Peng, 1995	0.4	Subrecedent
69	*Heteropoda venatoria* (Linnaeus, 1767)	0.8	Subrecedent
70	*Leucauge decorata* (Blackwall, 1864)	0.7	Subrecedent
71	*Leucauge dorsotuberculata* Tikader, 1982	2.0	Recedent
72	*Tetragnatha javana* (Thorell, 1890)	1.9	Recedent
73	*Tetragnatha mandibulata* Walckenaer, 1842	2.4	Subdominant
74	*Tetragnatha viridorufa* Gravely, 1921	0.6	Subrecedent
75	*Tylorida striata* (Thorell, 1877)	0.1	Subrecedent
76	*Tylorida ventralis* Thorell, 1877	1.7	Recedent
77	*Argyrodes kumadai* Chida & Tanikawa, 1999	0.2	Subrecedent
78	*Argyrodes sp.*	0.1	Subrecedent
79	*Ariamnes flagellum* (Doleschall, 1857)	1.3	Recedent
80	*Meotipa argyrodiformis* (Yaginuma, 1952)	1.4	Recedent
81	*Theridion manjithar* Tikader, 1970	1.3	Recedent
82	*Thomisus projectus* Tikader, 1960	1.0	Subrecedent
83	*Indoxysticus minutus* Tikader 1960	0.9	Subrecedent
84	*Oxytate virens* (Thorell, 1891)	0.9	Subrecedent
85	*Strigoplus netravati* Tikader, 1963	0.2	Subrecedent
86	*Uloborus krishnae* Tikader, 1971	0.1	Subrecedent

Most abundant species in NKR is *I. insularis, M. plataleoides* and *C. viduus* with 88, 85 and 62 individuals, respectively. 12 subdominant species, 28 recedent species and 65 subrecedent species have been reported from there (Table 4.13.).

Table 4.13. Individual dominance index of NKR

Sl. No.	*Species*	NKR	Category
1	*Anepsion maritatum* (O. Pickard-Cambridge, 1877)	2.71	Subdominant
2	*Bijoaraneus mitificus* (Simon, 1886)	0.59	Subrecedent
3	*Argiope aemula* (Walckenaer, 1842)	1.48	Recedent
4	*Argiope anasuja* Thorell, 1887	1.58	Recedent
5	*Argiope catenulata* (Doleschall, 1859)	0.44	Subrecedent
6	*Argiope pulchella* Thorell, 1881	1.73	Recedent
7	*Cyclosa bifida* (Doleschall, 1859)	0.59	Subrecedent

8	*Cyclosa confraga* (Thorell, 1893)	0.10	Subrecedent
9	*Cyclosa hexatuberculata* Tikader, 1982	1.04	Recedent
10	*Cyclosa sp.*	0.10	Subrecedent
11	*Cyrtophora cicatrosa* (Stoliczka, 1869)	1.92	Recedent
12	*Cyrtophora citricola* (Forsskal, 1775)	1.33	Recedent
13	*Cyrtophora moluccensis* (Doleschall, 1857)	0.25	Subrecedent
14	*Cyrtophora sp.*	0.25	Subrecedent
15	*Eriovixia excelsa* (Simon, 1889)	0.94	Subrecedent
16	*Eriovixia laglaizei* (Simon, 1877)	0.84	Subrecedent
17	*Gasteracantha geminata* Fabricius *1798*	0.99	Subrecedent
18	*Gea subarmata* Thorell, 1890	0.20	Subrecedent
19	*Neoscona elliptica* Tikader & Bal, 1981	1.08	Recedent
20	*Neoscona inustua (*L. Koch, 1871)	2.66	Subdominant
21	*Neoscona mukerjei Tikader*, 1980	1.28	Recedent
22	*Neoscona sp.*	0.05	Subrecedent
23	*Neoscona vigilans* (Blackwall, 1865)	1.23	Recedent
24	*Nephila pilipes (Fabricius, 1793)*	0.20	Subrecedent
25	*Clubiona drassodes* O.P. Cambridge, 1874	0.05	Subrecedent
26	*Castianeira zetes* Simon, 1897	0.64	Subrecedent
27	*Hahnia mridulae* Tikader, 1970	0.05	Subrecedent
28	*Hersilia savignyi* Lucas, 1836	0.64	Subrecedent
29	*Hersilia sumatrana* (Thorell, 1890)	0.10	Subrecedent
30	*Hippasa agelenoides* (Simon, 1884)	2.61	Subdominant
31	Lycosa mackenziei Gravely, 1924	1.18	Recedent
32	*Lycosa tista* Tikader, 1970	0.30	Subrecedent
33	*Pardosa pseudoannulata* Bosenberg & Strand, 1906	1.18	Recedent
34	*Pardosa sumatrana* (Thorell, 1890)	1.04	Recedent
35	*Hamadruas sikkimensis* (Tikader,1970)	0.05	Subrecedent
36	*Oxyopes bharatae* Gajbe, 1999	0.49	Subrecedent
37	*Oxyopes birmanicus* Thorell, 1887	0.94	Subrecedent
38	*Oxyopes hindostanicus* Pocock, 1901	0.49	Subrecedent
39	*Oxyopes javanus* Thorell, 1887	0.35	Subrecedent

40	*Oxyopes lineatipes* (C L Koch, 1847)	0.59	Subrecedent
41	*Oxyopes shweta* Tikader, 1970	0.79	Subrecedent
42	*Oxyopes sunandae* Tikader, 1970	0.84	Subrecedent
43	*Oxyopes sp.*	0.20	Subrecedent
44	*Peucetia viridana* (Stoliczka, 1869)	0.99	Subrecedent
45	*Peucetia ananthakrishnani* Murugesan *et al*., 2006	0.15	Subrecedent
46	*Psellonus sp.*	0.05	Subrecedent
47	*Thanatus parangvulgaris* Barrion & Litsinger, 1995	0.10	Subrecedent
48	*Crossopriza lyoni* (Blackwall, 1867)	0.49	Subrecedent
49	*Pholcus phalangioides* (Fuesslin, 1775)	0.25	Subrecedent
50	*Asemonea tenuipes* (O. Pickard-Cambridge, 1869)	2.17	Subdominant
51	*Bianor angulosus* (Karsch, 1879)	1.23	Recedent
52	*Brettus cingulatus* Thorell, 1895	2.32	Subdominant
53	*Carrhotus viduus* (C. L. Koch, 1846)	3.35	Subdominant
54	*Chalcotropis pennata* Simon, 1902	0.79	Subrecedent
55	*Chrysilla volupe* (Karsch, 1879)	1.63	Recedent
56	*Epeus indicus* Proszynski,1992	0.25	Subrecedent
57	*Epeus tener* (Simon, 1877)	1.82	Recedent
58	*Evarcha falcata* (Clerck, 1757)	0.89	Subrecedent
59	*Evarcha sp.*	0.10	Subrecedent
60	*Hasarius adansoni* (Audouin, 1826)	2.12	Subdominant
61	*Hyllus semicupreus* (Simon, 1885)	2.66	Subdominant
62	*Indopadilla insularis* Malamel *et al., 2015*	4.34	Subdominant
63	*Menemerus bivittatus* (Dufour, 1831)	1.43	Recedent
64	*Myrmaplata plataleoides* (O. Pickard-Cambridge, 1869)	4.19	Subdominant
65	*Myrmarachne melanocephala* MacLeay, 1839	1.33	Recedent
66	*Phaeacius lancearius* (Thorell, 1895)	0.15	Subrecedent
67	*Phidippus yashodharae* Tikader, 1977	0.69	Subrecedent
68	*Phintella vittata* (C. L. Koch, 1846)	1.97	Recedent
69	*Plexippus paykulli* (Audouin, 1826)	2.17	Subdominant
70	*Plexippus petersi* (Karsch, 1878)	1.78	Recedent

71	*Portia fimbriata* (Doleschall, 1859)	0.54	Subrecedent
72	*Rhene flavigera* (C. L. Koch, 1846)	1.28	Recedent
73	*Siler semiglaucus* (Simon, 1901)	1.87	Recedent
74	*Stenaelurillus lesserti* Reimoser, 1934	0.30	Subrecedent
75	*Stenaelurillus sp.*	0.44	Subrecedent
76	*Telamonia dimidiata* (Simon, 1899)	2.32	Subdominant
77	*Thiania bhamoensis* Thorell, 1887	1.78	Recedent
78	*Thyene bivittata* Xie & Peng, 1995	0.49	Subrecedent
79	*Scytodes fusca* Walckenaer, 1837	0.39	Subrecedent
80	*Scytodes sp.*	0.05	Subrecedent
81	*Heteropoda venatoria* (Linnaeus, 1767)	0.89	Subrecedent
82	*Olios milleti* (Pocock, 1901)	0.35	Subrecedent
83	*Thelcticopis moolampilliensis* Jose & Sebastian, 2007	0.35	Subrecedent
84	*Leucauge decorata* (Blackwall, 1864)	0.64	Subrecedent
85	*Leucauge dorsotuberculata* Tikader, 1982	0.99	Subrecedent
86	*Tetragnatha cochinensis* Gravely, 1921	0.74	Subrecedent
87	*Tetragnatha javana* (Thorell, 1890)	1.23	Recedent
88	*Tetragnatha keyserlingi* Simon, 1890	0.10	Subrecedent
89	*Tetragnatha mandibulata* Walckenaer, 1842	1.23	Recedent
90	*Tetragnatha viridorufa* Gravely, 1921	0.44	Subrecedent
91	*Tylorida striata* (Thorell, 1877)	0.39	Subrecedent
92	*Tylorida ventralis* Thorell, 1877	1.23	Recedent
93	*Argyrodes kumadai* Chida & Tanikawa, 1999	0.30	Subrecedent
94	*Ariamnes flagellum* (Doleschall, 1857)	0.69	Subrecedent
95	*Meotipa argyrodiformis* (Yaginuma, 1952)	1.08	Recedent
96	*Meotipa sp.*	0.10	Subrecedent
97	*Phoroncidia septemaculeata* O. Pickard-Cambridge, 1873	0.30	Subrecedent
98	*Theridion manjithar* Tikader, 1970	0.84	Subrecedent
99	*Thomisus projectus* Tikader, 1960	1.13	Recedent
100	*Amyciaea forticeps* (O. Pickard-Cambridge, 1873)	0.39	Subrecedent
101	*Indoxysticus minutus* Tikader, 1960	1.13	Recedent

102	*Oxytate virens* (Thorell, 1891)	0.20	Subrecedent
103	*Runcinia insecta* (L. Koch, 1875)	0.05	Subrecedent
104	*Miagrammopes extensus* Simon, 1889	0.20	Subrecedent
105	*Uloborus krishnae* Tikader, 1971	0.05	Subrecedent

I. insularis (68 individuals) ranked in the first position of numerical dominance in KZR and *N. inustus* (65 individuals) and *H. semicupreus* (62 individuals) came in the next two levels of abundance. 20 subdominants, 25 recedents and 37 subrecedents were reported from the site (Table 4.14.).

Table 4.14. Individual dominance index of KZR

Sl. No.	*Species*	IDI	Category
1	*Anepsion maritatum* (O. Pickard-Cambridge, 1877)	2.90	Subdominant
2	*Argiope aemula* (Walckenaer, 1842)	1.42	Recedent
3	*Argiope anasuja* Thorell, 1887	1.74	Recedent
4	*Argiope catenulata* (Doleschall, 1859)	0.32	Subrecedent
5	*Argiope pulchella* Thorell, 1881	1.95	Recedent
6	*Cyclosa bifida* (Doleschall, 1859)	0.47	Subrecedent
7	*Cyclosa confraga* (Thorell, 1893)	0.21	Subrecedent
8	*Cyclosa hexatuberculata* Tikader, 1982	2.06	Subdominant
9	*Cyrtophora cicatrosa* (Stoliczka, 1869)	2.16	Subdominant
10	*Cyrtophora citricola* (Forsskal, 1775)	2.53	Subdominant
11	*Cyrtophora moluccensis* (Doleschall, 1857)	0.37	Subrecedent
12	*Cyrtophora sp.*	0.16	Subrecedent
13	*Eriovixia excelsa* (Simon, 1889)	0.37	Subrecedent
14	*Eriovixia laglaizei* (Simon, 1877)	1.06	Recedent
15	*Gasteracantha geminata* (Fabricius, 1798)	1.21	Recedent
16	*Neoscona elliptica* Tikader & Bal, 1981	1.16	Recedent
17	*Neoscona inustua (*L. Koch, 1871)	3.43	Subdominant
18	*Neoscona mukerjei Tikader*, 1980	2.27	Subdominant
19	*Neoscona vigilans* (Blackwall, 1865)	0.74	Subrecedent

20	*Nephila pilipes (Fabricius, 1793)*	0.16	Subrecedent
21	*Cheiracanthium danieli* Tikader, 1975	0.58	Subrecedent
22	*Castianeira zetes* Simon, 1897	0.26	Subrecedent
23	*Bowie cochinensis* (Gravely, 1931)	0.32	Subrecedent
24	*Drassodes sp.*	0.11	Subrecedent
25	*Hersilia savignyisavignyi* Lucas, 1836	1.00	Recedent
26	*Hippasa agelenoides* (Simon, 1884)	1.74	Recedent
27	*Pardosa pseudoannulata* Bosenberg & Strand, 1906	1.00	Recedent
28	*Pardosa sumatrana* (Thorell, 1890)	0.63	Subrecedent
29	*Oxyopes bharatae* Gajbe, 1999	0.32	Subrecedent
30	*Oxyopes birmanicus* Thorell, 1887	2.27	Subdominant
31	*Oxyopes hindostanicus* Pocock, 1901	0.11	Subdominant
32	*Oxyopes javanus* Thorell, 1887	2.06	Subrecedent
33	*Oxyopes shweta* Tikader, 1970	0.47	Subrecedent
34	*Oxyopes sunandae* Tikader, 1970	0.74	Subrecedent
35	*Peucetia viridana* (Stoliczka, 1869)	0.74	Subrecedent
36	*Thanatus parangvulgaris* Barrion & Litsinger, 1995	0.05	Subrecedent
37	*Asemonea tenuipes* (O. Pickard-Cambridge, 1869)	0.26	Subrecedent
38	*Bianor angulosus* (Karsch, 1879)	0.26	Subrecedent
39	*Brettus cingulatus* Thorell, 1895	2.96	Subdominant
40	*Carrhotus viduus* (C. L. Koch, 1846)	2.27	Subdominant
41	*Chalcotropis pennata* Simon, 1902	0.21	Subrecedent
42	*Chrysilla volupe* (Karsch, 1879)	1.74	Recedent
43	*Epeus indicus* Proszynski,1992	0.58	Subrecedent
44	*Epeus tener* (Simon, 1877)	1.37	Recedent
45	*Evarcha falcata* (Clerck, 1757)	0.74	Subrecedent
46	*Hasarius adansoni* (Audouin, 1826)	2.53	Subdominant
47	*Hyllus semicupreus* (Simon, 1885)	3.27	Subdominant
48	*Indopadilla insularis* Malamel *et al., 2015*	3.59	Subdominant
49	*Menemerus bivittatus* (Dufour, 1831)	1.42	Recedent
50	*Myrmaplata plataleoides* (O. Pickard-Cambridge,	2.74	Subdominant

	1869)		
51	*Myrmarachne melanocephala* MacLeay, 1839	1.16	Recedent
52	*Phaeacius lancearius* (Thorell, 1895)	0.90	Subrecedent
53	*Phidippus yashodharae* Tikader, 1977	0.37	Subrecedent
54	*Phintella vittata* (C. L. Koch, 1846)	1.58	Recedent
55	*Plexippus paykulli* (Audouin, 1826)	1.42	Recedent
56	*Plexippus petersi* (Karsch, 1878)	2.69	Subdominant
57	*Portia fimbriata* (Doleschall, 1859)	0.42	Subrecedent
58	*Rhene flavigera* (C. L. Koch, 1846)	0.26	Subrecedent
59	*Siler semiglaucus* (Simon, 1901)	2.11	Subdominant
60	*Stenaelurillus sp.*	0.11	Subrecedent
61	*Telamonia dimidiata* (Simon, 1899)	1.85	Recedent
62	*Thiania bhamoensis* Thorell, 1887	0.74	Subrecedent
63	*Heteropoda venatoria* (Linnaeus, 1767)	1.00	Recedent
64	*Olios milleti* (Pocock, 1901)	1.42	Recedent
65	*Thelcticopis moolampilliensis* Jose & Sebastian, 2007	0.21	Subrecedent
66	*Leucauge dorsotuberculata* Tikader, 1982	1.37	Recedent
67	*Tetragnatha cochinensis* Gravely, 1921	0.47	Subrecedent
68	*Tetragnatha javana* (Thorell, 1890)	1.95	Recedent
69	*Tetragnatha mandibulata* Walckenaer, 1842	2.32	Subdominant
70	*Tetragnatha viridorufa* Gravely, 1921	1.06	Recedent
71	*Tylorida striata* (Thorell, 1877)	0.95	Subrecedent
72	*Tylorida ventralis* Thorell, 1877	2.32	Subdominant
73	*Argyrodes kumadai* Chida & Tanikawa, 1999	0.84	Subrecedent
74	*Argyrodes sp.*	0.16	Subrecedent
75	*Ariamnes flagellum* (Doleschall, 1857)	1.21	Recedent
76	*Meotipa argyrodiformis* (Yaginuma, 1952)	2.06	Subdominant
77	*Phoroncidia septemaculeata* O. Pickard-Cambridge, 1873	0.21	Subrecedent
78	*Theridion manjithar* Tikader, 1970	2.27	Subdominant
79	*Thomisus projectus* Tikader, 1960	1.00	Recedent
80	*Indoxysticus minutus* Tikader, 1960	1.06	Recedent

81	*Oxytate virens* (Thorell, 1891)	1.27	Recedent
82	*Strigoplus netravati* Tikader, 1963	0.16	Subrecedent

4.2.4. Species richness and diversity in different habitats

Species richness generally refers to the number of species inhabiting a particular habitat in a particular point of time. It gives an insight to the diversity in the habitat. Usually, it does not consider the abundance and distribution, but simply quantified as the number of species present in the habitat. It provides an insight into the stability and health of the ecosystem. Greater the species richness, greater will be the stability and resilience of the ecosystem. It is a fundamental metric in the study of ecosystems and biodiversity. Study on species richness is very much helpful in planning and implementation of conservation strategies in the habitats. The present study recorded a total of 105 species of spiders from NKR, followed by NGM (86 species) and KZR (82 species). 74 and 73 species were recorded from BTA and CRA respectively (Figure 4.7). Salticidae was the richest family in all the five sites followed by Araneidae.

Many richness estimators such as Chao 1 (Chao, 1984), Chao1-bc, iChao 1, ACE (Abundance-based Coverage Estimator), ACE 1(Chao & Lee, 1992) were used to estimate true species richness in the study sites by eliminating the possible bias happened in the sampling as well as the potential under estimation issues. The richness estimated by all the estimators were found to be slightly greater than the observed richness in all the five study sites (Table 4.15). This point towards a small degree of underestimation of richness implying a small inadequacy in the sampling effort.

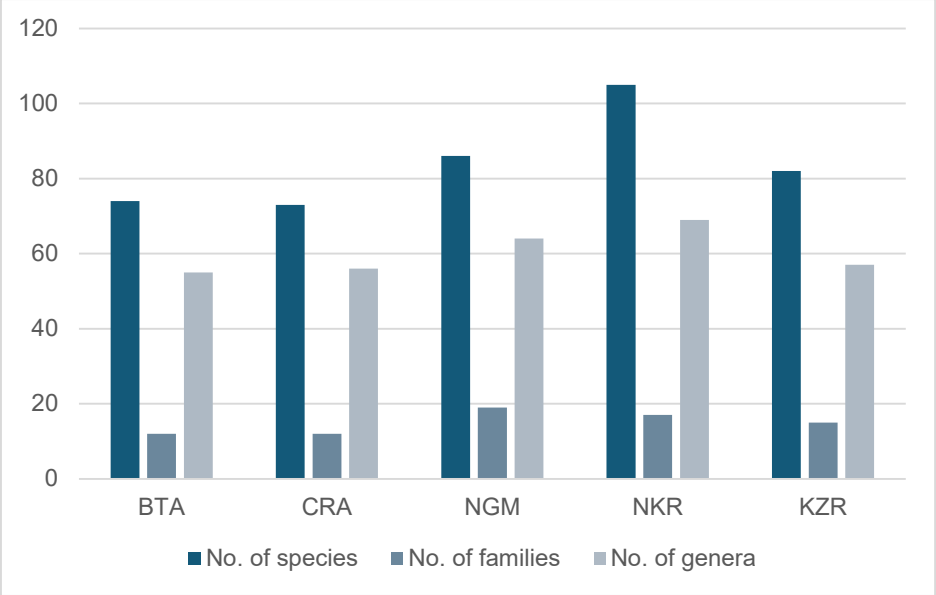


Figure 4.7. Comparison of Species, genus and family diversity across the study site

Table 4.15. Species richness of the study sites as calculated by various estimators

Richness estimator	Estimated richness± SE				
	BTA	CRA	NGM	NKR	KZR
Chao1	75.5± 2.3	75.2 ± 3.4	88.8 ± 3.5	109.6 ± 4.2	82.2± 0.5
Chao1-bc	74.7± 1.4	74.0 ± 1.8	87.5 ± 2.2	108.5± 3.4	82.0 ± 0.9
iChao1	75.8± 1.7	75.5 ± 2.8	88.9 ± 2.9	110.2 ± 3.2	82.2 ± 0.5
ACE	74.8± 1.2	74.0 ± 1.3	87.2 ± 1.4	108.8 ± 2.9	82.2 ±0.5
ACE-1	74.9± 1.2	74.1± 1.5	87.3 ± 1.5	109.3 ± 3.3	82.2 ± 0.6

4.2.5. Habitat wise diversity indices

Diversity assesses and quantifies the diversity of species within a community. Shannon - Wiener diversity index (H) and Simpson index (D) of the spiders of all the study sites were calculated. The high Shannon indices in all the five sites indicates that the selected horticultural crop fields support considerably high diversity of spiders (Table 4.16). Highest Shannon index was observed in NKR (4.272±0.019) followed by KZR (4.115±0.013) and NGM (4.113±0.016) respectively. The lowest value for H was reported from CRA (3.982 ±0.014).

Simpson index for all the five study sites were low indicating higher richness and evenness. Its value is closest to zero in the case of NKR (0.0175±0.0004) and then KZR (0.0191±0.0005). Highest value for D is observed in the site CRA (0.0196±0.0004) indicating comparatively higher dominance and lower richness and evenness there.

Table 4.16. Diversity indices of spiders in the horticultural crop fields of Thrissur district

Site	H ± SE	D ± SE
BTA	4.035±0.023	0.0217± 0.0009
CRA	3.982 ±0.014	0.0225±0.0007
NGM	4.113±0.016	0.0196±0.0004
NKR	4.272±0.019	0.0175±0.0004
KZR	4.115±0.013	0.0191±0.0005

Diversity profile curves of the spiders in all the five study sites were constructed and the curves show a moderately uneven distribution of species in all the five sites. Shape of the diversity profile curves helps to compare the evenness of the communities under study. The faster the decline in the curve, the more uneven will be distribution. CRA showed the fastest decline in the curve and (Figure 4.8.). This point towards the existence of community with a few species dominates over the majority others. NKR showed the slowest decline in the curve indicating a more even distribution of species when compared to the other sites. The diversity profile curves of NGM and KZR showed highest degree of similarity. It is also noted that in all the cases diversity profile estimator derived by Chao & Jost (2015) is higher than the diversity profile of observed diversity. Richness, Shannon diversity and Simpson diversity were highest in NKR and lowest in CRA (Table 4.17.).

Table 4.17. Hill numbers corresponding to q equal to 0, 1 and 2 in the study sites

Site	Estimator	^{0}D (Richness)	^{1}D (Shannon diversity)	^{2}D (Simpson diversity)
BTA	Chao Joast	75.50	58.38	47.84
	Observed	74.00	56.51	46.06
CRA	Chao Joast	75.25	54.67	44.54
	Observed	73.00	53.60	44.52
NGM	Chao Joast	88.67	62.45	52.21
	Observed	86.00	61.11	50.95
NKR	Chao Joast	109.57	73.72	58.76
	Observed	105.00	71.69	57.13
KZR	Chao Joast	82.16	62.60	53.86
	Observed	82.00	61.24	52.4

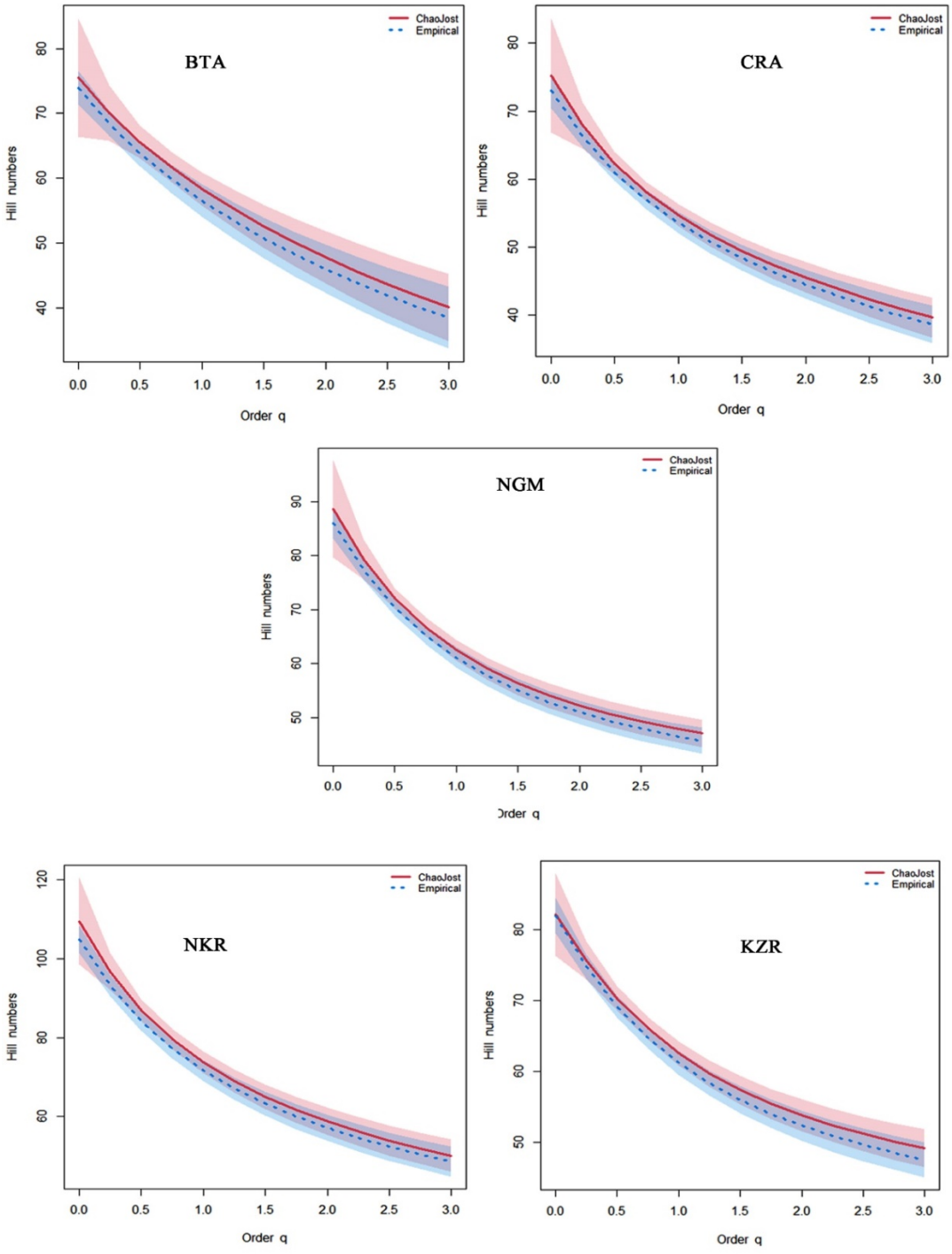


Figure 4.8. Diversity profile curves of spiders in the study sites

4.2.6. Comparison of spider diversity across the habitats

Comparison of variation in species composition and their contribution to the overall diversity of different habitats are one of thrust area in the field of study of biodiversity. This is extremely helpful in understanding how various factors such as environmental gradient, human interactions like changes in land use and other ecological factors affect various habitats. A Kruskal Wallis test was conducted for the comparison of overall abundance and diversity across the habitats. As the test static (H) was greater the critical value, there existed a significant difference in the abundance of spiders in different study sites (Table 4.18).

Table 4.18. Site wise comparison of abundance of spiders using Kruskal Wallis test

Test static H	Degree of freedom	p value
14.32	4	0.0064

The Post-Hoc Dunn's test with a Bonferroni correction is done to understand which pairs truly contributes towards this difference. The test revealed that the pair BTA-NKR shows statistically different (Table 4.19).

Table 4.19. Pair wise comparison of spider abundance using Dunn's test with Bonferroni correction

Column1	**BTA**	**CRA**	**NGM**	**NKR**	**KZR**
BTA		1	0.0966	**0.003185**	0.3195
CRA	1		1	0.3694	1
NGM	0.0966	1		1	1
NKR	**0.003185**	0.3694	1		1
KZR	0.3195	1	1	1	

A total of 51 species was common to all the five study sites. It means 43.9% of the total species recorded from the selected horticultural ecosystems of Thrissur districts are common (Table 4.20).

Table 4.20. Species common to all the study sites

SPECIES	FAMILY
Anepsion maritatum (O. Pickard-Cambridge, 1877)	Araneidae
Argiope anasuja Thorell, 1887	
Argiope pulchella Thorell, 18811	
Cyclosa hexatuberculata Tikader, 1982	
Cyrtophora cicatrosa (Stoliczka, 1869)	
Cyrtophora citricola (Forsskal, 1775)	
Eriovixia laglaizei (Simon, 1877)	
Gasteracantha geminata Fabricius 1798	
*Neoscona inustua (*L. Koch, 1871)	
Neoscona mukerjei Tikader, 1980	
Neoscona vigilans (Blackwall, 1865)	
Hippasa agelenoides (Simon, 1884)	Lycosidae
Pardosa pseudoannulata Bosenberg & Strand, 1906	
Oxyopes birmanicus Thorell, 1887	Oxyopidae
Oxyopes hindostanicus Pocock, 1901	
Oxyopes javanus Thorell, 1887	
Oxyopes shweta Tikader, 1970	
Oxyopes sunandae Tikader, 1970	
Peucetia viridana (Stoliczka, 1869)	
Asemonea tenuipes (O. Pickard-Cambridge, 1869)	Salticidae
Brettus cingulatus Thorell, 1895	
Carrhotus viduus (C. L. Koch, 1846)	
Chalcotropis pennata Simon, 1902	
Chrysilla volupe (Karsch, 1879)	
Epeus tener (Simon, 1877)	
Evarcha falcata (Clerck, 1757)	
Hasarius adansoni (Audouin, 1826)	

Hyllus semicupreus (Simon, 1885) *Indopadilla insularis* Malamel *et al*, 2015 *Menemerus bivittatus* (Dufour, 1831) *Myrmaplata plataleoides* (O. Pickard-Cambridge, 1869) *Myrmarachne melanocephala* Macleay, 1839 *Phidippus yashodharae* Tikader, 1977 *Phintella vittata* (C. L. Koch, 1846) *Plexippus paykulli* (Audouin, 1826) *Plexippus petersi* (Karsch, 1878) *Rhene flavigera* (C. L. Koch, 1846) *Siler semiglaucus* (Simon, 1901) *Telamonia dimidiata* (Simon, 1899) *Thiania bhamoensis* Thorell, 1887	
Heteropoda venatoria (Linnaeus, 1767)	Sparassidae
Leucauge dorsotuberculata Tikader, 1982 *Tetragnatha javana* (Thorell, 1890) *Tetragnatha mandibulata* Walckenaer, 1842 *Tylorida ventralis* Thorell, 1877	Tetragnathidae
Argyrodes kumadai Chida & Tanikawa, 1999 *Ariamnes flagellum* (Doleschall, 1857) *Meotipa argyrodiformis* (Yaginuma, 1952) *Theridion manjithar* Tikader, 1970	Theridiidae
Thomisus projectus Tikader, 1960 *Indoxysticus minutus* Tikader, 1960	Thomisidae

All the common species belonged to eight families. 21 common species belonged to the family Salticidae, 11 species to Araneidae. Family Oxyopidae owned 6 common species and Tetragnathidae and Theridiidae possessed 4 common species. Lycosidae and Thomisidae comprise 2 common species and Sparassidae comprises 1 common species. Their versatile predatory behaviour and excellent power of vision may be the reasons behind their wide distribution.

BTA showed one species that is not available in any other sites. NGM reported two unique species while NKR showed eight unique species. No unique species was reported from KZR and CRA (Table 4.21.).

Table 4.21. List species recorded from single study site

Site	Species
BTA	*Epeus sp.*
NGM	*Cheiracanthium melanostomum* (Thorell, 1895)
	Apochionomma sp.
NKR	*Cyclosa sp.*
	Neoscona sp.
	Lycosa tista Tikader, 1970
	Hamadruas sikkimensis (Tikader, 1970)
	Peucetia ananthakrishnani Murugesan *et al*., 2006
	Scytodes sp.
	Tetragnatha keyserlingi Simon, 1890
	Meotipa sp.

A PERMANOVA study was conducted in order to investigate the variation among the different site (beta diversity) and the results showed that there was some significant variation among the sites. The p-value obtained was 0.006, which indicates that the differences are statistically significant. Additionally, the F-value was 2.574, suggesting that the extent of this variation is relatively moderate (Table 4.22.). Specific pair wise comparison did not result a p value less than 0.05 in any case indicating that there is no statistically significant variation among any of the two sites directly.

Table 4.22 PERMANOVA analysis to investigate beta diversity

Permutation N:	Total sum of squares:	Within-group sum of squares:	F:	p
999	0.7944	0.3914	2.574	0.006

An nMDS (non-metric multidimensional scaling) plot was constructed using the data for a better understanding (Figure 4.9.). Highly clustered data points in the plot also supports the homogeneity among the sites.

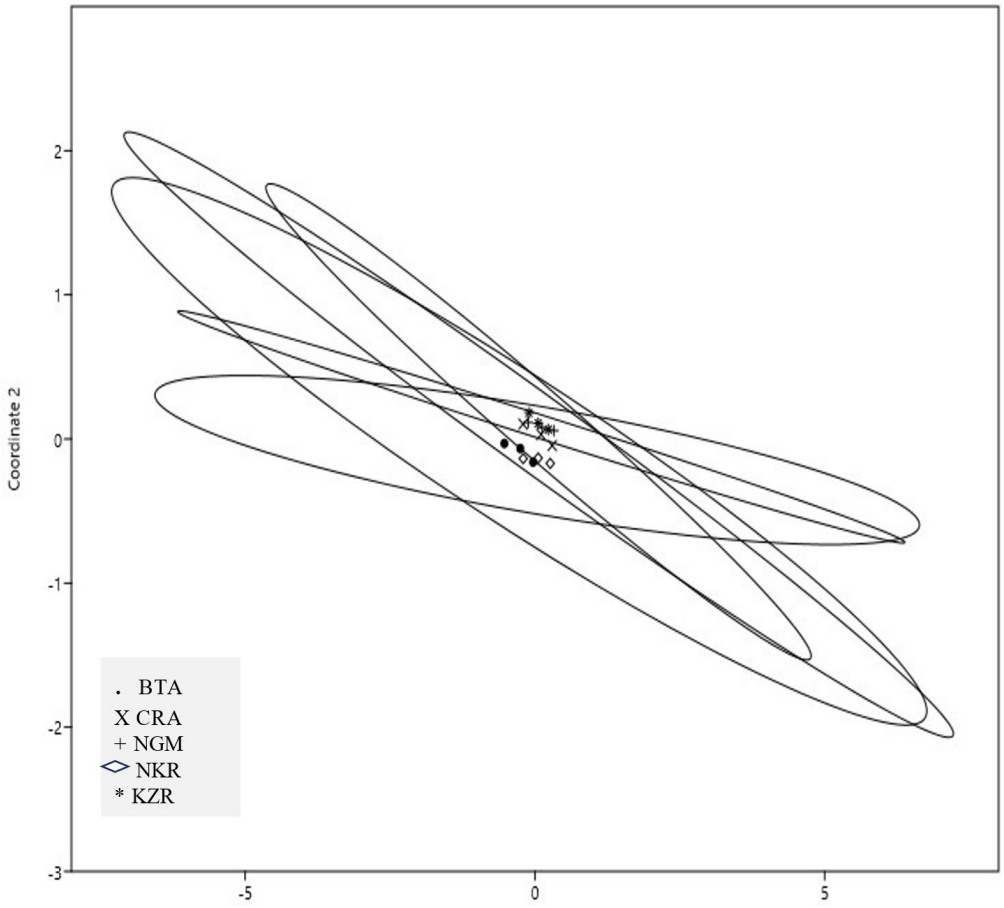


Figure 4.9. nMDS plot of study sites spider assemblage of the study sites

SIMPER analysis was conducted to calculate the dissimilarity among the sites. The overall average dissimilarity among the sites were 31.25 indicating a moderate dissimilarity. The pair wise analysis of dissimilarity was also calculated. It

was observed that overall average dissimilarity was highest between BTA and NGM (38.36) followed by BTA and CRA (37.90) and was lowest in the case of NGM-KZR (28.29) (Table 4.23). The range of average dissimilarity between the pairs also a suggested a moderate variation exists between these site pairs in terms of species composition and characteristics.

Table: 4.23. Pair wise comparison of overall average dissimilarity by Simper analysis

Pair	Overall average dissimilarity
BTA- NGM	38.36
BTA-CRA	37.90
BTA- KZR	36.99
BTA-NKR	36.32
NGM-NKR	32.79
CRA- NKR	32.56
NKR-KZR	31.35
NGM-KZR	31.35
CRA- KZR	30.83
CRA-NGM	28.29

Most influential groups contributing towards the dissimilarity in each pair was also identified using SIMPER. *Indopadilla insularis* was the one with the highest overall average dissimilarity in the case BTA-CRA, CRA-NGM, *Hyllus semicupreus* was the most influential one in the case of the dissimilarity between BTA -NGM, it was *Carrhotus viduus* in the case of BTA-NKR. *Oxyopes javanus* contributed the greatest to the dissimilarity between NGM-NKR, NKR-CRA. *Asemonea tenuipes* was the greatest contributor of dissimilarity of NKR-KZR, CRA-KZR and NGM-KZR. *Neoscona inustua* contributed to maximum to the dissimilarity of BTA-KZR (Table 4.24).

Table 4.24. Average dissimilarity and % contribution of most influential species in Similarity percentage study

Sites	Species	Av. dissimilarity	Contribution %
BTA – CRA	*Indopadilla insularis* (Malamel et al., 2015)	1.41	3.72
	Hasarius adansoni (Audouin, 1826)	1.24	3.27
	Asemonea tenuipes (O. Pickard-Cambridge, 1869)	1.22	3.22
BTA -NGM	*Hyllus semicupreus* (Simon, 1885)	1.34	3.49
	Cyrtophora cicatrosa (Stoliczka, 1869)	1.3	3.4
	Hasarius adansoni (Audouin, 1826)	1.29	3.37
BTA-NKR	*Carrhotus viduus* (C. L. Koch, 1846)	1.27	3.5
	Myrmaplata plataleoides (O. Pickard-Cambridge, 1869)	1.02	2.81
	Hyllus semicupreus (Simon, 1885)	0.99	2.72
BTA -KZR	*Neoscona inustua (*L. Koch, 1871)	1.38	3.71
	Hyllus semicupreus (Simon, 1885)	1.27	3.42
	Brettus cingulatus Thorell, 1895	1.15	3.18
CRA-NGM	*Indopadilla insularis* (Malamel et al., 2015)	1.89	4.11
	Anepsion maritatum (O. Pickard-Cambridge, 1877)	0.98	3.4
	Cyclosa hexatuberculata Tikader, 1982	0.82	2.82
CRA-NKR	*Oxyopes javanus* Thorell 1887	1.26	3.88
	Indopadilla insularis (Malamel et al., 2015)	0.77	2.37
	Anepsion maritatum (O. Pickard-Cambridge, 1877)	0.69	2.1
CRA-KZR	*Asemonea tenuipes* (O. Pickard-Cambridge, 1869)	1.29	4.18
	Indopadilla insularis (Malamel et al., 2015)	1.2	3.88
	Myrmaplata plataleoides (O. Pickard-Cambridge, 1869)	0.92	2.99
NGM-NKR	*Oxyopes javanus* Thorell, 1887	1.08	3.24
	Cyclosa hexatuberculata Tikader, 1982	0.94	2.88
	Oxyopes birmanicus Thorell, 1887	0.93	2.86
NGM-KZR	*Asemonea tenuipes* (O. Pickard-Cambridge, 1869)	1.34	4.73
	Brettus cingulatus Thorell, 1895	0.83	2.93
	Dendrolycosa gitae (Tikader, 1970)	0.77	2.71
NKR-KZR	*Asemonea tenuipes* (O. Pickard-Cambridge, 1869)	1.04	3.33
	Myrmaplata plataleoides (O. Pickard-Cambridge, 1869)	0.9	2.87
	Oxyopes javanus Thorell, 1887	0.86	2.74

One-way ANOSIM results were also agreeing to the existence of moderate dissimilarity among the diversity of study sites (Table 4.25. & Figure 4.10.). As the R values is much less than 1 (0.453), the dissimilarity between the group is moderate but it is statistically significant as the p value is less than 0.05 (0.03).

Table 4.25. Result of ANOSIM analysis of the study sites

Permutation N:	Mean rank within:	Mean rank between:	R:	p
999	32.6	56.4	0.453	0.03

The box plot of ranked distances also indicated that the dissimilarity between the groups is higher than the dissimilarity within the groups in all the five study sites.

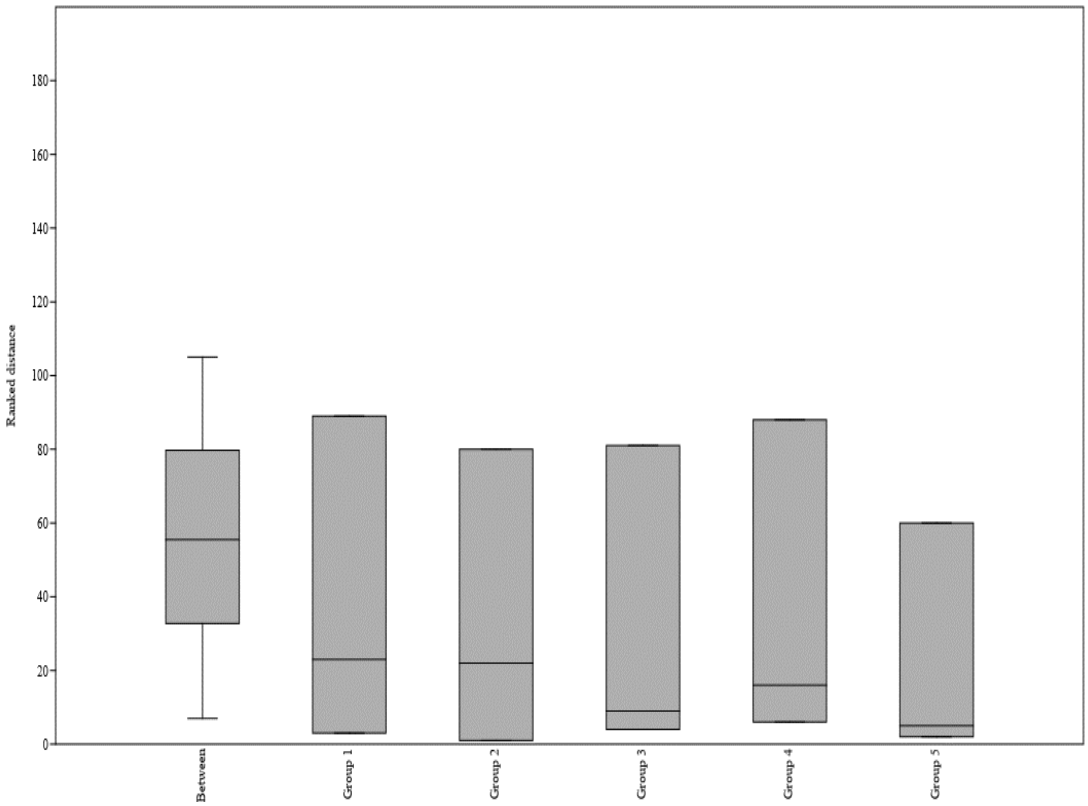


Figure 4.10. Comparison of dissimilarity between the groups and within the groups of spider assemblage in the study sites

From the statistical tools employed for the analysis of site wise diversity indicated that all the five sites showing high diversity of spiders and differs from each other moderately. Even though there are observable differences in the species composition, it contributed to a moderate level of dissimilarity only. It is also noteworthy that almost fifty percentage of species were common to all the five study sites.

4.3. Seasonal abundance, richness and diversity

Spider assemblage varied in types and numbers during different seasons. There are several factors responsible for these variations. Environmental conditions such as temperature, humidity, vegetation and availability of food etc. are some among them. The study period is split into three seasons each contains a quarter of year. Pre-monsoon (PRM- extends from February to May), Monsoon (MON- includes the months from June to September) and Post-monsoon (POM- October-January). Comparisons of spider abundance and richness during these study periods have been done.

4.3.1. Seasonal trends in spider abundance

Spider assemblage of horticultural crop fields of Thrissur district shows significant variation across the seasons. POM showed highest species abundance with 4227 individuals. MON ranked second with a toll of 2966 individuals and PRM came out with lowest abundance with only 1957 individuals (Figure 4.11.).

Indopadilla insularis was the most numerically abundant species in all the three seasons with 110, 135 and 163 individuals, respectively. Salticidae (903, 1018 and 1765 individuals respectively in PRM, MON and POM respectively) and Araneidae (464 individuals, 691 individual and 964 individuals in PRM, MON, POM respectively) ranked first and second position in the case of numerical abundance of individuals in all the three seasons.

Rank abundance curves were plotted with the abundance of spiders in all the three seasons (Figure 4.12.). High values of α (PRM - 16.66, MON - 17.29 and POM - 18.49) indicated high species richness during all the seasons. Richness is greatest in POM and lowest in PRM. The high value of shape parameter (PRM -

0.995, MON - 0.997, POM - 0.9978) indicated relatively even distribution of the abundance throughout the seasons.

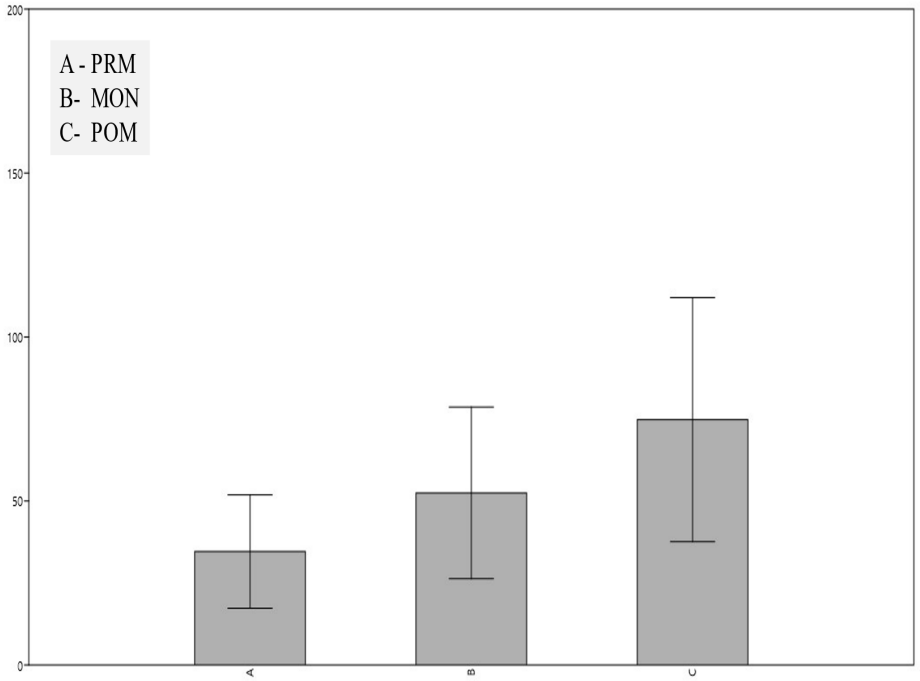


Figure 4.11. Seasonal variation in abundance of spiders

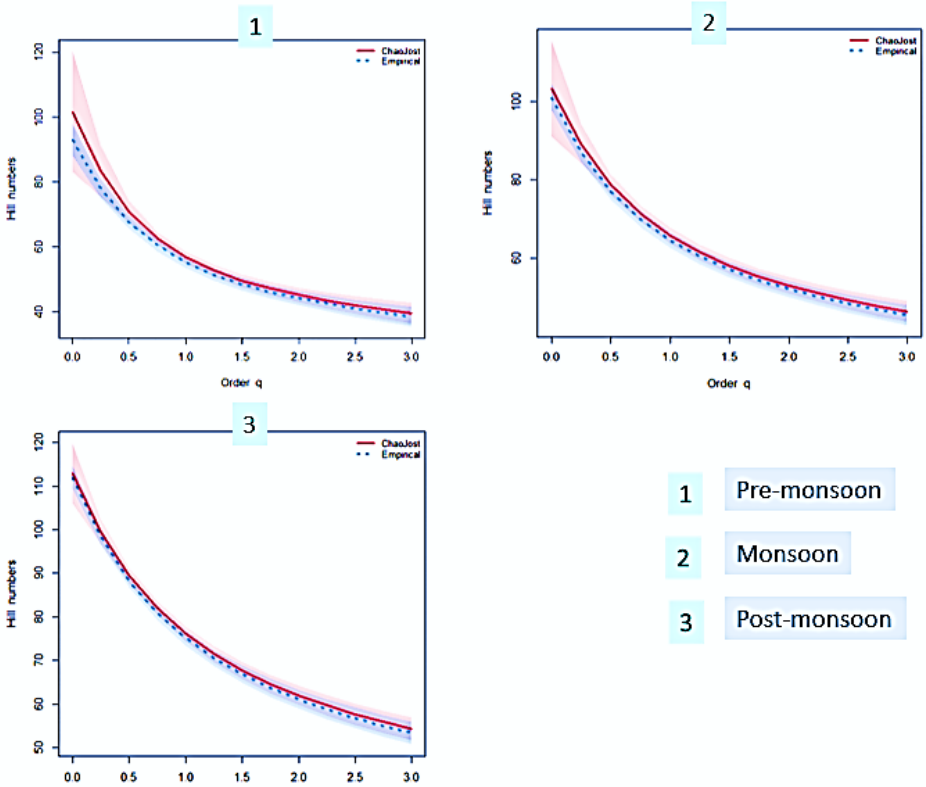


Figure 4.12. Rank abundance distribution of spiders during different seasons

4.3.2. Dominance structure of spiders across the seasons

Dominance structure of spider assemblage during PRM, MON and POM were studied by calculating individual dominance index and the species were categorised in to five dominance categories (eudominant, dominant, sub dominant, recedent, subrecedent) using Tischler's scale. No eudominant species was reported anywhere from the study sites. Only one dominant category was reported during PRM. Number of subdominants were 22 in PRM, 16 in MON and 10 in POM. Number of recedents were 15,22 and 30 in PRM, MON and POM, respectively. Number of individuals in subrecedent category was 55, 63 and 72 in PRM, MON and POM, respectively. This result also indicated the absence of higher degree of dominance during the seasons. It also pointed towards a higher degree of evenness during the seasons. It was also clear that the dominance structure also varies across the seasons (Table 4.26, 4.27 & 4.28).

Table 4.26. Analysis of dominance structure of spiders during PRM

Species	IDI	Category
Indopadilla insularis Malamel *et al*., 2015	5.62	Dominant
Myrmaplata plataleoides (O. P. Cambridge, 1869)	4.39	Subdominant
Carrhotus viduus (C. L. Koch, 1846)	3.27	Subdominant
Hyllus semicupreus (Simon, 1885)	3.22	Subdominant
*Neoscona inustua (*L. Koch, 1871)	3.07	Subdominant
Anepsion maritatum (O. Pickard-Cambridge, 1877)	2.96	Subdominant
Cyrtophora cicatrosa (Stoliczka, 1869)	2.86	Subdominant
Hasarius adansoni (Audouin, 1826)	2.81	Subdominant
Lycosa mackenziei Gravely, 1924	2.50	Subdominant
Brettus cingulatus Thorell, 1895	2.50	Subdominant
Plexippus paykulli (Audouin, 1826)	2.50	Subdominant
Plexippus petersi (Karsch, 1878)	2.50	Subdominant
Oxyopes birmanicus Thorell, 1887	2.40	Subdominant

Phintella vittata (C. L. Koch, 1846)	2.40	Subdominant
Cyclosa hexatuberculata Tikader, 1982	2.35	Subdominant
Telamonia dimidiata (Simon, 1899)	2.35	Subdominant
Cyrtophora citricola (Forsskal, 1775)	2.30	Subdominant
Oxyopes javanus Thorell, 1887	2.25	Subdominant
Asemonea tenuipes (O. Pickard-Cambridge, 1869)	2.20	Subdominant
Tetragnatha mandibulata Walckenaer, 1842	2.10	Subdominant
Chrysilla volupe (Karsch, 1879)	2.04	Subdominant
Siler semiglaucus (Simon, 1901)	2.04	Subdominant
Tetragnatha javana (Thorell, 1890)	2.04	Subdominant
Argiope pulchella Thorell, 18811	1.89	Recedent
Neoscona mukerjei Tikader, 1980	1.74	Recedent
Tylorida ventralis Thorell, 1877	1.74	Recedent
Theridion manjithar Tikader, 1970	1.64	Recedent
Myrmarachne melanocephala MacLeay, 1839	1.58	Recedent
Meotipa argyrodiformis (Yaginuma, 1952)	1.53	Recedent
Leucauge dorsotuberculata Tikader, 1982	1.48	Recedent
Pardosa sumatrana (Thorell, 1890)	1.38	Recedent
Epeus tener (Simon, 1877)	1.38	Recedent
Ariamnes flagellum (Doleschall, 1857)	1.33	Recedent
Thomisus projectus Tikader, 1960	1.28	Recedent
Heteropoda venatoria (Linnaeus, 1767)	1.23	Recedent
Argiope anasuja Thorell, 1887	1.12	Recedent
Menemerus bivittatus (Dufour, 1831)	1.07	Recedent
Gasteracantha geminata (Fabricius, 1798)	1.02	Recedent
Indoxysticus minutus Tikader, 1960	0.92	Subrecedent
Oxytate virens (Thorell, 1891)	0.92	Subrecedent
Eriovixia laglaizei (Simon, 1877)	0.87	Subrecedent
Rhene flavigera (C. L. Koch, 1846)	0.82	Subrecedent
Thiania bhamoensis Thorell, 1887	0.82	Subrecedent
Argiope aemula (Walckenaer, 1842)	0.77	Subrecedent
Neoscona vigilans (Blackwall, 1865)	0.66	Subrecedent
Peucetia viridana (Stoliczka, 1869)	0.66	Subrecedent

Olios milleti (Pocock, 1901)	0.61	Subrecedent
Chalcotropis pennata Simon, 1902	0.56	Subrecedent
Phidippus yashodharae Tikader, 1977	0.56	Subrecedent
Cyrtophora moluccensis (Doleschall, 1857)	0.51	Subrecedent
Hersilia sumatrana (Thorell, 1890)	0.41	Subrecedent
Bianor angulosus (Karsch, 1879)	0.41	Subrecedent
Tetragnatha viridorufa Gravely, 1921	0.41	Subrecedent
Cyclosa bifida (Doleschall, 1859)	0.36	Subrecedent
Eriovixia excelsa (Simon, 1889)	0.36	Subrecedent
Neoscona elliptica Tikader & Bal, 1981	0.31	Subrecedent
Tylorida striata (Thorell, 1877)	0.31	Subrecedent
Cyrtophora sp.	0.26	Subrecedent
Clubiona drassodes O.P. Cambridge, 1874	0.26	Subrecedent
Evarcha falcata (Clerck, 1757)	0.26	Subrecedent
Portia fimbriata (Doleschall, 1859)	0.26	Subrecedent
Hamadruas sikkimensis (Tikader,1970)	0.20	Subrecedent
Oxyopes sp.	0.20	Subrecedent
Tetragnatha cochinensis Gravely, 1921	0.20	Subrecedent
Argyrodes kumadai Chida & Tanikawa, 1999	0.20	Subrecedent
Bijoaraneus mitificus (Simon, 1886)	0.15	Subrecedent
Cheiracanthium melanostomum (Thorell, 1895)	0.15	Subrecedent
Corinnomma sp.	0.15	Subrecedent
Hahnia mridulae Tikader, 1970	0.15	Subrecedent
Lycosa tista Tikader, 1970	0.15	Subrecedent
Oxyopes hindostanicus Pocock, 1901	0.15	Subrecedent
Oxyopes lineatipes (C L Koch, 1847)	0.15	Subrecedent
Oxyopes shweta Tikader, 1970	0.15	Subrecedent
Oxyopes sunandae Tikader, 1970	0.15	Subrecedent
Stenaelurillus sp.	0.15	Subrecedent
Bowie cochinensis (Gravely, 1931)	0.10	Subrecedent
Oxyopes bharatae Gajbe, 1999	0.10	Subrecedent
Epeus indicus Proszynski,1992	0.10	Subrecedent
Evarcha sp.	0.10	Subrecedent

Thyene bivittata Xie & Peng, 1995	0.10	Subrecedent
Scytodes fusca Walckenaer, 1837	0.10	Subrecedent
Amyciaea forticeps (O. Pickard-Cambridge, 1873)	0.10	Subrecedent
Argiope catenulata (Doleschall, 1859)	0.05	Subrecedent
Cyclosa confraga (Thorell, 1893)	0.05	Subrecedent
Neoscona sp.	0.05	Subrecedent
Cheiracanthium danieli Tikader, 1975	0.05	Subrecedent
Drassodes sp.	0.05	Subrecedent
Crossopriza lyoni (Blackwall, 1867)	0.05	Subrecedent
Epeus sp.	0.05	Subrecedent
Phaeacius lancearius (Thorell, 1895)	0.05	Subrecedent
Scytodes sp.	0.05	Subrecedent
Argyrodes sp.	0.05	Subrecedent
Strigoplus netravati Tikader, 1963	0.05	Subrecedent

Table 4.27. Dominance structure of spider assemblage during MON

Species	IDI	Category
Indopadilla insularis Malamel, Sankaran & Sebastian, 2015	4.55	Subdominant
Myrmaplata plataleoides (O. Pickard-Cambridge, 1869)	4.01	Subdominant
Anepsion maritatum (O. Pickard-Cambridge, 1877)	3.17	Subdominant
Carrhotus viduus (C. L. Koch, 1846)	3.14	Subdominant
Hyllus semicupreus (Simon, 1885)	2.87	Subdominant
*Neoscona inustua (*L. Koch, 1871)	2.66	Subdominant
Hasarius adansoni (Audouin, 1826)	2.56	Subdominant
Cyrtophora cicatrosa (Stoliczka, 1869)	2.39	Subdominant
Plexippus petersi (Karsch, 1878)	2.39	Subdominant
Siler semiglaucus (Simon, 1901)	2.26	Subdominant
Lycosa mackenziei Gravely, 1924	2.16	Subdominant
Tetragnatha mandibulata Walckenaer, 1842	2.16	Subdominant
Plexippus paykulli (Audouin, 1826)	2.12	Subdominant
Oxyopes birmanicus Thorell, 1887	2.06	Subdominant
Brettus cingulatus Thorell, 1895	2.06	Subdominant

Phintella vittata (C. L. Koch, 1846)	2.06	Subdominant
Telamonia dimidiata (Simon, 1899)	2.06	Recedent
Cyrtophora citricola (Forsskal, 1775)	1.99	Recedent
Oxyopes javanus Thorell, 1887	1.99	Recedent
Chrysilla volupe (Karsch, 1879)	1.99	Recedent
Asemonea tenuipes (O. Pickard-Cambridge, 1869)	1.89	Recedent
Tetragnatha javana (Thorell, 1890)	1.89	Recedent
Argiope pulchella Thorell, 1881	1.82	Recedent
Neoscona mukerjei Tikader, 1980	1.75	Recedent
Tylorida ventralis Thorell, 1877	1.75	Recedent
Myrmarachne melanocephala MacLeay, 1839	1.72	Recedent
Cyclosa hexatuberculata Tikader, 1982	1.58	Recedent
Meotipa argyrodiformis (Yaginuma, 1952)	1.58	Recedent
Epeus tener (Simon, 1877)	1.55	Recedent
Leucauge dorsotuberculata Tikader, 1982	1.48	Recedent
Pardosa sumatrana (Thorell, 1890)	1.28	Recedent
Argiope anasuja Thorell, 1887	1.25	Recedent
Theridion manjithar Tikader, 1970	1.25	Recedent
Gasteracantha geminata (Fabricius, 1798)	1.21	Recedent
Menemerus bivittatus (Dufour, 1831)	1.21	Recedent
Ariamnes flagellum (Doleschall, 1857)	1.11	Recedent
Peucetia viridana (Stoliczka, 1869)	1.08	Recedent
Thomisus projectus Tikader, 1960	1.08	Recedent
Heteropoda venatoria (Linnaeus, 1767)	1.05	Subrecedent
Thiania bhamoensis Thorell, 1887	0.98	Subrecedent
Argiope aemula (Walckenaer, 1842)	0.91	Subrecedent
Phidippus yashodharae Tikader, 1977	0.91	Subrecedent
Rhene flavigera (C. L. Koch, 1846)	0.91	Subrecedent
Eriovixia laglaizei (Simon, 1877)	0.88	Subrecedent
Indoxysticus minutus Tikader, 1960	0.84	Subrecedent
Cyrtophora moluccensis (Doleschall, 1857)	0.71	Subrecedent
Oxyopes shweta Tikader, 1970	0.71	Subrecedent
Tetragnatha viridorufa Gravely, 1921	0.67	Subrecedent

Oxyopes sunandae Tikader, 1970	0.64	Subrecedent
Olios milleti (Pocock, 1901)	0.64	Subrecedent
Oxytate virens (Thorell, 1891)	0.64	Subrecedent
Dendrolycosa gitae (Tikader, 1970)	0.61	Subrecedent
Evarcha falcata (Clerck, 1757)	0.61	Subrecedent
Neoscona vigilans (Blackwall, 1865)	0.57	Subrecedent
Hersilia sumatrana (Thorell, 1890)	0.57	Subrecedent
Neoscona elliptica Tikader & Bal, 1981	0.54	Subrecedent
Hamadruas sikkimensis (Tikader,1970)	0.54	Subrecedent
Chalcotropis pennata Simon, 1902	0.51	Subrecedent
Portia fimbriata (Doleschall, 1859)	0.47	Subrecedent
Oxyopes lineatipes (C L Koch, 1847)	0.44	Subrecedent
Clubiona drassodes O.P. Cambridge, 1874	0.40	Subrecedent
Phaeacius lancearius (Thorell, 1895)	0.40	Subrecedent
Tetragnatha cochinensis Gravely, 1921	0.40	Subrecedent
Bijoaraneus mitificus (Simon, 1886)	0.37	Subrecedent
Cyclosa confraga (Thorell, 1893)	0.37	Subrecedent
Eriovixia excelsa (Simon, 1889)	0.37	Subrecedent
Corinnomma sp.	0.37	Subrecedent
Epeus indicus Proszynski,1992	0.37	Subrecedent
Argyrodes kumadai Chida & Tanikawa, 1999	0.37	Subrecedent
Leucauge decorata (Blackwall, 1864)	0.34	Subrecedent
Bianor angulosus (Karsch, 1879)	0.30	Subrecedent
Lycosa tista Tikader, 1970	0.27	Subrecedent
Oxyopes bharatae Gajbe, 1999	0.27	Subrecedent
Oxyopes hindostanicus Pocock, 1901	0.27	Subrecedent
Thyene bivittata Xie & Peng, 1995	0.27	Subrecedent
Tylorida striata (Thorell, 1877)	0.24	Subrecedent
Argiope catenulata (Doleschall, 1859)	0.20	Subrecedent
Cyclosa bifida (Doleschall, 1859)	0.20	Subrecedent
Pholcus phalangioides (Fuesslin, 1775)	0.13	Subrecedent
Stenaelurillus lesserti Reimoser, 1934	0.13	Subrecedent
Araneus sp.	0.10	Subrecedent

Gea subarmata Thorell, 1890	0.10	Subrecedent
Cheiracanthium danieli Tikader, 1975	0.10	Subrecedent
Hahnia mridulae Tikader, 1970	0.10	Subrecedent
Crossopriza lyoni (Blackwall, 1867)	0.10	Subrecedent
Thelcticopis moolampilliensis Jose & Sebastian, 2007	0.10	Subrecedent
Strigoplus netravati Tikader, 1963	0.10	Subrecedent
Cyclosa sp.	0.07	Subrecedent
Cyrtophora sp.	0.07	Subrecedent
Cheiracanthium melanostomum (Thorell, 1895)	0.07	Subrecedent
Hippasa agelenoides (Simon, 1884)	0.07	Subrecedent
Oxyopes sp.	0.07	Subrecedent
Stenaelurillus sp.	0.07	Subrecedent
Scytodes fusca Walckenaer, 1837	0.07	Subrecedent
Phoroncidia septemaculeata O. Pickard-Cambridge, 1873	0.07	Subrecedent
Drassodes sp.	0.03	Subrecedent
Thanatus parangvulgaris Barrion & Litsinger, 1995	0.03	Subrecedent
Epeus sp.	0.03	Subrecedent
Evarcha sp.	0.03	Subrecedent
Amyciaea forticeps (O. Pickard-Cambridge, 1873)	0.03	Subrecedent
Miagrammopes extensus Simon, 1889	0.03	Subrecedent

Table 4.28. Dominance structure of spider assemblage during POM

Species	IDI	Category
Indopadilla insularis Malamel, Sankaran & Sebastian, 2015	3.86	Subdominant
Myrmaplata plataleoides (O. Pickard-Cambridge, 1869)	3.48	Subdominant
Anepsion maritatum (O. Pickard-Cambridge, 1877)	3.19	Subdominant
Hyllus semicupreus (Simon, 1885)	2.58	Subdominant
Carrhotus viduus (C. L. Koch, 1846)	2.48	Subdominant
*Neoscona inustua (*L. Koch, 1871)	2.34	Subdominant
Cyrtophora cicatrosa (Stoliczka, 1869)	2.32	Subdominant
Hasarius adansoni (Audouin, 1826)	2.13	Subdominant
Plexippus petersi (Karsch, 1878)	2.13	Subdominant

Brettus cingulatus Thorell, 1895	2.13	Subdominant
Lycosa mackenziei Gravely, 1924	2.01	Recedent
Siler semiglaucus (Simon, 1901)	1.99	Recedent
Plexippus paykulli (Audouin, 1826)	1.99	Recedent
Phintella vittata (C. L. Koch, 1846)	1.89	Recedent
Asemonea tenuipes (O. Pickard-Cambridge, 1869)	1.82	Recedent
Tetragnatha mandibulata Walckenaer, 1842	1.80	Recedent
Oxyopes birmanicus Thorell, 1887	1.80	Recedent
Oxyopes javanus Thorell, 1887	1.80	Recedent
Telamonia dimidiata (Simon, 1899)	1.77	Recedent
Cyrtophora citricola (Forsskal, 1775)	1.73	Recedent
Tetragnatha javana (Thorell, 1890)	1.70	Recedent
Chrysilla volupe (Karsch, 1879)	1.68	Recedent
Argiope pulchella Thorell, 1881	1.68	Recedent
Neoscona mukerjei Tikader, 1980	1.68	Recedent
Myrmarachne melanocephala MacLeay, 1839	1.66	Recedent
Cyclosa hexatuberculata Tikader, 1982	1.61	Recedent
Meotipa argyrodiformis (Yaginuma, 1952)	1.49	Recedent
Epeus tener (Simon, 1877)	1.42	Recedent
Tylorida ventralis Thorell, 1877	1.40	Recedent
Menemerus bivittatus (Dufour, 1831)	1.40	Recedent
Pardosa sumatrana (Thorell, 1890)	1.35	Recedent
Leucauge dorsotuberculata Tikader, 1982	1.32	Recedent
Theridion manjithar Tikader, 1970	1.25	Recedent
Peucetia viridana (Stoliczka, 1869)	1.18	Recedent
Indoxysticus minutus Tikader, 1960	1.18	Recedent
Argiope anasuja Thorell, 1887	1.16	Recedent
Ariamnes flagellum (Doleschall, 1857)	1.14	Recedent
Thomisus projectus Tikader, 1960	1.14	Recedent
Rhene flavigera (C. L. Koch, 1846)	1.06	Recedent
Heteropoda venatoria (Linnaeus, 1767)	1.02	Recedent
Oxyopes sunandae Tikader, 1970	1.02	Subrecedent
Gasteracantha geminata (Fabricius, 1798)	0.99	Subrecedent

Argiope aemula (Walckenaer, 1842)	0.88	Subrecedent
Thiania bhamoensis Thorell, 1887	0.83	Subrecedent
Oxyopes shweta Tikader, 1970	0.83	Subrecedent
Evarcha falcata (Clerck, 1757)	0.80	Subrecedent
Neoscona vigilans (Blackwall, 1865)	0.80	Subrecedent
Chalcotropis pennata Simon, 1902	0.80	Subrecedent
Hamadruas sikkimensis (Tikader,1970)	0.78	Subrecedent
Phidippus yashodharae Tikader, 1977	0.73	Subrecedent
Oxytate virens (Thorell, 1891)	0.69	Subrecedent
Eriovixia laglaizei (Simon, 1877)	0.66	Subrecedent
Cyrtophora moluccensis (Doleschall, 1857)	0.66	Subrecedent
Olios milleti (Pocock, 1901)	0.64	Subrecedent
Dendrolycosa gitae (Tikader, 1970)	0.64	Subrecedent
Argyrodes kumadai Chida & Tanikawa, 1999	0.64	Subrecedent
Hersilia sumatrana (Thorell, 1890)	0.62	Subrecedent
Neoscona elliptica Tikader & Bal, 1981	0.62	Subrecedent
Oxyopes lineatipes (C L Koch, 1847)	0.62	Subrecedent
Bianor angulosus (Karsch, 1879)	0.59	Subrecedent
Tetragnatha viridorufa Gravely, 1921	0.57	Subrecedent
Stenaelurillus lesserti Reimoser, 1934	0.52	Subrecedent
Araneus mitificus Simon 1886	0.50	Subrecedent
Epeus indicus Proszynski,1992	0.50	Subrecedent
Leucauge decorata (Blackwall, 1864)	0.50	Subrecedent
Oxyopes hindostanicus Pocock, 1901	0.50	Subrecedent
Corinnomma sp.	0.47	Subrecedent
Oxyopes bharatae Gajbe, 1999	0.47	Subrecedent
Clubiona drassodes O.P. Cambridge, 1874	0.43	Subrecedent
Tetragnatha cochinensis Gravely, 1921	0.43	Subrecedent
Cyclosa confraga (Thorell, 1893)	0.43	Subrecedent
Cyclosa bifida (Doleschall, 1859)	0.43	Subrecedent
Lycosa tista Tikader, 1970	0.40	Subrecedent
Eriovixia excelsa (Simon, 1889)	0.38	Subrecedent
Portia fimbriata (Doleschall, 1859)	0.35	Subrecedent

Phaeacius lancearius (Thorell, 1895)	0.35	Subrecedent
Thyene bivittata Xie & Peng, 1995	0.35	Subrecedent
Tylorida striata (Thorell, 1877)	0.35	Subrecedent
Strigoplus netravati Tikader, 1963	0.33	Subrecedent
Stenaelurillus sp.	0.33	Subrecedent
Pholcus phalangioides (Fuesslin, 1775)	0.28	Subrecedent
Araneus sp.	0.26	Subrecedent
Gea subarmata Thorell, 1890	0.24	Subrecedent
Phoroncidia septemaculeata O. Pickard-Cambridge, 1873	0.24	Subrecedent
Drassodes sp.	0.24	Subrecedent
Argiope catenulata (Doleschall, 1859)	0.19	Subrecedent
Thelcticopis moolampilliensis Jose & Sebastian, 2007	0.19	Subrecedent
Cheiracanthium melanostomum (Thorell, 1895)	0.19	Subrecedent
Crossopriza lyoni (Blackwall, 1867)	0.17	Subrecedent
Hippasa agelenoides (Simon, 1884)	0.17	Subrecedent
Thanatus parangvulgaris Barrion & Litsinger, 1995	0.14	Subrecedent
Pardosa pseudoannulata (Bosenberg& Strand, 1906)	0.14	Subrecedent
Cheiracanthium danieli Tikader, 1975	0.12	Subrecedent
Scytodes fusca Walckenaer, 1837	0.12	Subrecedent
Amyciaea forticeps (O. Pickard-Cambridge, 1873)	0.12	Subrecedent
Psellonus sp.	0.12	Subrecedent
Hahnia mridulae Tikader, 1970	0.09	Subrecedent
Oxyopes sp.	0.09	Subrecedent
Cyrtophora sp.	0.07	Subrecedent
Epeus sp.	0.07	Subrecedent
Miagrammopes extensus Simon, 1889	0.07	Subrecedent
Hersilia savignyisavignyi Lucas, 1836	0.07	Subrecedent
Peucetia ananthakrishnani Murugesan et al., 2006	0.07	Subrecedent
Argyrodes sp.	0.07	Subrecedent
Evarcha sp.	0.05	Subrecedent
*Apochionomma sp.*1	0.05	Subrecedent
Tetragnatha keyserlingi Simon, 1890	0.05	Subrecedent
Meotipa sp.	0.05	Subrecedent

Uloborus krishnae Tikader, 1971	0.05	Subrecedent
Castianeira zetes Simon, 1897	0.02	Subrecedent
Nephila pilipes (Fabricius, 1793)	0.02	Subrecedent
Runcinia insecta (L. Koch, 1875)	0.02	Subrecedent

4.3.3. Season- wise in richness of spiders

Seasonal changes in environmental conditions affect not only the numerical abundance of spiders but also their species richness in the habitats. Seasonal variations are a little bit more complex in the case of a semi-natural ecosystem like agricultural fields due to the constant human interventions. Practises like irrigation, application of agrochemicals, the stage of growth of crop plants etc. also contribute towards the variation in the species richness. The number of species reported showed noticeable variation across the seasons. POM showed highest richness with 112 Species while PMN showed the lowest with 93 species (Table 4.29. & Figure 4.13.)

Table 4.29. Dynamics of species richness across the seasons

Season	No. of species	No. of families	No. of genera	Singletons	Doubletons
PRM	93	13	62	11	7
MON	101	15	68	6	8
POM	112	21	75	3	5

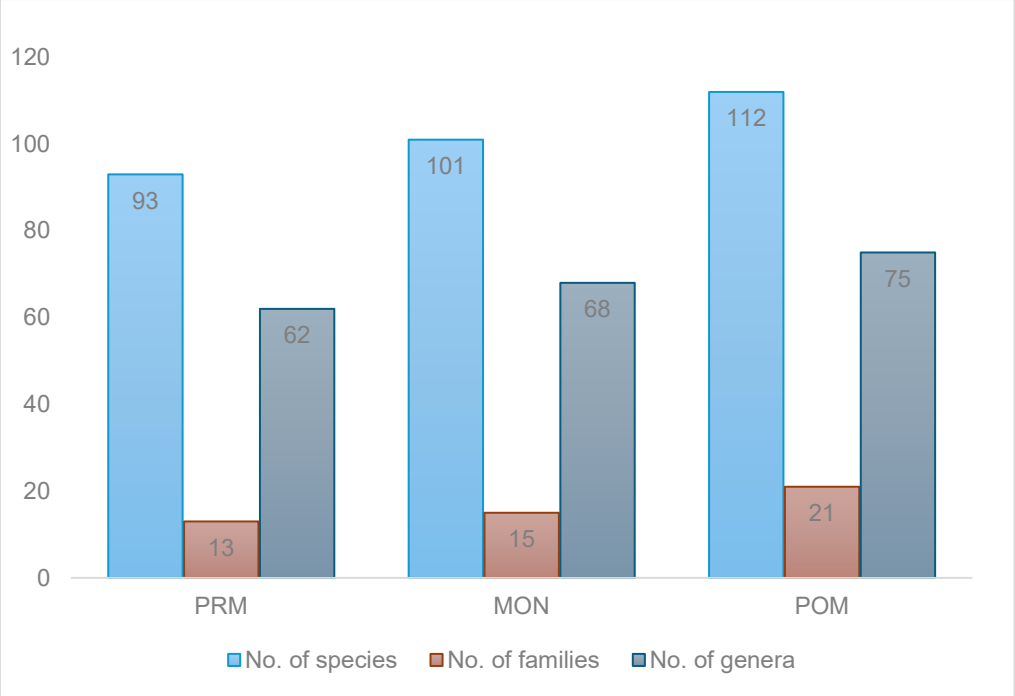


Figure 4.13. Comparison of the seasonal variation in the number of species genera and families

All the species richness estimators employed to understand the issue of under estimation, suggested a moderately high species richness than the observed richness (Table 4.30.). The difference between the species richness calculated by the estimators and observed richness was highest in the case of POM and it was least in the case of PRM. So, inadequacy in sample estimation is small.

Table 4.30. Season wise species richness predicted by different species richness estimators

	Chao1 (Chao, 1984)	Chao1-bc	iChao1	ACE (Chao & Lee, 1992)	ACE-1 (Chao & Lee, 1992)
PRM	101.6±6.8	99.9±5.6	103.0±3.8	99.6 ±4.2	100.6±5.0
MON	103.2±2.5	102.7±2.0	103.2±2.5	104.7±2.9	105.2±3.4
POM	112.9±1.5	112.5±1.0	112.9±1.5	113.2±1.4	113.2±1.5

Species accumulation curve during different seasons (Figure 4.14.) was also plotted during the three study seasons to estimate the sampling efficiency. As the plot almost approached to form a plateau, we could assume that the collection efficiency was almost adequate. The estimated sampling efficiency was highest in POM (99.4%) and lowest in PRM (98.4%). It was 98.8% in the case of MON. This agrees with the difference in the richness calculated by different estimators and observed richness.

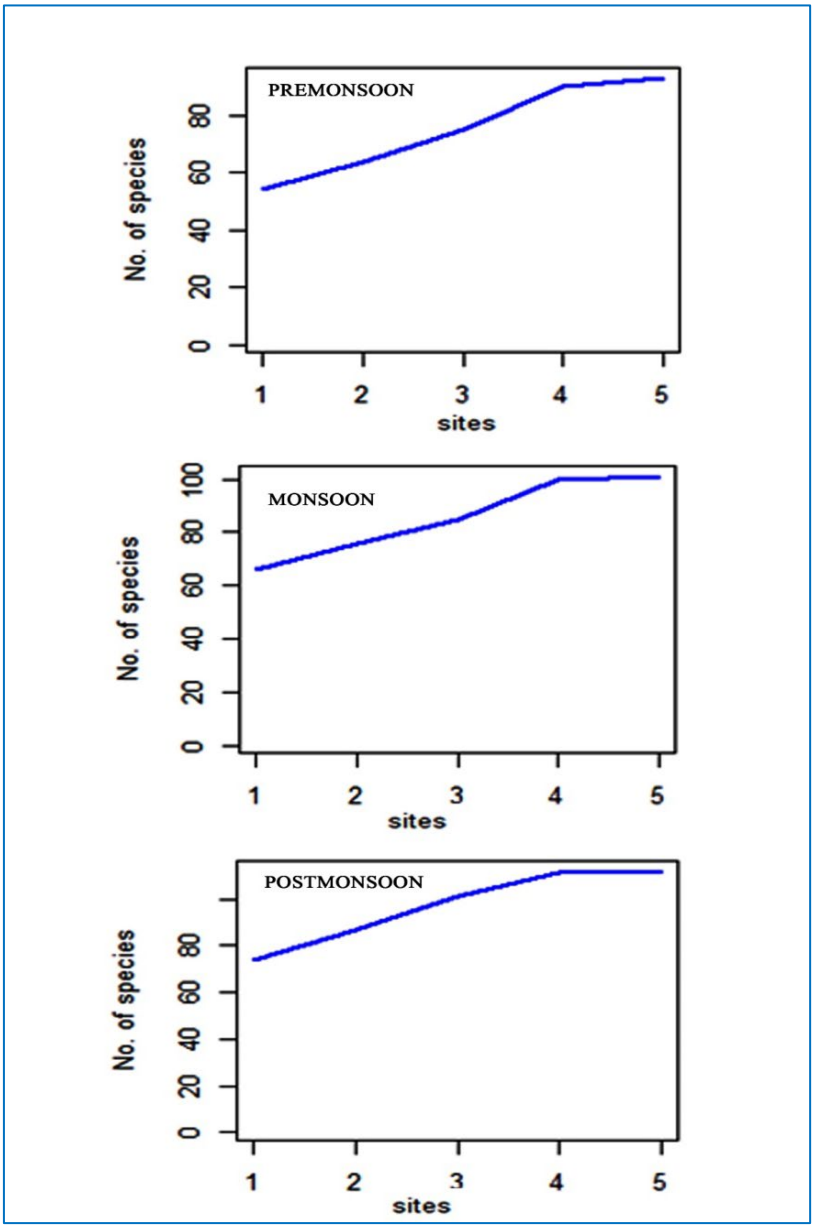


Figure 4.14. Species accumulation curve (Collector's curve) during different seasons

4.3.4. Diversity indices during different seasons

Shannon-Wiener index (H) and Simpson index (D) were calculated for the spider assemblage during the seasons PRM, MON and POM. Value of H is highest in POM and lowest in PRM (Table 4.31). D value is smallest in the case of POM followed by MON. This revealed the highest diversity in the POM followed by MON and lowest in the case of PRM.

Table 4.31. Diversity indices during different seasons

Season	H ± SE	D ± SE
PRM	4.014±0.018	0.0221± 0.0006
MON	4.167±0.016	0.0188 ±0.0004
POM	4.319±0.012	0.01614±0.0003

Effective numbers/ Hill numbers were also calculated for the spiders of different seasons for the better understanding of the multidimensional diversity (Table 4.32.). The richness, Shannon diversity and Simpson diversity were greatest for POM and least for PRM. In all the cases, richness, Shannon and Simpson diversities predicted by Chao & Joast was greater than the observed values. The difference between all the parameters estimated by Chao Joast estimator and observed values, were the greatest in the case of PRM. The estimator also predicts highest richness and diversity during POM.

Table 4.32. Hill number corresponding to q=0,1, and 2 during different seasons

Season	Estimator	^{0}D (Richness)	^{1}D (Shannon diversity)	^{2}D (Simpson diversity)
PRM	Chao Joast	101.64	56.90	45.30
	Observed	93.00	55.37	44.30
MON	Chao Joast	103.24	65.80	53.10
	Observed	101.00	64.23	52.18
PON	Chao Joast	112.9	76.12	61.97
	Observed	112.00	75.09	61.09

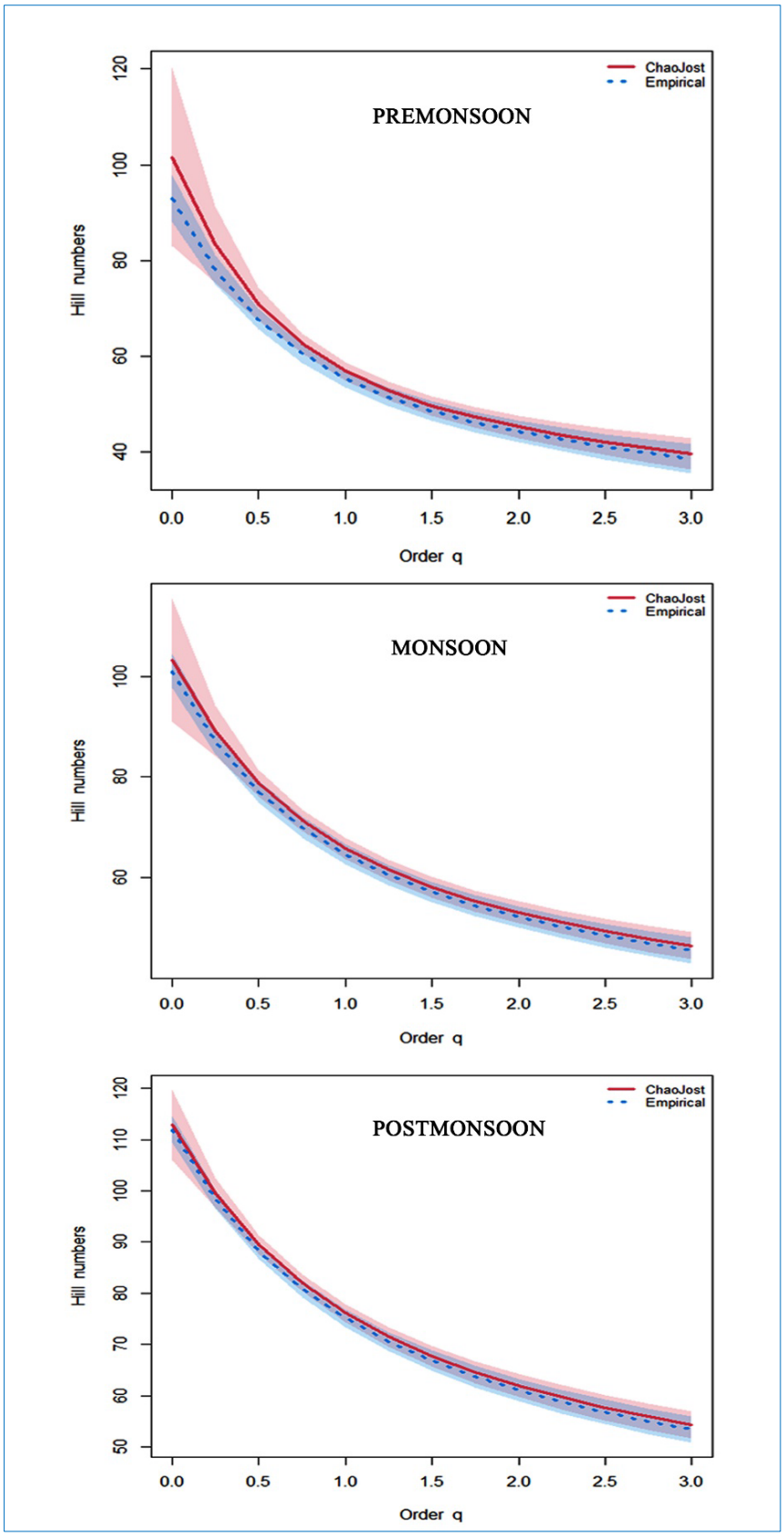


Figure 4.15. Diversity profile curve of spider assemblage during different seasons

Diversity profile curves are constructed by plotting hill numbers against q, the shapes of curves revealed that there exists moderate degree of evenness among different species of spiders. The steepest decline in the case of PRM revealed lowest evenness and comparatively higher dominance existed during the season.

4.3.5. Comparison of spider diversity during different seasons

The abundance and richness of spiders were found to be highest in POM and lowest in PRM. 89 species out of the 116 species (76.7%) reported are common to all the three seasons even though their numerical abundance varied between seasons. Three species reported only during PRM, One only during MON and 11 species reported on during POM (Table 4.33.).

Table 4.33. Number species recorded during single season only

SEASON	SPECIES
PRM	*Neoscona sp.*
	Corinnomma sp.
	Scytodes sp.
MON	*Cyclosa sp.*
POM	*Clubiona drassodes* O.P. Cambridge, 1874
	Apochionomma sp.
	Hahnia mridulae Tikader, 1970
	Lycosa tista Tikader, 1970
	Hamadruas sikkimensis (Tikader,1970)
	Peucetia ananthakrishnani Murugesan *et al*., 2006
	Psellonus sp.
	Tetragnatha keyserlingi Simon, 1890
	Meotipa sp.
	Runcinia insecta (L. Koch, 1875)
	Uloborus krishnae Tikader, 1971

Kruskal Wallis test was done to find out whether the difference in the abundance of different seasons is statistically significant. It substantiated the existence of a statistically significant difference in the abundance of spiders across the seasons as $p < .005$ (Table 4.34).

Table 4.34. Season wise comparison of abundance of spiders by Kruskal Wallis test

χ^2	Df	P
29.34	2	4.106e-7,

A Post-Hoc Dunn's test was conducted to pick out which pairs have been significantly contributed to this difference. The Post-Hoc Dunn's test using a Bonferroni corrected alpha indicated that the all the three pairs are significantly different since p value is less than 0.005 in all the cases (Table 4.35).

Table 4.35. Pair wise comparison of abundance of spiders using Dunn's test

Column1	**PRN-MON**	**PON-PRN**	**MON-PON**
PRN-MON		0.03106	1.78E-07
PON-PRN	0.03106		0.01284
MON-PON	1.78E-07	0.01284	

SIMPER analysis was conducted to assess the overall average dissimilarity. The pooled overall average dissimilarity was 34.1. The average dissimilarity between PRM-MON, MON-POM, PRM- POM was 31.71, 28.88 and 41.45, respectively. This made it clear that the species composition differed the most between PRM and POM. *Asemonea tenuipes* contributed the highest dissimilarity in case of PRM-POM and MON-POM while *Carrhotus viduus* was the most influential species that resulted in the dissimilarity between PRM-MON (Table 4.36).

Table 4.36. Most influential species contributed towards the dissimilarity of spiders during different seasons

Season	Species	Av. dissimilarity	% Contrib.
PRN-MON	*Carrhotus viduus* (C. L. Koch, 1846)	0.85	2.687
	Asemonea tenuipes (O. Pickard-Cambridge, 1869)	0.83	2.631
	Myrmaplata plataleoides (O. Pickard-Cambridge, 1869)	0.82	2.597
PON-PRN	*Anepsion maritatum* (O. Pickard-Cambridge, 1877)	1.24	3
	Myrmaplata plataleoides (O. Pickard-Cambridge, 1869)	1.02	2
	Indopadilla insularis Malamel, Sankaran & Sebastian, 2015	0.97	2
MON-PON	*Asemonea tenuipes* (O. Pickard-Cambridge, 1869)	0.66	2.271
	Carrhotus viduus (C. L. Koch, 1846)	0.63	2.189
	Anepsion maritatum (O. Pickard-Cambridge, 1877)	0.63	2.171

4.3.6. Seasonal spider diversity across different sites - A comparison

The variation in richness and abundance in distinct sites during the different seasons also studied. It is found that the abundance of spiders was highest during POM in all the five sites and lowest in PRM (Figure 4.16.). The difference between the abundance in PRM and MON was found to be highest in CRA while the difference in the abundance between POM and MON as well as POM and PRM was highest in the case of NKR. Highest numerical abundance was highest in NGM during all the three seasons while the species richness was highest in NKR (Table 4.37.).

Table 4.37. Comparison of richness and abundance during different seasons

Season		BTA	CRA	NGM	NKR	KZR
PRM	Abundance	241	405	436	419	456
	Richness	54	56	60	72	66
MON	Abundance	393	650	669	643	611
	Richness	66	60	68	86	67
POM	Abundance	577	883	973	966	828
	Richness	74	72	84	99	78

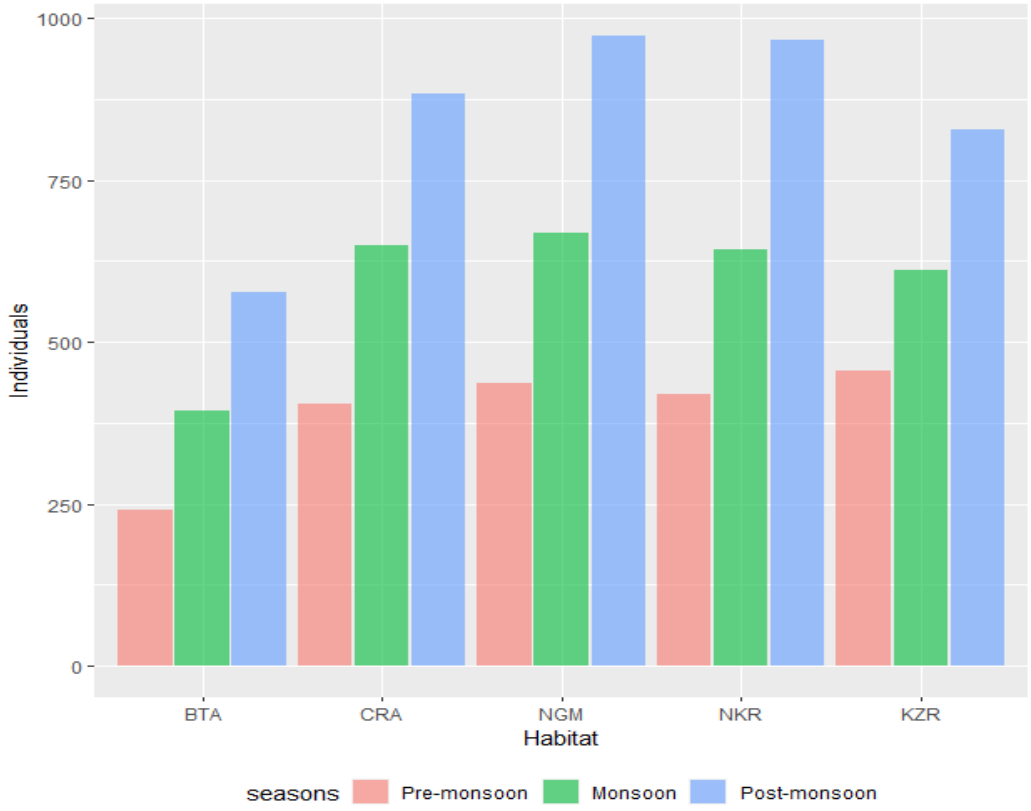


Figure 4.16. Comparison of season wise abundance in different study sites

Rarefaction curves are plotted to compare the season wise species richness in each site, as it is a valuable tool for an accurate comparison of species richness if the sample sizes are different. This helps in the comparison of species richness by eliminating the accidental bias occurred in the sampling effort in different sites during different seasons (Figure 4.17.). It is noted that the richness was highest in NKR during all the three seasons and that was lowest in CRA during all the seasons

after rarefaction. Rarefaction curves, Shannon diversity (Exp H) and Simpson diversity ($^{1}/D$) also agreed with this (Figure 4.18. & 4.19.).

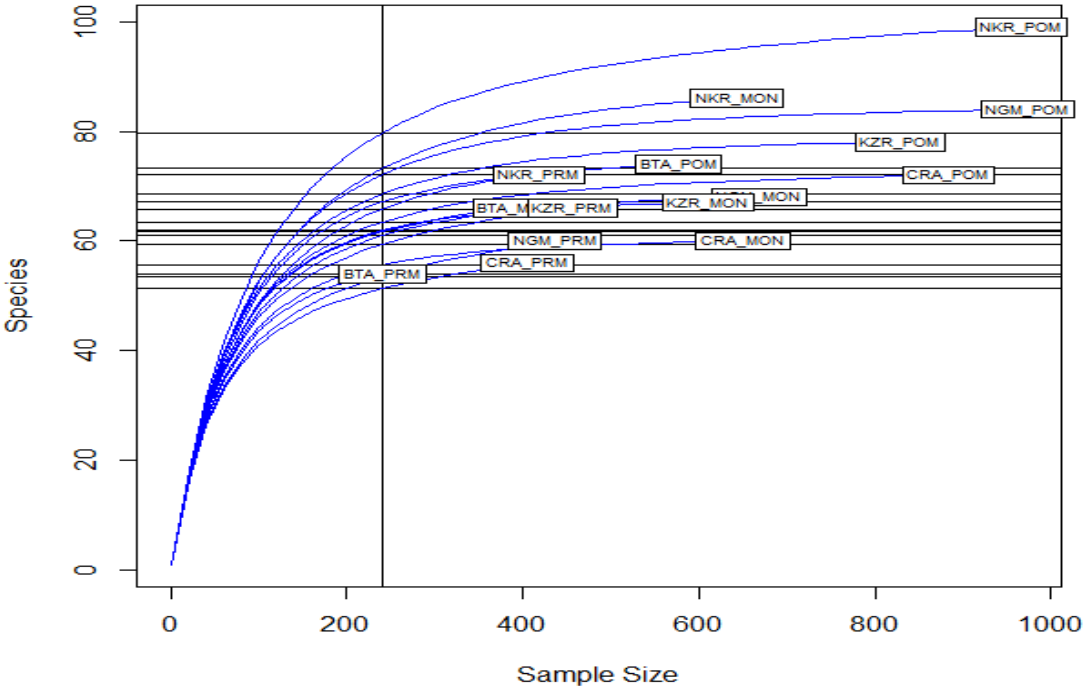
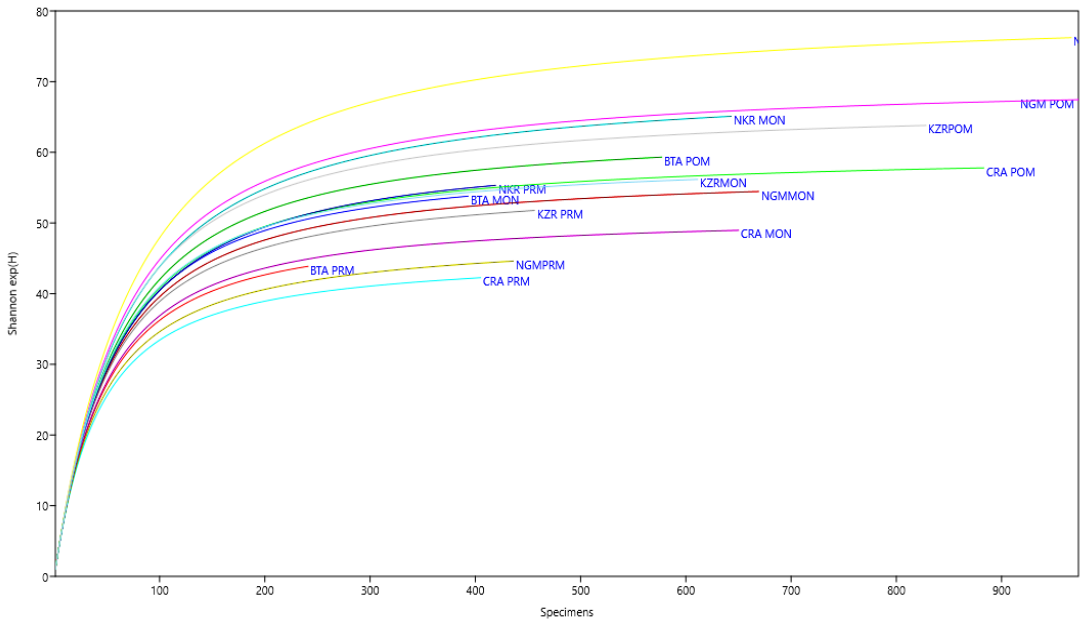


Figure 4.17. Comparison of season wise species richness of different study sites



4.18. Comparison of season wise Shannon diversity of different study sites

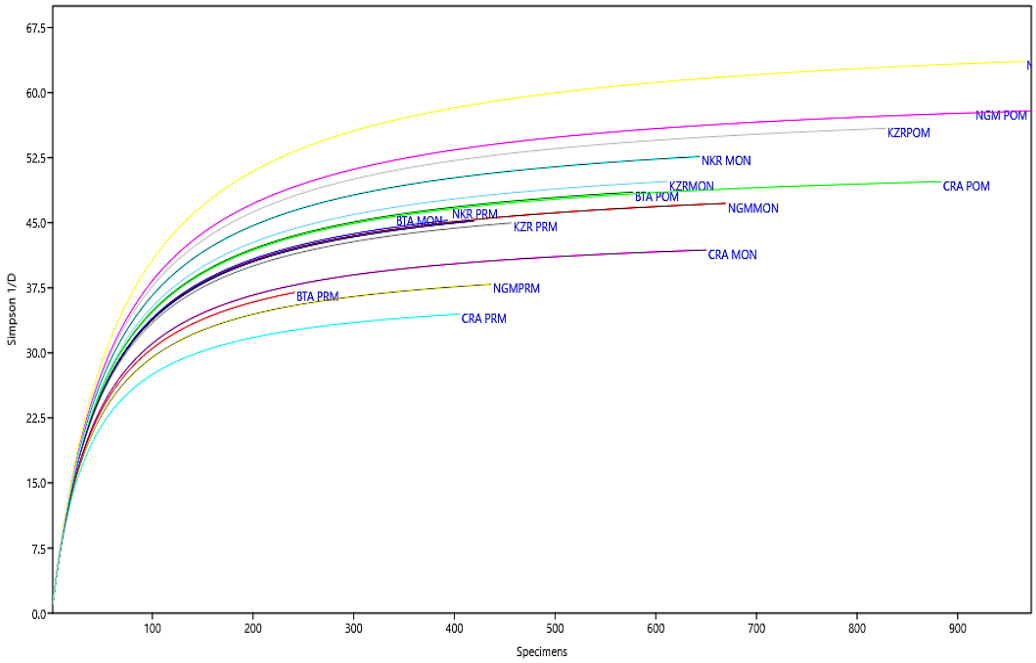


Figure 4.19. Comparison of Season wise Simpson's diversity of different study sites

4.4. Feeding guilds: Unravelling the resource utilisation patterns

In ecology, feeding guilds refer to groups of species within an ecosystem that exhibit comparable feeding behaviours or strategies. These groups form based on the availability of dietary resources and the manner in which species exploit those resources. Roots (1967) defined guilds as the group of species that share common resources in a similar way. The major advantage of the guild approach is that the categorisation of species with similar roles and functions into distinct groups called guilds makes the complex community studies simpler by forming a unit between individual species and community (Austen *et al.,* 1994).

As the guilds influence the flow of energy and nutrients through food webs, feeding guilds can play crucial roles in ecosystem dynamics. For instance, species within a feeding guild may compete for similar food resources, resulting in niche differentiation and resource partitioning to reduce competition and maximise

resource use efficiency. Feeding guilds can also affect community structure and species interactions.

Several efforts have so far been reported to categorise various spider families into different foraging guilds. It may range between as few as 2 guilds to as many as 11 feeding guilds. Uetz (1977) categorised spiders into two guilds such as web builders and wandering spiders. Post & Riechert (1977) suggested 11 foraging guilds of spiders. The spider guild described by them are hackled band weavers, scattered line weavers, orb weavers, pirate spiders, sheet line weavers, hahniid spiders, funnel web spiders, diurnal running spiders, nocturnal running spiders, crab spiders and jumping spiders. Based on quantitative analysis of ecological characteristics such as foraging behaviour and microhabitat utilisation patterns of various spider families, Uetz *et al.* (1999) proposed eight main spider guilds. Stalkers, ambushers, foliage runners, ground runners, sheet web builders, wandering sheet web builders, orb weavers, and space web builders are recognised guilds by them. Cardoso *et al.* (2011) categorised spider families into 8 feeding guilds viz. sensing web weavers, sheet web weavers, specialists, ground hunters, orb web weavers, other hunters, ambush hunters and space web weavers. Present study follows the categorisation of spider guilds followed by Cardoso *et al.* (2011).

4.4.1. Description of different guild categories of horticultural crop fields of Thrissur district

The guild structure of horticultural crop fields includes 7 different feeding guilds according to the guild categorisation of Cardoso *et al.* (2011) (Table 4.38.). In the guild category, specialist hunter was absent in all five study areas.

Table 4.38. Guild structure of spiders in Thrissur horticultural crops: A table summary

Sl. No.	Guild	Families
1	Ambush hunter	Thomisidae
2	Ground hunter	Gnaphosidae, Lycosidae, Corinnidae
3	Orb web weaver	Araneidae, Tetragnathidae, Uloboridae, Nephilidae
4	Other hunter	Oxyopidae, Clubionidae, Sparassidae, Cheiracanthiidae, Philodromidae, Scytodidae, Ctenidae, Salticidae
5	Sensing web weaver	Hersiliidae
6	Sheet web weaver	Hahniidae, Pisauridae
7	Space web weaver	Pholcidae, Theridiidae

1. **Ambush hunters**: Ambush hunters are an interesting group of spiders that can camouflage due to their cryptic colouration. Most of the time, they hide in wait for their prey, which they then attack with great speed and skill. This is a good way to capture prey for the spiders who inhabit the areas with lush vegetation. Some of the most well-known ambush hunter spiders are crab spiders (Family Thomisidae), which can match with the respective floral colours. Present study records 291 individuals belonging to 6 species.

2. **Ground hunters**: Ground hunters are the spiders which hunt their prey from ground rather than sit in wait for their prey on the vegetation. A variety of habitats like forests, grasslands and many crop fields are ideal for this type of guild. They are robust bodied spiders with powerful legs for chasing their prey. 445 individuals belonging to 10 species were reported under this guild. Family Lycosidae comprise

408 spiders belonging to 6 species. Family Gnaphosidae comprises 10 individuals of 1 species and Family Corinnidae comprises 37 individuals belonging to 3 species.

3. **Orb web weavers:** They are spiders which construct distinctive circular webs (orb webs) and wait there for their prey. They can be seen in a wide variety of habitats ranging from forest to grasslands and from croplands to urban human settlements. This is the second largest guild recorded from the horticultural crop fields of Thrissur district in the present study. Families Araneidae, Nephilidae, Tetragnathidae and Uloboridae come under this guild. Araneidae was the most abundant family under this guild followed by Tetragnathidae. This guild comprises 2908 individuals belonging to 36 species. Family Araneidae includes 2132 individuals of 25 species. Tetragnathidae contains 9 species and 770 individuals. Uloboridae contains only 6 individuals belonging to 2 species.

4. **Sensing web weavers**: These spiders can sense the vibrations of the sense threads of their web which allows them to detect their prey. 60 individuals belonging to 2 species under family Hersiliidae are recorded from the crop fields under study.

5. **Sheet web weavers**: Spiders which weave sheet like webs for capturing arboreal arthropod prey are called sheet web weavers. Two families (Hahniidae and Pisauridae) belonging to this guild have been reported in the present study. 48 individuals of two species were collected from the study area. Family Hahniidae includes 3 individuals of a single species and Pisauridae includes 45 individuals of a single species.

6. **Space web builders**: Space web builders construct irregular, branched space web which entangles the prey with its non-sticky threads. Spiders belonging to families Pholcidae and Theridiidae belong to this guild. A total of 456 individuals under 9 species were collected during the current study. 27 individuals of 2 species were

recorded from family Pholcidae while 429 individuals belonging to 9 species were from Theridiidae.

7. **Other hunters**: Actively hunting spiders, such as foliage runners and stalkers, fall under this category. They vigorously chase their prey and ultimately capture it by leaping over it. This group constitutes the most numerous guild in the study site. Families Oxyopidae, Clubionidae, Salticidae, Sparassidae, Cheiracanthiidae, Philodromidae, Scytodidae, and Ctenidae falls under this guild. 4932 individuals of 51 species were recorded under this guild. Salticidae was the most abundant family under this guild with 3986 individuals belonging to 30 species. Oxyopidae comprise 699 individuals of 10 species. 2 individuals of a single species are included in family Clubionidae. Family Ctenidae comprise 12 individuals of one single species. Family Sparassidae contains 167 individuals of 3 different species. Cheiracanthiidae include 44 individuals of 2 species. 12 individuals belonging to two different species were present under family Philodromidae. 10 individuals of two different species are recorded under the family Scytodidae.

4.4.2. Guild composition of horticultural crop fields of Thrissur district

Over all 7 seven foraging guilds of spiders were reported from the crop fields of Thrissur district (Ambush hunters, Ground hunters, Orb web weavers, Sensing web weavers, Sheet web weavers, Space web weavers and Other hunters). The guild 'Specialists' were absent in all the five study areas. This may be because of their narrow predatory range which is not much suitable for ecosystems like crop fields where human interferences are significant. Ambush hunters, Ground hunters, Orb web weavers, Space web weavers and Other hunters were present in all the five cropland ecosystems. Sheet web weavers were absent in BTA and CRA, while Sensing web weavers were absent in CRA.

Other hunters emerged as the major guild with 43.97% of the total species recorded, while Orb web weavers with 31.03% species richness come in the second position (Fig 4.20. & Fig.4 22.). Sensing web weavers and sheet web weavers come in the last position (1.72% of the total species recorded). Ground hunters comprise 8.62%, Space web weavers, 7.76 % Ambush hunters 5.17 %.

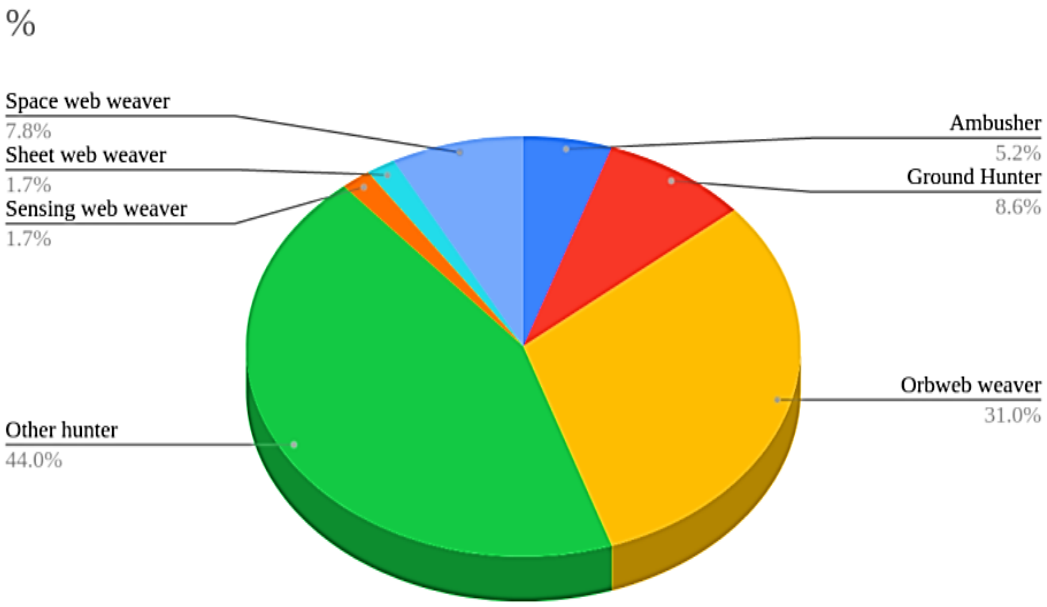


Figure 4.20. Guild structure of spiders in croplands of Thrissur based on species richness

Using the number of individual spiders that were captured, an abundance-based analysis of guild composition was conducted. The results showed that Other hunters made up 53.90% of the guild, followed by Orb web weavers with 31.78%. The least abundant guild wars Sheet web weavers which comprise only 0.52% (Fig. 4. 21 & Fig 4. 23). Space web weavers constituted 4.98% and Ground hunters 4.97%. Ambush hunters comprise 3.18 % and Sensing web weavers constitute 0.66%.

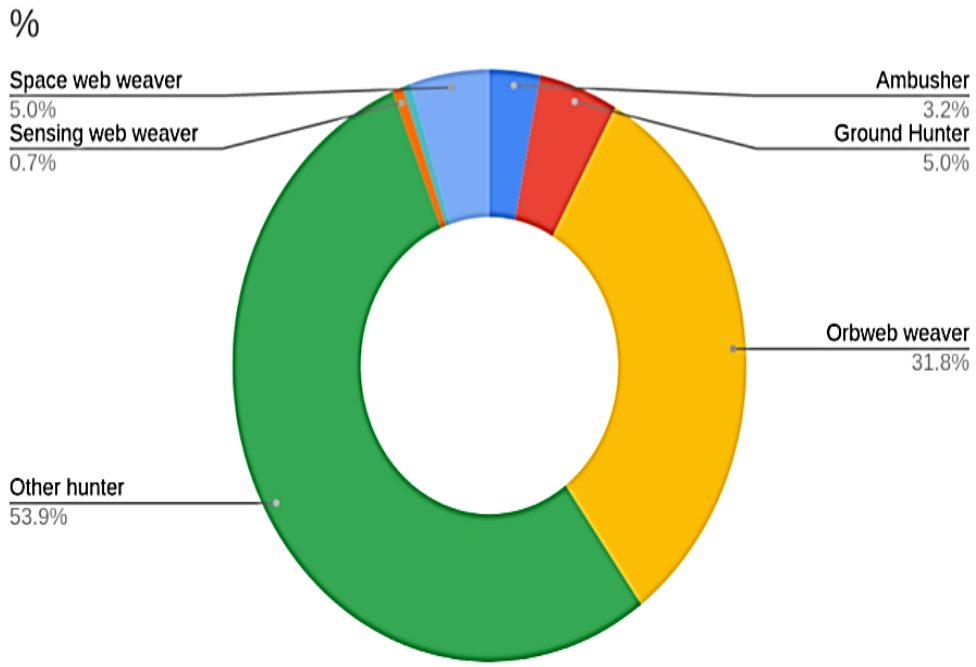


Figure 4.21. Guild structure of spiders in horticultural crop fields of Thrissur based on abundance

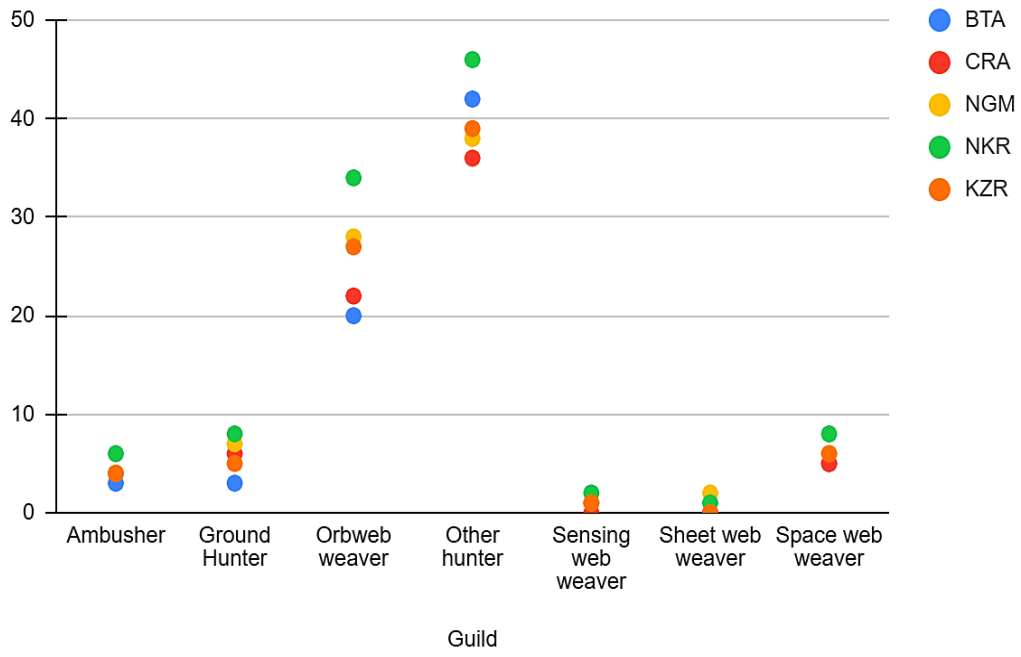


Figure 4.22. Comparison of species richness-based guild structure across different crop fields of Thrissur

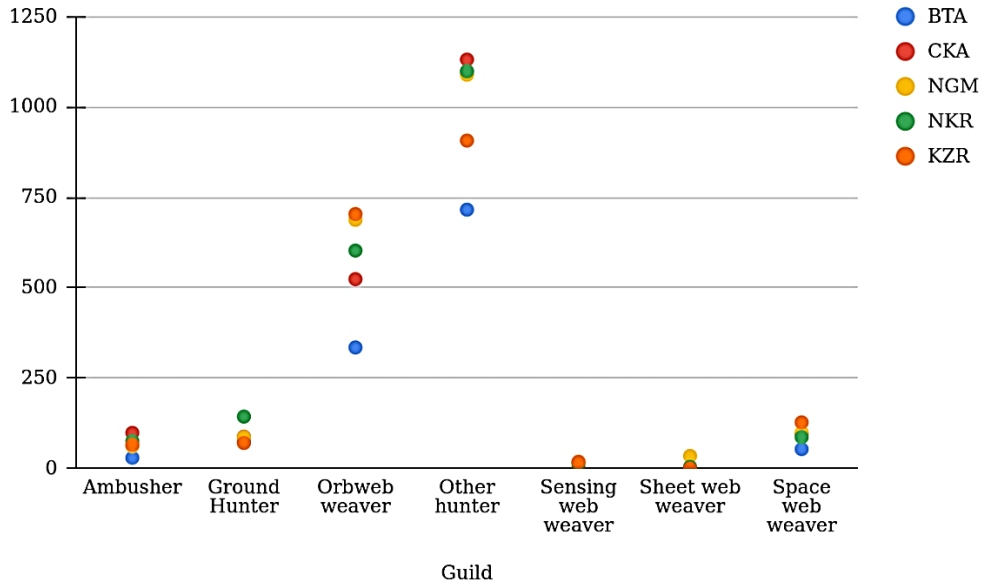


Figure 4.23. Comparison of relative abundance of guilds across different crop fields of Thrissur

Other hunters were the most dominant guild in all the five horticultural crop fields under study (Table 4.39.). Numerical abundance as well as species richness was highest for the guild other hunter followed by orb web weavers (Figure 4.24. to Figure 4.28.)

Table 4.39. Representation of Guild structure across horticultural crop fields of Thrissur

Guild	Representation of Guilds in Crop fields (in %)									
	BTA		CKA		NGM		NKR		KZR	
	Richness wise	Abundance wise	Richness wise	Abundance wise	Richness wise	Abundance wise	Richness wise	Abundance wise	Richness wise	Abundance wise
Ambush hunters	4.1	2.5	5.6	5.1	4.7	3.0	5.7	3.7	4.9	3.5
Ground hunters	4.1	6.1	8.2	4.5	8.1	4.2	7.6	7.1	6.1	3.7
Orb web weaver	27.0	27.1	30.1	27.0	32.6	33.1	32.4	29.7	32.9	37.2
Other hunters	56.8	59.1	49.3	58.4	44.2	52.4	43.8	54.2	47.6	47.9
Sensing web weaver	1.4	0.2	0.0	0.0	1.2	0.8	1.9	0.7	1.2	1.0
Sheet web weaver	0.0	0.0	0.0	0.0	2.3	1.7	1.0	0.2	0.0	0.0
Space web weaver	6.8	4.5	6.8	5.0	7.0	4.8	7.6	4.3	7.3	6.8

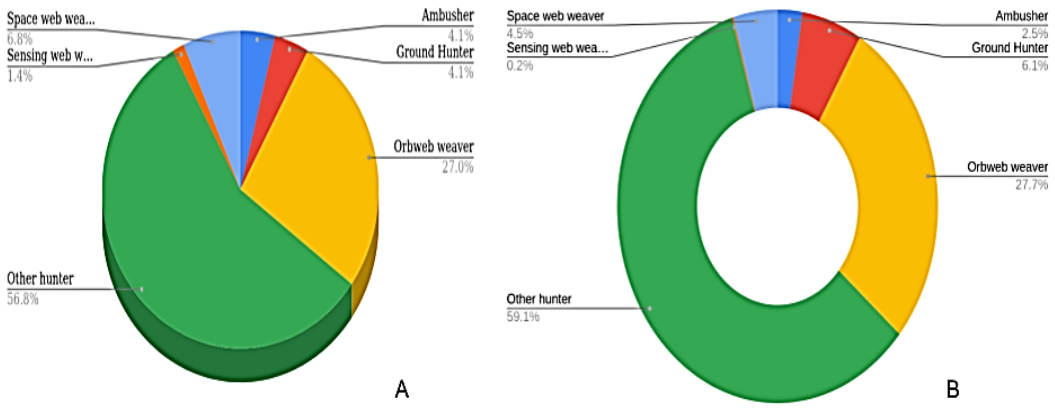


Figure 4.24. Guild structure of horticultural crop fields of BTA (A-species richness, B- abundance wise)

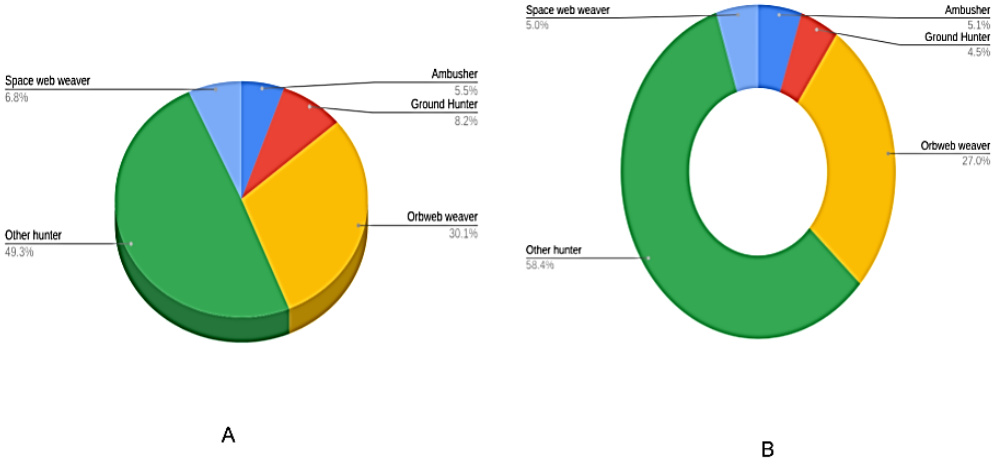


Figure 4.25. Guild structure of horticultural crop fields of CRA (A-species richness, B- abundance wise)

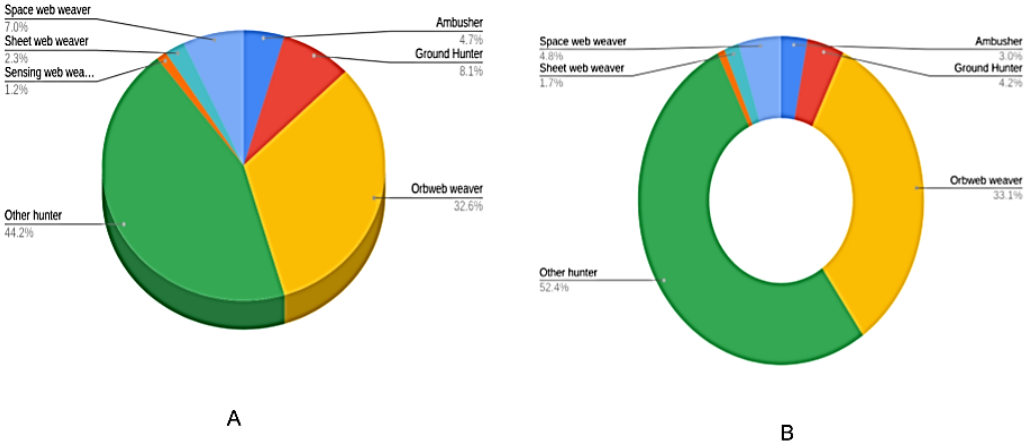


Figure 4.26. Guild structure of horticultural crop fields of NGM (A-species richness, B- abundance wise)

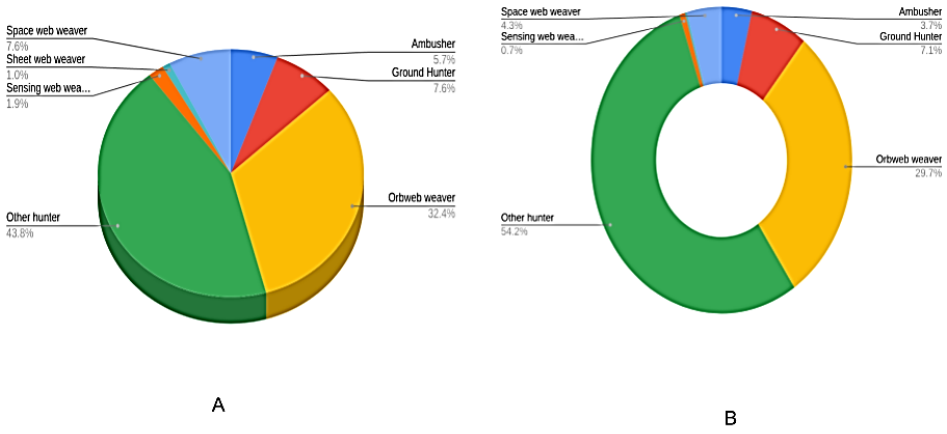


Figure 4.27. Guild structure of horticultural crop fields of NKR (A-species richness, B- abundance wise)

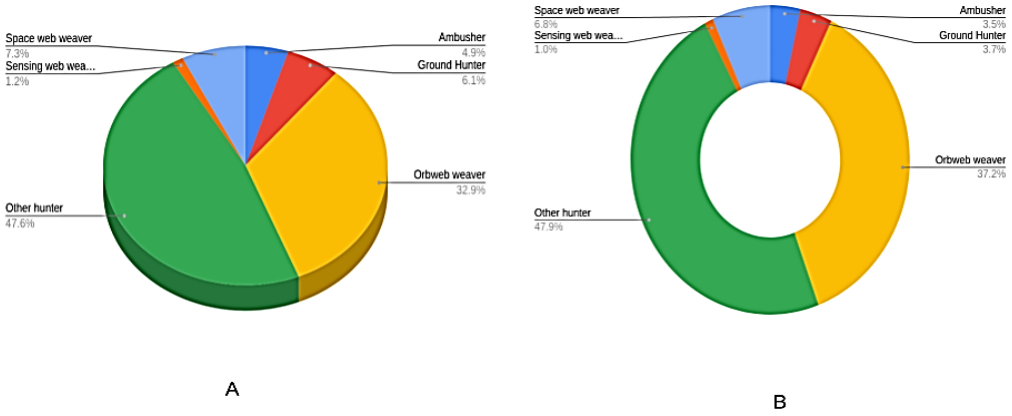


Figure 4.28. Guild structure of horticultural crop fields of KZR (A-species richness, B- abundance wise)

4.5. Influence of pesticides on spiders and their feeding efficacy

Pesticides are one of the most dangerous agrochemicals used in our agricultural sector. Even though they help to control serious pests of crop plants, they adversely affect many beneficial organisms also. Being, a sensitive group of organisms, spiders are also adversely affected by these toxic chemicals. They are affected by direct exposure to these chemicals as well as the contamination of their food with these chemicals. The present study investigated the susceptibility of selected spiders (*A. pulchella, O. javanus, I. insularis* and *M. plataleoides*) to two widely used pesticides; one organophosphate (Quinalphos) and one pyrethroid (Lambda Cyhalothrin) and their effect on the feeding efficacy of the spiders.

4.5.1. Vulnerability of spiders to pesticides

Being contact pesticides, exposure to quinalphos as well as lambda cyhalothrin adversely affected the spiders under study. Even a dosage equal to half of the field recommended dosage for one hour resulted in a high degree of mortality of all the spiders under study (Figure 4.29.). Mortality was higher on exposure to lambda cyhalothrin than quinalphos in all the cases. *M. plataleoides* was most vulnerable to both the pesticides (Table 4.40.).

Table 4.40. Average mortality of spiders treated with synthetic pesticides

species	Average mortality in				
	No. of spiders	1ml/L ʎ cyhalothrin		1ml/L quinalphos	
		Mean ± SD	%	Mean ± SD	%
A. pulchella	8	5.75±0.82	71.85	5.50±0.5	68.75
O. javanus	8	5.30±0.43	65.63	5.00±0.83	62.50
I. insularis	8	6.00±0.71	75.00	5.75±0.83	71.88
M. plataleoides	8	6.25±0.50	78.13	6.0±0.71	75.00

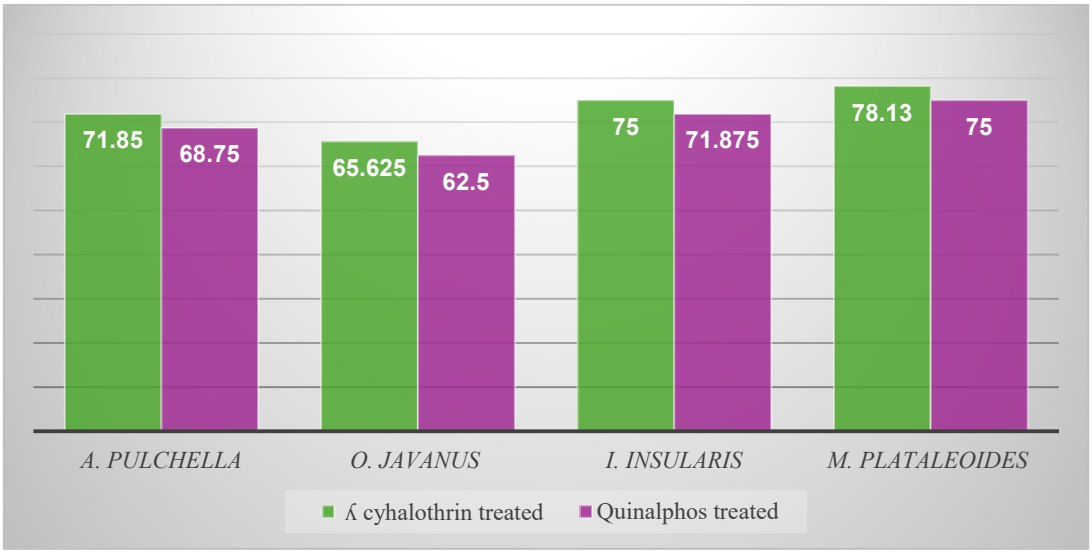


Figure 4.29. Comparison of average mortality of spiders on exposure to two pesticides

An analysis using Kruskal Wallis test showed that the variation in the average mortality of *A. pulchella* in the control group, lambda cyhalothrin treated group and quinalphos treated group are statistically significant (χ^2 =7.42, p=0.019). A Post-Hoc analysis using Dunn's test has revealed that the mortality rate in lambda cyhalothrin treated group was significantly different from control group (p=0.034). The variation in mortality of the group treated with quinalphos and control group is also statistically significant (p=0.05), while the difference in the mortality rate between the both the treated group is not significant (p=1.0).

Mortality of *O. javanus* is highest in lambda cyhalothrin treated group than quinalphos treated group. The difference in the number of deaths in 24-hour duration in control and treated groups are found to be significant in the Kruskal Wallis test (χ^2 =7.47, p=0.016). Cyhalothrin treated groups significantly differ from the control group in death rate (p= 0.026) while that of quinalphos treated group did not differ from the control group significantly as the p value is 0.06. The two treated groups also did not differ among themselves in the mortality (p=1.0).

The study of susceptibility of *I. insularis* using Kruskal Wallis test has been revealed that the difference in the mortality rate of pesticide treated groups and the control is statistically significant (χ^2 =7.38, p=0.020). Both the pesticide treated groups were proved to be with significant variation in mortality from the control group with p value 0.046 on Post-Hoc analysis Dunn's test. Here also the treated groups did not show a significant variation in mortality among themselves.

The death rate in treated group and control group differed significantly in the case of *M. plataleoides* also (χ^2 =7.47, p=0.016). The cyhalothrin treated group differ significantly from control group (p=0.027) while quinalphos treated group did not (p= 0.062). The treated groups also did not differ significantly among themselves (p= 1.0).

4.5.2. Avoidance behaviour of spiders

Avoidance behaviour towards the pesticides is the response of spiders to steer away from the areas which are treated with these poisonous chemicals. It is a self-protective response to minimise the exposure to these toxic substances. It plays a crucial role in the pesticide resistance of spiders. The ability of *A. pulchella, O. javanus, I. insularis* and *M. plataleoides* to retreat away from the areas treated with lambda cyhalothrin and quinalphos is studied in the present study. It was noted that

all the four species of spiders show avoidance response to both the pesticides (Table 4.41.). The highest avoidance response was exhibited by *M. plataleoides* to both the pesticides. *A. pulchella* ranks the second in the response towards lambda cyhalothrin. Both *A. pulchella and O. javanus* together shares the second place in the avoidance reaction to quinalphos. *I. insularis* showed the lowest avoidance response to both the pesticides. A paired t test was conducted to understand whether the difference in the time spend on untreated and pesticide treated part is significant statistically. The result showed that the difference in the time spent on the pesticide treated area and time spent by avoiding pesticide exposure is statistically significant (Table 4.42.).

Table 4.41. Avoidance behaviour of selected spiders to ʎ cyhalothrin and quinalphos

Species	Time spent in (seconds)			
	1ml/L ʎ cyhalothrin treated area	Untreated area	1ml/L quinalphos treated area	Untreated area
A. pulchella	42.33±3.30	1757.7 ± 4.04	50.66±2.52	1749.3 ± 2.52
I. insularis	59.0±5.72	1741.0± 7.01	57.000±2.65	1743.0± 2.65
M. plataleoides	37.33±5.56	1762.7 ±6.81	39.33±3.06	1760.7± 3.10
O. javanus	45.67±1.70	1754.3± 2.08	50.66±2.52	1749.3± 2.52

Table 4.42. Result of t test for comparing avoidance behaviour of spiders to pesticides

Species	ʎ cyhalothrin treated		Quinalphos treated	
	t	P	t	P
A. pulchella	-367.6 7	40E-06	-584.6	2.93E-06
O. javanus	-710.9	1.98E-06	-584.6	2.93E-06
I. insularis	-581.7	2.31E-05	-551.9	3.28E-06
M. plataleoides	-710.9	1.98E-06	-584.6	2.93E-06

4.5.3. Effect of pesticides on the feeding efficacy of spiders

Feeding efficacy is the effectiveness in food capture and its utilisation. It can be synonymously referred to as predatory potential in case of predatory animals. Quality of food, metabolic rate of animals, environmental conditions etc. affect the feeding potential of an animal. It can be evaluated by various methods such as quantification of food taken in, or assessment of assimilation efficiency or growth rate. The inherent hunting and foraging behaviour of several predators can be effectively used in agriculture to reduce the usage of synthetic pesticides for managing the pest attack and thereby maintaining a sustainable and balanced agroecosystem. Considering the polyphagous nature, spiders could be considered as one of the most suitable models for biological pest management. But the unscientific usage of agrochemicals in the crop fields adversely affects the feeding potential of spiders as they are more sensitive to these chemicals. This adverse effect was assessed in the case of some selected spiders (*A. pulchella, O. javanus, I. insularis* and *M. plataleoides*) using two commonly used pesticides (Lambda Cyhalothrin and Quinalphos). *A. pulchella* showed a decrease in the feeding potential on exposure to both the pesticides (Table 4.41., Figure 4.30.). Analysis by Kruskal Wallis test made it clear that the feeding potential in the treated and control group differed significantly (χ^2 =7.11, p=0.028). Post-Hoc analysis by Mann Whitney test with Bonferroni corrected p values showed that Cyhalothrin treated group (B) and Quinalphos treated group (C) differed from control group (A) in feeding efficacy (p= 0.019 and 0.012 respectively). But the difference in feeding efficacy between two treated group was not statistically significant (p=0.8).

Table 4.43. Impact of pesticides on feeding potential of selected spiders

Species	Feeding potential in		
	Control	Quinalphos treated	ʎ cyhalothrin treated
A. pulchella	13.00±1.8	9.50±0.57	7.75±0.5
O. javanus	17.25±0.9	12.75±0.50	9.75±0.5
I. insularis	16.00±0.8	10.25±0.95	7.50±1.0
M. plataleoides	11.50±1.2	5.50±0.57	5.75±0.5

A similar result obtained in the case of *O. javanus* (Table 4.43., Figure 4.31). The difference in feeding efficacy between the treated and control groups was found to be statistically significant (χ^2 =9.97, p=0.006). The difference in predatory potential between group A and B as well as A and C are also revealed to be statistically significant in Mann Whitney test (p= 0.016 and 0.006 respectively). But the difference between B and C is not significant (p=0.40).

Feeding potential of *I. insularis* (Table 4.43., Figure 4.32) also varied among treated and control groups significantly (χ^2 =8.78, p=0.012). The variation between A and B, A and C are also significant (p= 0.030, 0.008 respectively). But variation between B and C is insignificant (p= 0.47).

Difference in the predatory capability of *M. plataleoides* (Table 4.43, Figure 4.33) was also significant (χ^2 =8.47, p=0.013). The treated groups (B and C) varied with the control (p=0.019, 0.024 respectively). But the groups B and C did not show significant difference (p=0.9).

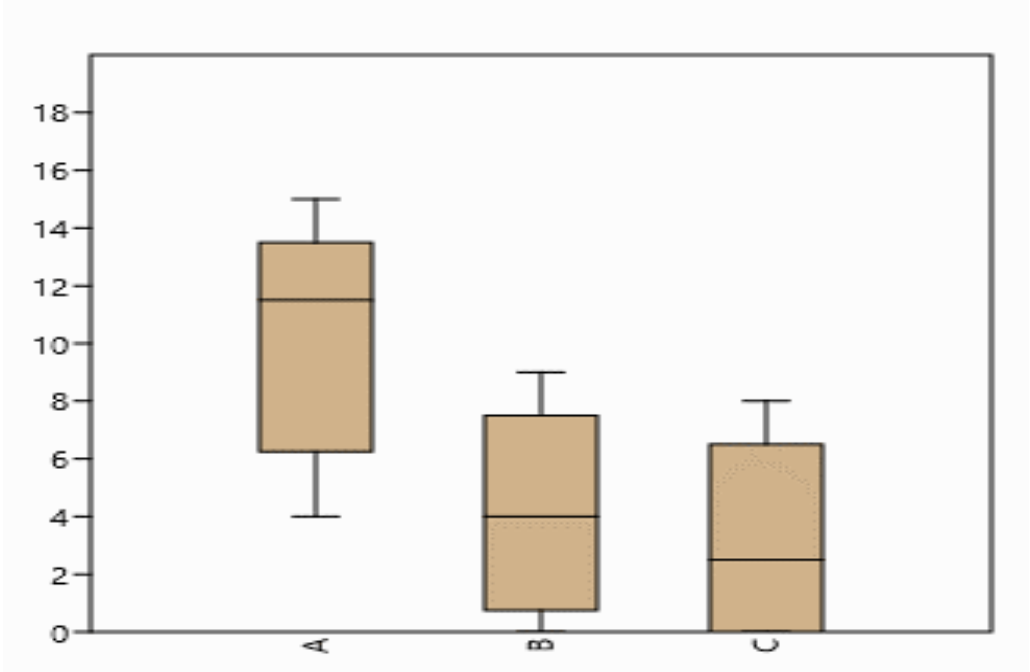


Figure 4.30. Impact of ʎ cyhalothrin and quinalphos on the feeding potential of *A. pulchella*

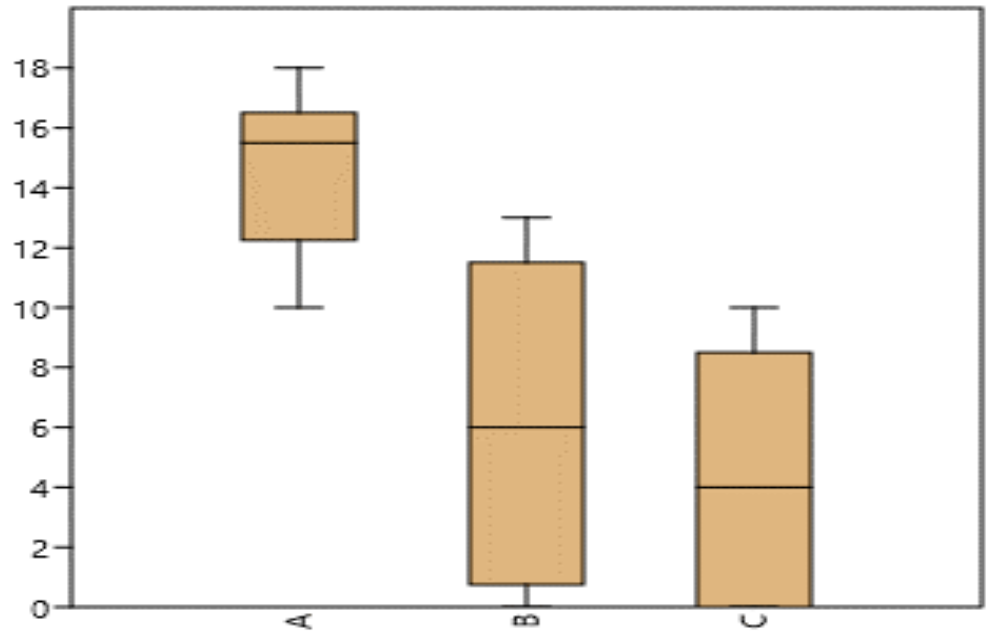


Figure 4.31. Impact of ʎ cyhalothrin and quinalphos on the feeding potential of *O. javanus*

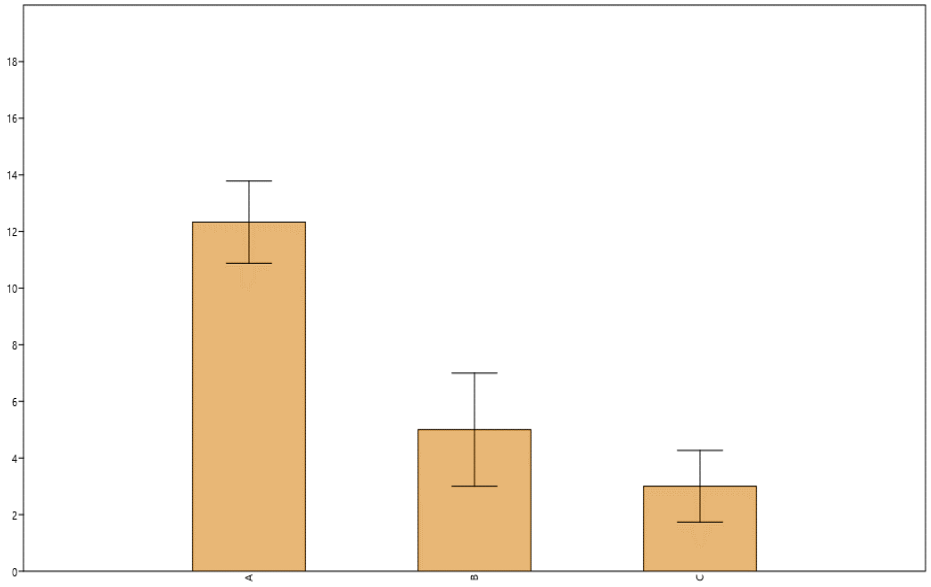


Figure 4.32. Impact of ʎ cyhalothrin and quinalphos on the feeding potential of *I. insularis*

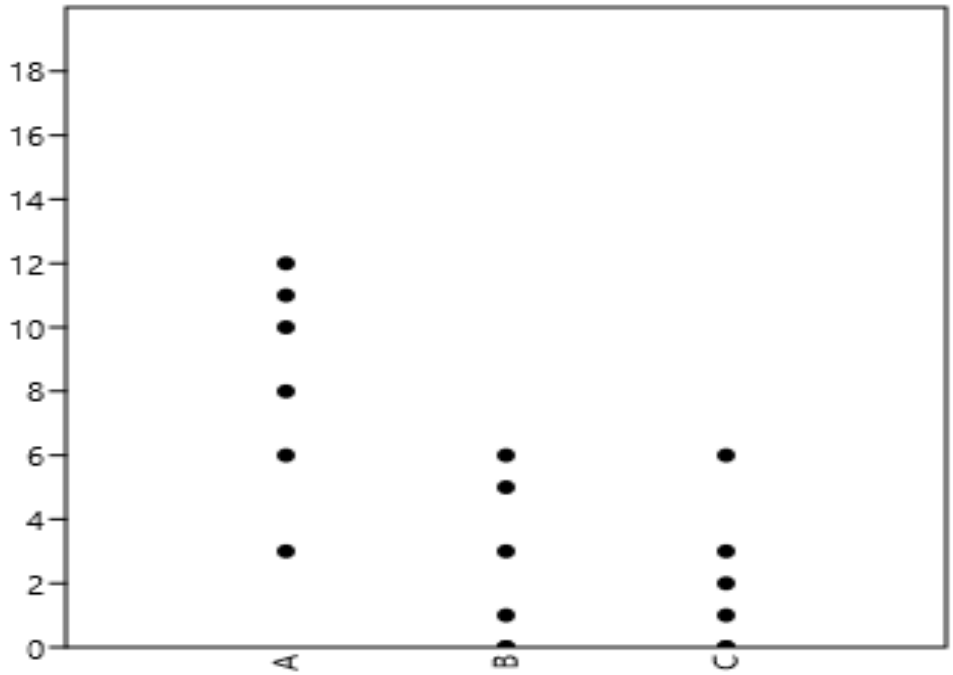
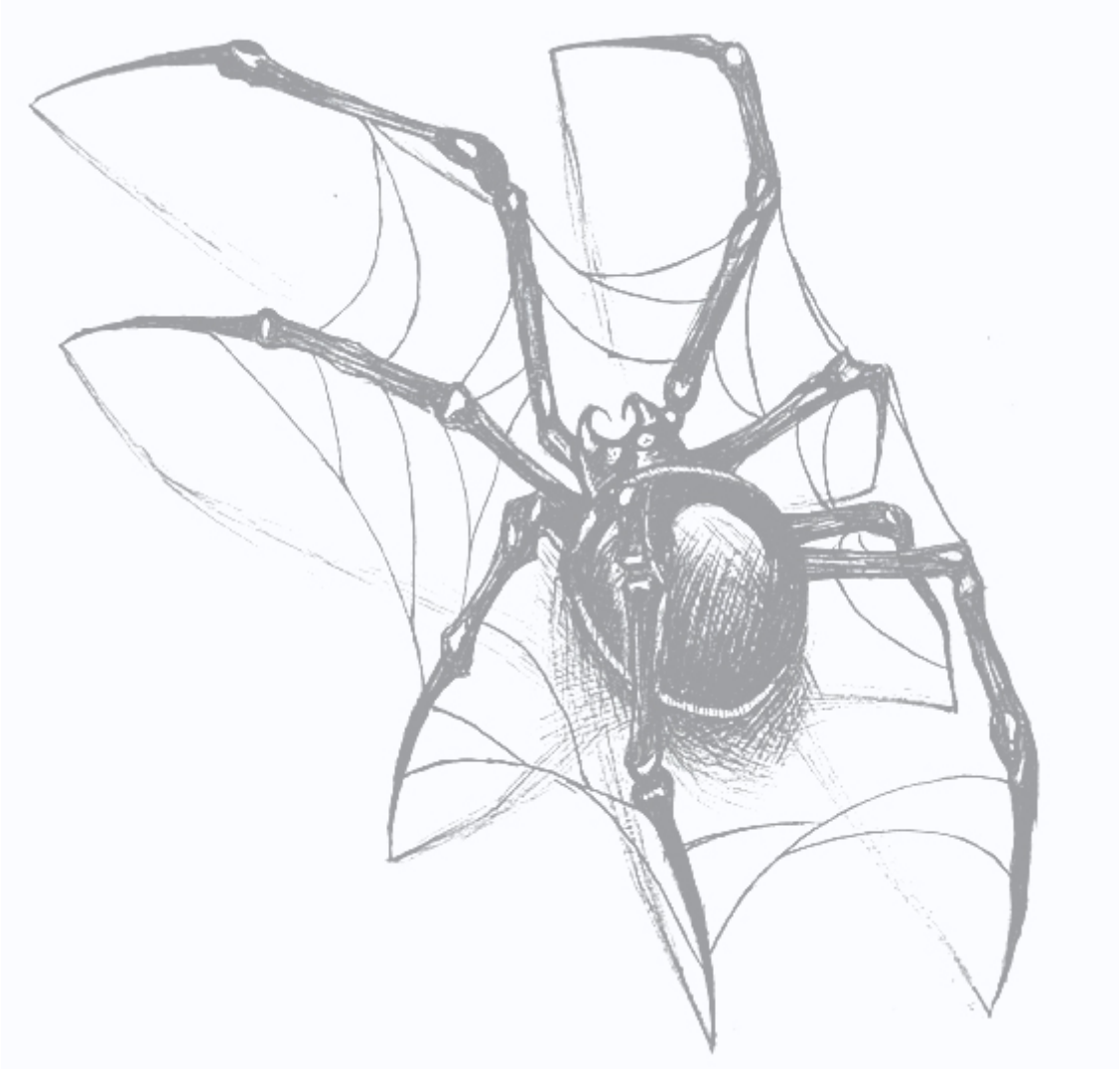


Figure 4.33. Impact of ʎ cyhalothrin and quinalphos on the feeding potential of *M. plataleoides*

It is clear that pesticides are having a negative impact on the faunal diversity of spiders and foraging behaviour. To understand the real impact, we need to conduct a more practical study directly in the field.



CHAPTER 5

DISCUSSION

DISCUSSION

5. Spiders in agro ecosystems

Traditional studies in biodiversity are more often focused on natural ecosystems and the faunal diversity associated with them. But in the current scenario, the increased human interventions like urbanization, agriculture, industrialization etc. alters the land usage patterns and affects the faunal diversity. So, studying ecosystems in their altered state becomes very significant (Shochat *et al.,* 2008). Even in the present time we are unable to accurately anticipate in advance how human activities impact the diversity of various organisms (Purgat *et al*., 2020). In this perspective, recording the biodiversity patterns in seminatural, human influenced ecosystems become very significant. Agricultural landscapes represent a novel ecosystem with prevailing human altered conditions. The present study focusing on the documentation of spider diversity of horticultural ecosystems of Thrissur district and impact of agrochemicals on their diversity is highly significant in this regard.

5.1. Exploring Spider diversity in the Horticultural croplands of Thrissur

Spiders are one of the most abundant groups of invertebrates found in cropland ecosystems (Lawler, 2001; Bambaradeniya *et al*., 2004). Increased availability of prey, availability of supporting vegetation and creation of microclimate suitable for their growth, reproduction and survival make agroecosystems suitable for supporting spider fauna (Samiayyan, 2014; Jayasree *et al*., 2023). They provide many ecological services there like pest control (Tscharntke & Brandl, 2004; Oberg & Ekbom, 2006; Hogg, & Daane, 2011), pollination (Brechbuhl *et al*., 2010) etc. Assessment of diversity of spiders in agroecosystems, their ecological functions and

conservation is one of the thrust areas in arachnology. Despite of a number of studies on agrobiont spiders of Kerala, almost all those are focused on rice farmlands (Sebastian *et al*., 2005; Mathew *et al*., 2014; Anis & Premila, 2016). Exploration of araneofauna associated with horticultural croplands in Kerala is still in infantile stage. Present study involved a faunistic survey of spiders from the selected patches of horticultural croplands of Thrissur during the time frame of 2016-2018 and documented 116 species of spiders belonging to 75 genera and 21 families. This forms approximately 50% of the total faunal diversity (28 families, 139 genera, 234 species) recorded from Thrissur district so far (Singh, 2023). Salticidae ranked the most abundant family followed by Araneidae. This is in accordance with several studies in different agroecosystems in various parts of India (Saha *et al*., 2020 ; Smitha & Sudhikumar, 2020) and contrary to this several other explorations which holds Araneidae as the most abundant family followed by Salticidae (Sharma, 2014; Bade & Ade, 2017; Variale, 2019; Jayasree et al., 2023; Priyadarshini & Mahapatra, 2023). Robust physique, keen eyesight and tactful predatory methods along with increased resilience to adverse conditions may be some of the potential factors for the successful distribution of salticids and araneids in agroecosystems.

5.1.1. Abundance of spiders

A total of 1211 individuals belonging to 74 species was recorded from BTA, while 1938 individuals of 73 different species from CRA. 2078 individuals of 86 species and 2028 individuals of 105 species were reported from NGM and NKR, respectively. A total of 1,895 individuals representing 85 different species were documented from KZR. The abundance was found be least in BTA than all other sites which may be due to the monoculture practise prevailed there. There are

several studies corroborating this (Vehvilainen *et al*., 2008; Lopes *et al*., 2010; Darmawan *et al*., 2019; Munevar *et al*., 2022). It is worth noting that among the sites implementing mixed cropping, the abundance was greater in the one practicing organic farming (NGM with 2,078 individuals) than the traditional agrochemical-based cultivation. Several previous explorations of spider fauna of agricultural croplands support this claim (Feber *et al*., 1998; El-Karim *et al*., 2016; He *et al*., 2020). According to Schmidt *et al*. (2005) organic farming does not increase species richness but increases the abundance and density of spider fauna. Present study supported this as the highest richness was reported from NKR than NGM.

A study of dominance structure of the spider fauna was carried out by calculating Individual Dominance index. No 'Eudominant' species was reported from any of the study sites. The greater fraction of the total species reported belonged to the 'Subrecedent' category. This is the indication of higher evenness and richness and low dominance exhibited by the population prevailing there. This higher evenness and low dominance in horticultural croplands under study may be due to the diversity of crops under mixed cultivation. The presence of two species belonging to the group 'Dominant' in BTA where monoculture practiced can be considered as evidence for this. Besides that, in CRA where the types of crops cultivated are less in number compared to the other sites with mixed cultivation, one species belongs to the category 'Dominant'. Analysis of rank abundance curves also supported the existence of a moderately dominant population with high evenness and richness in all the five study sites. The curves with steeper slopes are with greater dominance (Avolio *et al.*, 2019). CRA with highest slope value (steepest curve) exhibits greater dominance when compared to the other four sites. Diversity profile curves also support this view. The curve with the fastest rate of decline is the

one with higher dominance. An in-depth examination of diversity profile curves made it clear that CRA exhibited the highest degree of dominance and NKR the lowest among all the five sites under exploration. The hierarchical order of the dominance is CRA > BTA > KZR > NGM > NKR. All the non-parametric richness estimators like Chao 1, Chao I bc, i Chao, ACE predicted a richness moderately higher than the observed richness indicating a small degree of underestimation. The higher Shannon diversity index and lower Simpson index were reported in all the sites under study which also supported the existence of lower dominance and higher evenness of the spider fauna there. The highest Simpson index and lowest Shannon index was found in CRA which also supported the highest dominance and lowest evenness there. The highest number of singletons and doubletons were observed from NKR while lowest number of singletons were observed from KZR, and lowest number of doubletons were observed from CRA.

Comparison of the diversity was conducted using Kruskal Wallis test, a non-parametric test for comparing two or more samples. The statistical outcomes indicated that the diversity differs among the sites in a significant way. As the p value is less than 0.05 (0.006) the difference observed cannot be due to mere chance. A Post-Hoc analysis using Dunn's test with Bonferroni correction revealed that the pair BTA-NKR has specifically contributed to this difference. The study of β diversity was also carried out using PERMANOVA and established the existence of statistically significant variation among the sites. Numerous literature sources are available describing PERMANOVA as a suitable tool for investigation of β diversity (Avila *et al*., 2017; Carvalho *et al*., 2020; Valence *et al*., 2022). SIMPER analysis was also done to calculate the overall average dissimilarity and most influential species contributed to the observed dissimilarity. There are several studies that

suggest SIMPER to find out the species that contribute maximum to the observed dissimilarity (Hore & Uniyal, 2008; Sereda *et al*., 2014; Encarnacao *et al*., 2015; Toledo *et al*., 2020). *Indopadilla insularis, Hyllus semicupreus, Carrhotus viduus, Oxyopes javanus, Asemonea tenuipes* and *Neoscona inusta* were the reported to be the influential species in the study sites. All these belongs to three major families reported from the study sites: four species from the family Salticidae, one each from the families Araneidae and Oxyopidae.

There are 51 species common to all five sites. All these belongs to the four families: Salticidae, Araneidae, Oxyopidae and Lycosidae. Eight species had been documented exclusively from NKR. NGM and BTA have 2 and 1 exclusive species, respectively. Neither CRA nor NGM has any exclusive species.

5.2. Seasonal variations in spider diversity

The faunal diversity of spiders varies according to the seasons. There are several reasons behind the seasonal variation of spider fauna across the seasons. Temperature, humidity, precipitation, diversity of vegetation, availability of prey etc. are some among them. There are ample availability of literature describing the seasonal variations in spider population (Sudhikumar *et al*., 2005; Cardoso *et al*., 2007; Hsieh & Linsenmair, 2012; Rodriguez *et al*., 2015; Raghu & Kumar, 2022; Raja *et al*., 2023; Singh & Goswami, 2023). Seasonal variation in the diversity of spider fauna was reported from the horticultural crop fields of Thrissur district in the present investigation. The abundance and richness of spiders was highest in POM (4227 individual; 112 species) followed by MON (2966 individuals, 101 species) and PRM exhibited the lowest richness and abundance (1957 individuals, 93 species). The number of singletons and doubletons are highest in PRM and lowest in

POM. *Indopadilla insularis* was the most abundant species during all the seasons. Salticidae was the most abundant family followed by Araneidae in all the seasons. According to Vijayakumar & Patil (2004) spiders belonging to many families in agroecosystems peak in abundance and richness during the months of October and November. Ambily & Antony (2016) reported the highest diversity of spiders in agroecosystems of Ernakulam district, Kerala during the months October to January. The findings of Priyadarshini (2023) revealed that spider abundance and richness was highest during rabbi (November to January) season in the agroecosystem of Bargarh district of Odisha. All these findings are in alignment with the result of the present study. Sudhikumar *et al*. (2005a) and Raghu & Kumar (2022) documented highest spider population during the kharif season (June to October) in the agricultural fields of India. Moderate rain falls in the initial months of POM, high humidity, optimum wind speed with increased availability of prey may be the reasons behind the peak diversity during this season. Priyadarshini (2023) also agree with this.

Number of singletons and doubletons were highest in PRM and lowest in POM. Higher Shannon index and lower Simpson index throughout the seasons were the indications of the existence of low dominance and high evenness in the population throughout the year. The highest Shannon index and lowest Simpson index was reported during POM. Lowest Shannon index and highest Simpson index was documented during PRM. This substantiate that the population showed highest evenness and diversity during POM followed by MON and PRM. Study of diversity profile curves also supports this finding. The profile curves show the steepest decline in the case of PRM and lowest decline in the case of POM. Analysis by plotting rank abundance curve also has aligned properly with this finding. The curve

corresponding to POM with its highest α value (18.49), and shape parameter (0.9978) supports the fact that evenness is highest, and dominance is lowest in POM. Lowest α value and shape parameter of PRM indicated comparatively the highest dominance and lowest evenness during the time. As only a slight difference exists between the α values and shape parameters, it can be concluded that a consistent evenness exists throughout the seasons. Analysis of dominance structure utilizing individual dominance structure reinforced the view. No Eudominants were reported through the seasons. Only one Dominant species was reported during the season PRM and none during the other two seasons. Greater prevalence of Subrecedents than Subdominants and Recedents supported the higher degree of evenness and lower dominance prevailed throughout the year.

All the richness estimators showed slightly higher richness than the observed richness. The estimator i Chao 1 predicted the highest richness in PRM out of all the estimators employed. ACE 1 predicted the highest richness in POM. Species accumulation curves were approximating the asymptote which also indicated a small degree of under sampling. The highest sampling efficiency reported is at POM (99.4%) and lowest in PRM (98.4%). 89 species were reported in all the seasons which comprise 76.7% of the total richness. 11 species were exclusively reported from POM, 1 from MON and 3 from PRM.

Statistical analysis by Kruskal Wallis test supported the existence of significant difference in the diversity across the seasons. A Post-Hoc analysis by Dunn's test also reinforced the fact. According to the SIMPER analysis results, highest average dissimilarity was exhibited between the pair PRM-POM. *Carrhotus viduus* and *Asemonea tenuipes* were the major contributors to the observed dissimilarity between the seasons.

Several literatures suggest the construction of rarefaction curves for the meaningful comparison of species richness in order to avoid accidental bias in the sampling effort (Buddle *et al*., 2005; Fannes *et al*., 2008; Chao *et al*., 2014; Privet & Petillon, 2020). Comparison of rarified species richness also supported the existence of highest richness in NKR and lowest in CRA. In all the sites under study, rarified richness was found to be highest in POM and lowest in PRM.

5.3. Guild structure of spider fauna

Root (1967) for the first time introduced the concept of guild for grouping organisms that use the same environmental resources in a similar way. The guild structure is based on the functional role of species that share some common niche requirements rather than taxonomic features (Hawkins & MacMahon, 1989). Study of foraging guilds of spiders helps to understand their ecological interactions within the ecosystem. Categorization of spiders into various guilds is mainly based on their hunting strategies. An insight on the guild structure of spiders is very helpful in the adoption of various conservation strategies for them.

Several studies have been conducted to describe the guilds of agrobiont spiders and their relative dominance there (Uetz *et al*., 1999; Sharma, 2014; Anitha & Vijay, 2016; Benamu *et al*., 2017; Benhadi *et al*., 2020; Saha *et al*., 2020; Nakambam *et al*., 2021; Jayasree *et al*., 2023). Priyadarshini (2023) documented that orb web weavers as the most prevalent foraging guild in paddy crop field of Bargarh district of Odisha, India. Jayasree *et al*. (2023) similarly noted that orb web weavers as the dominant guild in mixed agroecosystems of Palakkad district, Kerala. Ambush hunters were reported to be the predominant foraging guild in Narendrapur district, West Bengal by Saha *et al*. (2020).

The present study follows the guild categorization of Cardoso *et al.* (2011). Current study unveiled seven feeding guilds: ambush hunters, ground hunters, orb web weavers, other hunters, sensing web weavers, sheet web weavers, and space web weavers out of the eight guilds described by them. Specialist hunters has not been recorded from any of the study site. This may be because of the simplified and altered habitat with high human interventions may lead to the absence prey types or microhabitats that support the specialist spiders in agroecosystems. Sheet web weavers were reported from three out of five study sites. Sensing web spiders recorded from four of the study sites. Other hunters ranked the first position in richness as well as in abundance in all the sites. Broad spectrum of prey, diverse hunting strategies and high adaptability to the variation in environment due to anthropogenic interference may be the traits responsible for their prevalence in crop fields.

5.4. Analysis of impact of toxic agrochemicals

Exploration of diversity of spiders in crop fields is of paramount importance because many of them can be employed in pest management, while some are good indicators of ecosystem health. But it is noted that the extensive usage of agrochemicals, especially pesticides may adversely affect biocontrol agents also. Several studies reported a significant decline in the diversity and abundance of spiders immediately after the application of pesticides (Vickerman & Sunderland, 1977; Paul & Thygarajan, 1992; Park *et al*., 2007; Solanki & Kumar, 2014; Sherawat *et al*., 2015; Kumari & Singh, 2019; Tahir *et al*., 2019; Preetha, 2023).

Present study focused on the impact of two widely used pesticides (quinalphos and ʎ cyhalothrin) on *A. pulchella, O. javanus, I. insularis* and *M.*

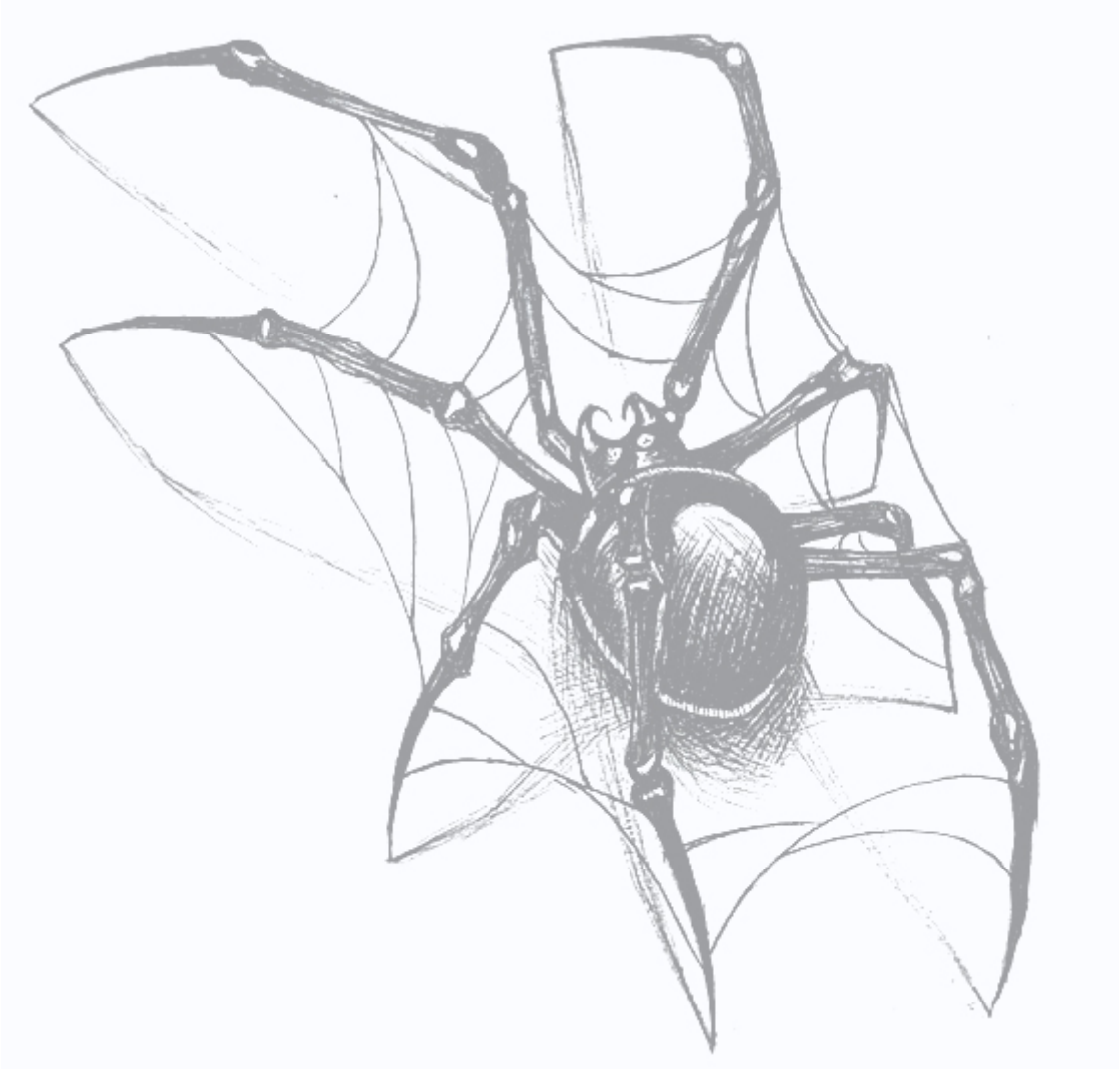
plataleoides and how it influenced the feeding efficacy of them. Application of both pesticides in half the field recommended dosage resulted more than 60% of mortality in all the four species under study. Death rate was higher in the case of ʎ cyhalothrin exposure than quinalphos in all the cases. Least susceptibility to both the pesticides was exhibited by *Oxyopes javanus* and highest susceptibility was shown by *Myrmaplata plataleoides*. Tahir *et al*. (2019) documented 70% mortality of *Neoscona theisi* (Walckenaer, 1841) on exposure to ʎ cyhalothrin which was comparable to the results recorded by present study. *Philodromus cespitum* (Walckenaer, 1802) and *Philodromus albidus* Kulczyński, 1911 also exhibited reduction in predatory potential on exposure to ʎ cyhalothrin (Michalko & Kosulic, 2016). It is also reported that the diversity and abundance of spiders in the brinjal farm decreased significantly on the application of quinalphos and ʎ cyhalothrin (Singh *et al*., 2020; Singh *et al*., 2021).

The feeding efficacies of all selected spiders were reduced on the exposure to both the pesticides. The effect of quinalphos was found to be lower than that of cyhalothrin in all the cases. It was reported that feeding potential of *Pardosa birmaica* Simon, 1884 (Tahir *et al*., 2015) and *N. theisi* (Tahir *et al*., 2019) was significantly reduced on exposure to ʎ cyhalothrin.

Chemical pesticides with short residual activity, narrow spectrum action, minimal impact on non-target organisms etc. are the qualities of pesticides that can be used in Integrated Pest Management (IPM). As both the pesticides used in the present study produced a mortality of more than 60% in all the spiders exposed and reduced their feeding efficacy significantly, their application of these cannot advised as part of IPM.

5.5. Limitation and scope of study

The primary and foremost important constraints of the research were concerned with the collection methods adopted. The study exclusively focused on diurnal spiders and neglected documentation of nocturnal spider fauna. As the explorations were done in the agricultural field, the collection techniques were limited to hand picking and sweep netting and avoided adopting methods such as beating, pitfall traps, etc. Many studies opined that adoption of different sampling techniques should be based on the vegetation type there. Adoption of any one or a few collection strategies alone may result in some degree of underestimation of population. This sampling bias may result in a certain degree of inaccuracy in estimating biodiversity.



CHAPTER 6

SUMMARY AND CONCLUSION

SUMMARY AND CONCLUSION

6.1. Spider Diversity of Horticultural Ecosystems of Thrissur: A Summary

The present study focused on unravelling the trends in the faunal diversity of spiders in Thrissur district. The explorations were done at five distinct horticultural crop fields of Thrissur district (BTA, CRA, KZR, NGM, NKR) for a duration of two years (2016-18). The study sites include fields with monoculture as well as mixed culture and organically cultivation as well as traditional agrochemical-based cultivation. The examination revealed the presence of 116 spider species, distributed among 75 genera and 21 families. The dominant family was Salticidae with significant dominance, and Araneidae secured the second rank. 3986 individuals belonging to 30 species and 25 genera have been recorded under Salticidae while 2119 individuals of 24 species of 9 genera from Araneidae. Among all the sites explored NGM showed the highest numerical abundance of spider fauna while NKR ranked the first in richness. It was also observed that the abundance was lowest in BTA while richness was lowest in CRA.

Analysis using individual dominance index and rank abundance curve revealed that the population is characterized by moderately high evenness and a diminished dominance. Higher Shannon wiener index and lower Simpsons index calculated in all the plots supported this view. The maximum dominance and minimum evenness were observed in CRA. This observation was corroborated by the diversity profile curves plotted. Different richness indicators predicted slightly greater richness values than what was observed, suggesting a minor underestimation and a small degree of unintentional sampling bias. Around 43.9% of the total species recorded are common to all the study sites.

An examination conducted on the abundance and diversity of spiders across the study sites, employing statistical tools such as the Kruskal Wallis test and post hoc Dunn's test with Bonferroni correction. The outcomes of these tests demonstrated a significant difference in spider diversity among the various horticultural ecosystems. NKR-BTA was the major contributor to this significant difference in diversity. A study of beta diversity through multivariate dispersion analysis via PERMANOVA unveiled substantial variations. Subsequently, a SIMPER analysis was executed to calculate the average dissimilarity among the sites and identify the key species responsible for the observed dissimilarities between the site pairs.

Examination of seasonal dynamics of spider fauna revealed that POM has highest diversity in terms of richness and abundance and PRM has the lowest. Shannon and Simpson indices suggested even distribution of the diversity through out the year. Diversity profile curves and rank abundance curves also supported this observation. PRM and MON showed a slightly diminished evenness than POM. As the species accumulation curves and richness estimators predicts a slight degree of under sampling. A substantial majority (76.7%) of the entire species documented are consistent across all the three seasons. Prevalence of these across the seasons highlights their adaptability and resilience which makes them fit to act as good bio control agents.

To understand the biocontrol potential of spiders, it is of high significance to get a clear picture of the functional role exhibited by them in the crop fields. The study of foraging guilds is inevitable for this. Other hunters out of the seven guilds recorded in the present study, ranked the most prevalent guild (43.97%) followed by orb weavers (31.03%). Specialists were reported from nowhere.

The sites being agroecosystems, it became imperative to understand how commonly used toxic agrochemicals impact potential biocontrol agents like spiders in the field. As a preliminary attempt in this direction, the susceptibility of selected spiders to two prevalent pesticides was examined. An exploration on the effect of the exposure to sublethal concentrations of them on the feeding efficacy of those spiders was also done. Notably, both pyrethroids, like lambda cyhalothrin, and organophosphates, such as quinalphos, exhibited detrimental effects on the feeding capabilities of these arachnids. It is observed that exposure to a concentration below the officially recommended field dosage proved sufficiently lethal, causing a mortality of over 60% of all spiders included in present study. This revealed the hazardous consequences of indiscriminate pesticide usage and highlights the need for judicious and informed usage of pesticides to mitigate potential risks to these essential biocontrol agents within the agroecosystems.

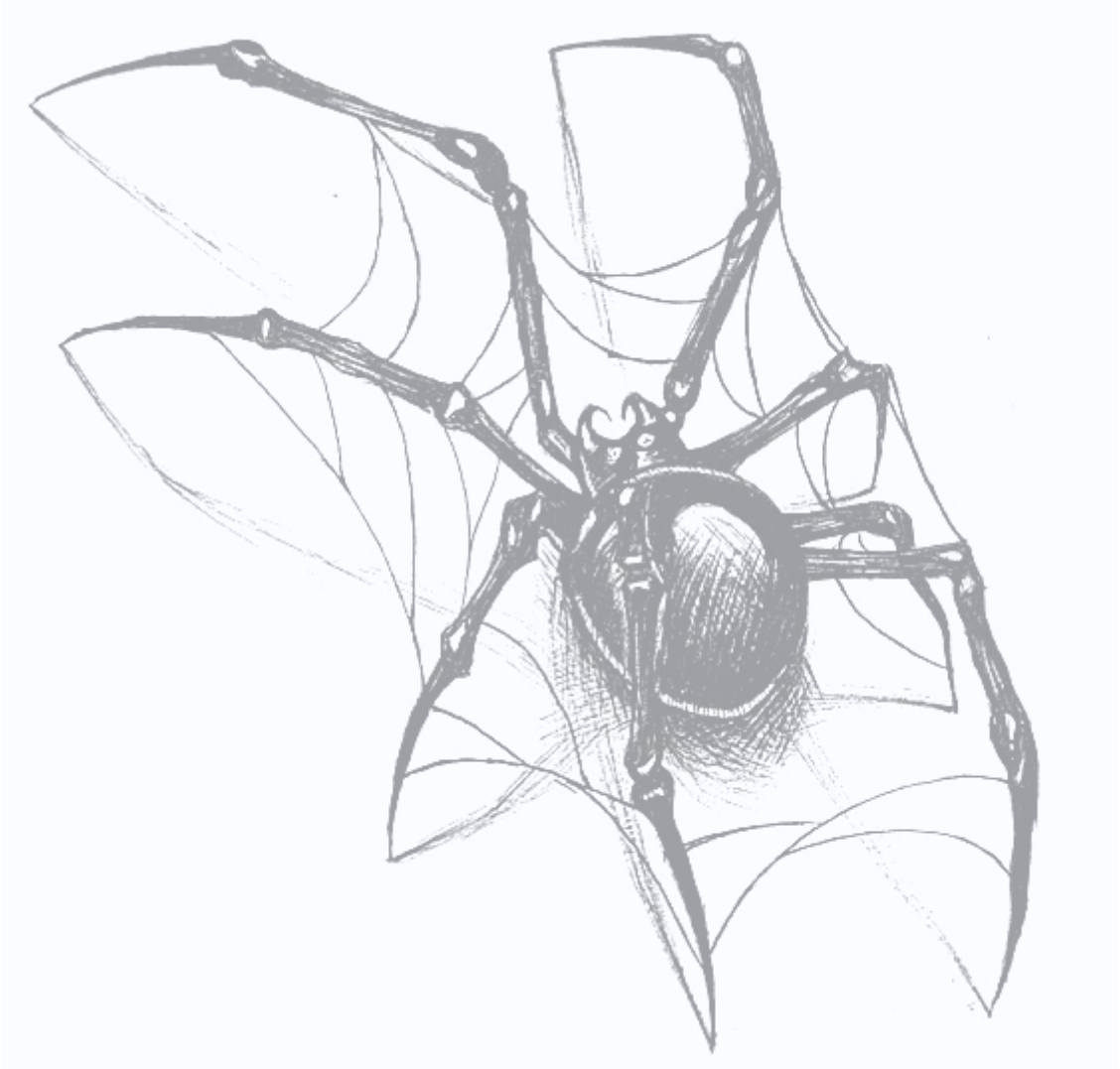
6.2. Conclusion

The study found that horticultural ecosystems in Thrissur district are influenced by several environmental and anthropogenic factors. The faunal diversity of spiders varied across different types of horticultural settings, with some areas showing higher biodiversity due to minimal human intervention and organic farming practices. However, intensive monoculture farming and excessive use of toxic agrochemical were observed to have severe negative effect on ecosystem stability.

Seasonal variations in the diversity of spiders in the horticultural ecosystem was also examined in the present exploration. 89 species out of the 116 species (76.7%) reported are common to all the three seasons even though their numerical abundance varied between seasons. This may be due to the manipulation of several climatic factors by human interventions like irrigation, weeding, etc.

More research in the diversity of spiders in crop lands and impact of various abiotic and biotic factors on their diversity holds practical implications for sustainable agriculture and ecosystem management. Being helpful in management of various pests in crop fields, spider community contributes significantly to the health and resilience of agroecosystems. Research in these directions should be encouraged to identify the services they provided in the delicate ecosystems like agricultural fields for the maintenance of ecological equilibrium and to plan various conservation strategies to enhance their presence in the croplands. Explorations on the ecological interactions of spiders with other organisms like pests, other beneficial fauna, vegetation etc. in real field conditions should be encouraged so that it will contribute toward Integrated Pest Management strategies in our fields. More research on the impacts of agricultural practices on our beneficial fauna may positively influence sustainable agriculture. More works addressing the conservation of beneficial fauna are desirable.

The study also revealed that exposure to many commonly used pesticides resulted in behavioural changes like decreased web building activity, reduced feeding potential etc. and physiological changes like increased mortality and reduced longevity. The study underscores the importance of adopting more sustainable pest management strategies to mitigate the adverse impact of toxic agrochemicals on beneficial fauna. In this point of view, encouragement of spider populations and their effective conservation in the agroecosystems is very important. Getting a comprehensive understanding of spider diversity and its seasonal variations is essential for this. It is noteworthy that a shift towards sustainable horticultural practices that balance agricultural productivity with biodiversity conservation is essential for ensuring the long-term health of agroecosystems.



CHAPTER 7

RECOMMENDATIONS

RECOMMENDATIONS

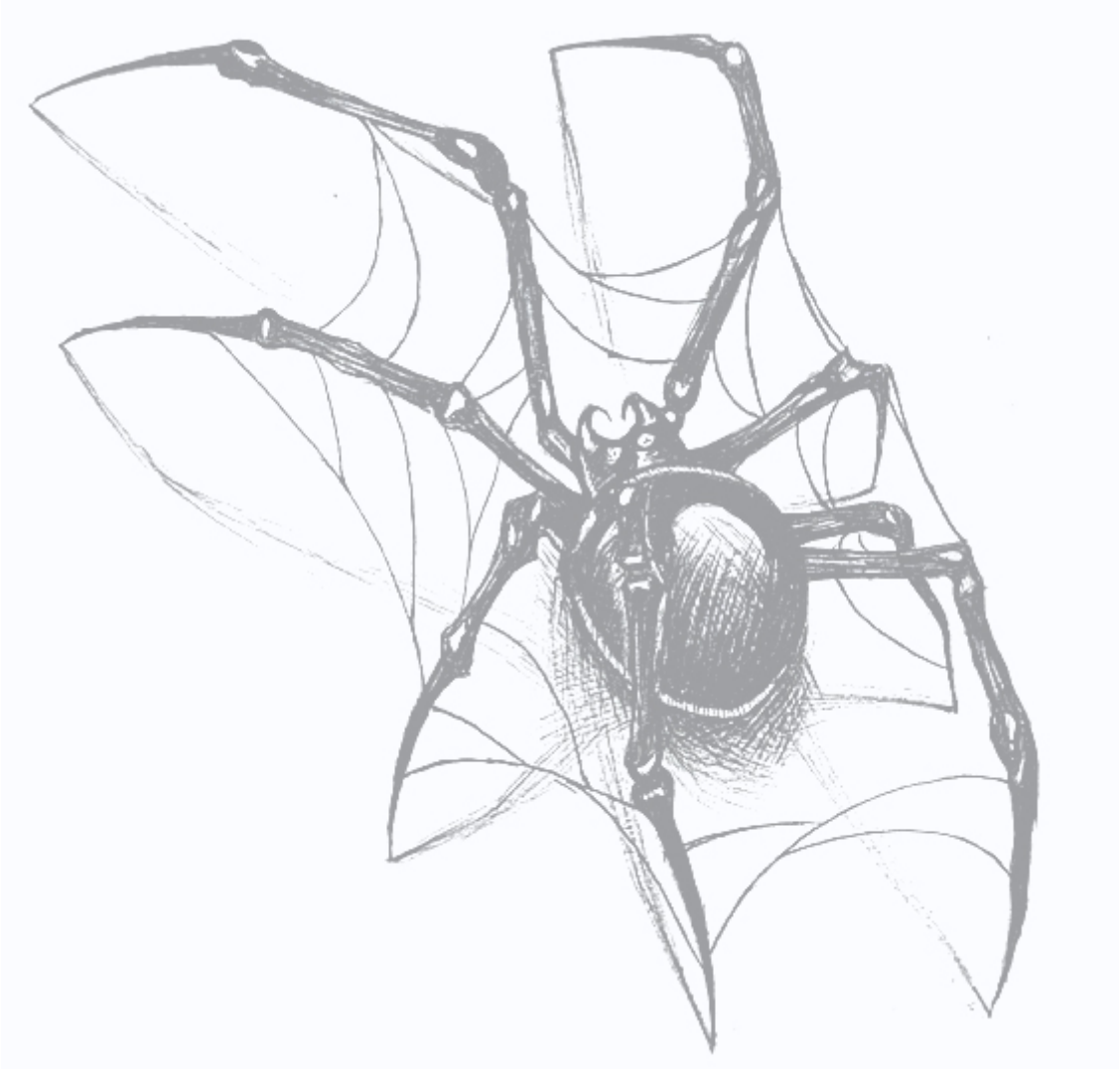
The present study aimed to depict the status of diversity of spiders in the horticultural ecosystems of Thrissur district. The major limitation of the study is the adoption of sampling methods. The study being conducted in the agro ecosystem and focused mainly on diurnal fauna, hand picking and sweep netting are the two methods adopted for sampling. For a comprehensive and realistic picturiation of diversity, an integrated approach employing a multitude of sampling strategies is irreplaceable. Inclusion of methods to sample nocturnal spider fauna like pit fall traps will result in a better portrayal of diversity. An investigation of the impact of vegetation and animal populations in the neighboring localities on the spider fauna of crop fields is also required.

It is noteworthy to document how various crops in the horticultural field and their different growing stages impact spider diversity. This is crucial as the spider assemblages can be deployed as pest control agents in these crop fields. A more comprehensive study of intricate trophic interactions of spiders in their habitat should be conducted for establishing their role as bio control agents accurately. A thorough knowledge of various pest groups, their biology and environmental conditions that enhance crop damage etc. is very important for the effective implementation of biological pest control. A worthwhile prediction of bio control agent for a particular pest could not be possible without a thorough investigation of feeding efficacy of various spiders considering the interactions like competition among spiders and other predators, prey preference of spiders, presence of parasites and pathogens etc. Efforts in this direction require investment of more human power and time. So, execution of decentralized studies integrating the efforts of experts and

interested local people is the need of the hour. Local self-governments should plan such detailed studies and government and various NGOs should provide funding for such studies. Engaging learners from nearby education institutions helps to create and perpetuate awareness on bio control and its importance. It helps them to view spiders from a different perspective and develop appreciation towards their beneficial roles in the ecosystems.

Spiders being more sensitive to pesticides, their non-judicious usage affect them to a greater extent than insects. Serious efforts are required to evaluate the impact of commonly used pesticides on non-target organisms like spiders. The present study examined the impact of two widely used pesticides; Lambda cyhalothrin and Quinalphos on the longevity and feeding efficacy of selected spiders in laboratory conditions. A more detailed exploration of the effect of different pesticides on various spiders should be encouraged so that more resistant species can be employed as part of Integrated Pest Management.

It is high time to adopt scientific conservation strategies to protect the spider fauna of our crop fields. Protocols should be formulated in this direction. Practices like mixed cropping, reduction in the use of agrochemicals, conducting community awareness programmes on spider conservation, increasing the availability of microhabitats in the crop field by adding leaf litter and mulch can be promoted. Adoption of Integrated Pest Management strategies should also be encouraged. A clear picture of the diversity of spiders in our crop fields is unavoidable for implementing various conservation strategies. It is highly demanded to increase efforts to assess the diversity of spiders, their interaction with other flora and fauna, their population dynamics and the services that they render to the ecosystem.



REFERENCE

REFERENCE

Adarsh, C.K. and Nameer, P.O., 2015. Spiders of Kerala Agricultural University Campus, Thrissur, Kerala, India. *Journal of Threatened Taxa*, *7*(15), pp.8288-8295.

Adarsh, C.K. and Nameer, P.O., 2016. A preliminary checklist of spiders (Araneae: Arachnida) in Chinnar Wildlife Sanctuary, Western Ghats, India. *Journal of Threatened Taxa*, *8*(4), pp.8703-8713.

Agnarsson, I., Coddington, J.A. and Kuntner, M., 2013. Systematics: progress in the study of spider diversity and evolution. *Spider research in the 21st century: trends and perspectives*. Siri Sci. Press, Manchester, UK, pp. 58-111.

Ahmed, A.F., 2018. A preliminary study on spider diversity in Matia, Goalpara District, Assam, India. *International Journal of Zoology and Applied Biosciences*, *3*(4), pp.369-374.

Ahmed, J., Khalap, R. and Sumukha, J.N., 2016. A new species of dry foliage mimicking *Eriovixia* archer, 1951 from Central Western Ghats, India (Araneae: Araneidae). *Indian Journal of Arachnology*, *5*(1-2), pp.24-27.

Aigner, T.B., Haynl, C., Salehi, S., O'Connor, A. and Scheibel, T., 2020. Nerve guidance conduit design based on self-rolling tubes. *Materials Today Bio*, *5*, pp.1-12.

Akilandeshwari P.D., 2021. Integrated Pest Management of Crops in India. *International Journal of Science and Research*, 10 (9) pp.760-763

Allan, R.A. and Elgar, M.A., 2001. Exploitation of the green tree ant, *Oecophylla smaragdina*, by the salticid spider *Cosmophasis bitaeniata*. *Australian Journal of Zoology*, *49*(2), pp.129-137.

Allan, R.A., Capon, R.J., Brown, W.V. and Elgar, M.A., 2002. Mimicry of host cuticular hydrocarbons by salticid spider *Cosmophasis bitaeniata* that preys on larvae of tree ants *Oecophylla smaragdina*. *Journal of Chemical Ecology*, *28*(4), pp.835-848.

Allmeling, C., Jokuszies, A., Reimers, K., Kall, S. and Vogt, P.M., 2006. Use of spider silk fibres as an innovative material in a biocompatible artificial nerve conduit. *Journal of Cellular and Molecular Medicine*, *10*(3), pp.770-777.

Ambily, C.B. and Antony, A., 2016. Diversity and distribution of spiders in agro ecosystem of Ernakulum, District, Kerala. *The Journal of Zoology Studies*, *3*(5), pp.73-77.

Anindita, B., Mahadev, C. and Prabal, S., 2017. Spider diversity in different habitats at Jaintia Hills of Meghalaya. *International Journal of Life Sciences*, 5(4), pp.613-619.

Anis Joseph, R. and Premila, K.S., 2016. A study on the richness of spider fauna in rice ecosystem. *Journal of Entomology and Zoology Studies*, 4(2), pp.425-430.

Anis Joseph, R., Premila, K.S., Nisha, V.G., Soorya Rajendran and Sarika Mohan, S. 2010. Safety of neem products to tetragnathid spiders in rice ecosystem. *Journal of Biopesticides*, *3*(1), pp.88-89.

Anitha, G. and Vijay, J., 2016. Quantification of the abundance and diversity of predatory spiders in rice ecosystem of Rajendranagar, Telangana, India. *Journal of Applied and Natural Science*, *8*(2), pp.1010-1014.

Armendano, A. and Gonzalez, A., 2011. Spider fauna associated with wheat crops and adjacent habitats in Buenos Aires, Argentina. *Revista Mexicana de Biodiversidad*, *82*(4), pp.1176-1182.

Asima, A., Prasad, G. and Sudhikumar, A.V., 2020. Spider diversity of Kerala University Campus, Thiruvananthapuram, Kerala, India. *Entomon*, *45*(3), pp.209-218.

Austen, D.J., Bayley, P.B. and Menzel, B.W., 1994. Importance of the guild concept to fisheries research and management. *Fisheries*, *19*(6), pp.12-20.

Avila, A.C., Stenert, C., Rodrigues, E.N.L. and Maltchik, L., 2017. Habitat structure determines spider diversity in highland ponds. *Ecological Research*, 32, pp.359-367.

Avolio, M.L., Carroll, I.T., Collins, S.L., Houseman, G.R., Hallett, L.M., Isbell, F., Koerner, S.E., Komatsu, K.J., Smith, M.D. and Wilcox, K.R., 2019. A comprehensive approach to analyzing community dynamics using rank abundance curves. *Ecosphere*, 10(10), pp.1-18.

Ax, P., 2000. *Multicellular animals: the phylogenetic system of the Metazoa* (Vol. 2). Springer Science & Business Media, Berlin, p.369.

Ax, P., 2012. *Multicellular Animals: A New Approach to the Phylogenetic Order in Nature Volume 1* (Vol. 1). Springer Science & Business Media, Berlin, p.317.

Bade, V.P. and Ade, P.P., 2017. Spider diversity in agroecosystem of Bori-Arab district-Yavatmal (Vidarbha). *International Journal of Research in Biosciences, Agriculture and Technology, Special Issue*, 5(2), pp.550-555.

Bambaradeniya, C.N.B. and Edirisinghe, J.P., 2009. Composition, structure and dynamics of arthropod communities in a rice agro ecosystem. *Ceylon Journal of Science (Biological Sciences)*, *37*(1), pp. 23-48.

Bambaradeniya, C.N.B., Edirisinghe, J.P., De Silva, D.N., Gunatilleke, C.V.S., Ranawana, K.B. and Wijekoon, S., 2004. Biodiversity associated with an irrigated rice agro ecosystem in Sri Lanka. *Biodiversity & Conservation*, *13*, pp.1715-1753.

Baoyong, L., Jian, Z., Denglong, C. and Min, L., 2010. Evaluation of a new type of wound dressing made from recombinant spider silk protein using rat models. *Burns*, *36*(6), pp.891-896.

Bao-Yu H., 2005. Difference in dynamic and structure of spider communities in organic and non-pollution and common tea gardens. *Acta Arachnologica Sinica*. 14(2), pp.104-107.

Basnet, K. and Mukhopadhyay, A., 2014. Biocontrol potential of the lynx spider *Oxyopes javanus* (Araneae: Oxyopidae) against the tea mosquito bug, *Helopeltis theivora* (Heteroptera: Miridae). *International Journal of Tropical Insect Science*, *34*(4), pp.232-238.

Basumatary, P. and Brahma, D., 2017. Checklist of spiders from Chakrashila Wildlife Sanctuary, Assam, India. *International Journal of Zoology Studies*, *2*(5), pp.22-26.

Batista, B.L., Arnedo, M., Carlozzi, A., Jorge, C., Pliscoff, P., Postiglioni, R., Simo, M. and Aisenberg, A., 2017. Dispersal strategies, genetic diversity, and distribution of two wolf spiders (Araneae, Lycosidae): potential bio-indicators of ecosystem health of coastal dune habitats of South America. In *Behaviour and Ecology of Spiders*, Springer, Cham, pp.109-135.

Beck, J. and Schwanghart, W., 2010. Comparing measures of species diversity from incomplete inventories: an update. *Methods in Ecology and Evolution*, *1*(1), pp.38-44.

Beevi, P.S. and Mahapatro, G.K., 2008. Species-spectrum and inter-relationship between ant and spider fauna in cashew agro-ecosystem. *Journal of Plantation Crops*, *36*(3), pp.375-381.

Beleznai, O., Dreyer, J., Tóth, Z. and Samu, F., 2017. Natural enemies partially compensate for warming induced excess herbivory in an organic growth system. *Scientific reports*, *7*(1), pp.1-9.

Beleznai, O., Tholt, G., Tóth, Z., Horváth, V., Marczali, Z. and Samu, F., 2015. Cool headed individuals are better survivors: non-consumptive and consumptive effects of a generalist predator on a sap feeding insect. *PloS one*, *10*(8), pp.1-19.

Benamu, M.A., Lacava, M., García, L.F., Santana, M. and Viera, C., 2017. Spiders associated with agroecosystems: Roles and perspectives. *Behaviour and ecology of spiders: contributions from the neotropical regio*n, pp.275-302.

Benamu, M.A., Schneider, M.I. and Sanchez, N.E., 2010. Effects of the herbicide glyphosate on biological attributes of *Alpaida veniliae* (Araneae, Araneidae), in laboratory. *Chemosphere*, *78*(7), pp.871-876.

Benhadimarín, J., Pereira, J.A., Sousa, J.P. and Santos, S.A., 2020. Distribution of the spider community in the olive grove agroecosystem (Portugal): potential bioindicators. *Agricultural and Forest Entomology*, 22(1), pp.10-19.

Benjamin, S.P. and Bambaradeniya, C.N., 2006. Systematics and conservation of spiders in Sri Lanka: current status and future prospects. *The Fauna of Sri Lanka. IUCN-The World Conservation Union, Colombo*, pp.70-76.

Bera, R., Datta, A., Bose, S., Mukhopadhyay, K., Goswami, K. K., Debnath, M., Mallick, R., Das, A., Bhattacharya, P., Barik, A. K., and Seal, A. 2022. A review on the colorimetric pesticide assay test for safe and sustainable agriculture with special reference to clean food production. *Current Journal of Applied Science and Technology*, 41(2), pp.6–35.

Bernardi, L.F.O., Wohltmann, A., Lorenzon, I.M. and Ferreira, R.L., 2017. A novel symbiotic relationship between mites and recluse spiders (Sicariidae: Loxosceles), with a description of a new *Callidosoma* species (Trombidiformes: Erythraeidae). *Zootaxa*, *4338*(3), pp.459-474.

Bhat, P.S., Srikumar, K.K. and Raviprasad, T.N., 2013. Seasonal diversity and status of spiders (Arachnida: Araneae) in cashew ecosystem. *World Applied Sciences Journal*, *22*(6), pp.763-770.

Bishop, H.I., Guan, D., Bocksteins, E., Parajuli, L.K., Murray, K.D., Cobb, M.M., Misonou, H., Zito, K., Foehring, R.C. and Trimmer, J.S., 2015. Distinct cell-and layer-specific expression patterns and independent regulation of Kv2 channel subtypes in cortical pyramidal neurons. *Journal of Neuroscience*, *35*(44), pp.14922-14942.

Blagoev, G., Deltshev, C., Lazarov, S. and Naumova, M., 2018. The spiders (Araneae) of Bulgaria. Bulgarian Academy of Sciences. Online at http://cl.bas.bg/bulgarianspiders/ (accessed on 08.02.2024).

Bond, J.E., Garrison, N.L., Hamilton, C.A., Godwin, R.L., Hedin, M. and Agnarsson, I., 2014. Phylogenomics resolves a spider backbone phylogeny and rejects a prevailing paradigm for orb web evolution. *Current Biology*, *24*(15), pp.1765-1771.

Bos, L. and Parlevliet, J.E., 1995. Concepts and terminology on plant/pest relationships: toward consensus in plant pathology and crop protection. *Annual review of Phytopathology*, *33*(1), pp.69-102.

Branco, V.V. and Cardoso, P., 2020. An expert-based assessment of global threats and conservation measures for spiders. *Global Ecology and Conservation*, *24*, p.e01290.

Brechbuhl, R., Kropf, C. and Bacher, S., 2010. Impact of flower-dwelling crab spiders on plant-pollinator mutualisms. *Basic and Applied Ecology*, 11(1), pp.76-82.

Brumm, H. and Slabbekoorn, H., 2005. Acoustic communication in noise. *Advances in the Study of Behaviour*, *35*, pp.151-209.

Bucher, R., Binz, H., Menzel, F. and Entling, M.H., 2014. Effects of spider chemo tactile cues on arthropod behaviour. *Journal of Insect Behaviour*, *27*(5), pp.567-580.

Buddle, C.M., Beguin, J., Bolduc, E., Mercado, A., Sackett, T.E., Selby, R.D., Varady-Szabo, H. and Zeran, R.M., 2005. The importance and use of taxon sampling curves for comparative biodiversity research with forest arthropod assemblages. *The Canadian Entomologist*, 137(1), pp.120-127.

Caleb, J.T., 2020a. Spider (Arachnida: Araneae) fauna of the scrub jungle in the Madras Christian College campus, Chennai, India. *Journal of Threatened Taxa*, *12*(7), pp.15711-15766.

Caleb, J.T., 2020b. Spiders (Arachnida: Araneae) from the vicinity of Araabath Lake, Chennai, India. *Journal of Threatened Taxa*, *12*(1), pp.15186-15193.

Caleb, J.T.D. & Sankaran, P.M. 2024. Araneae of India. Version 2024, online at http://www.indianspiders.in (accessed on 07.02.2024).

Cardoso, P., Pekar, S., Jocque, R. and Coddington, J.A., 2011. Global patterns of guild composition and functional diversity of spiders. *PloS one*, 6(6), pp.1-10.

Cardoso, P., Scharff, N., Gaspar, C., Henriques, S.S., Carvalho, R., Castro, P.H., Schmidt, J.B., Silva, I., Szuets, T., De Castro, A. and Crespo, L.C., 2008. Rapid biodiversity assessment of spiders (Araneae) using semi quantitative sampling: a case study in a Mediterranean forest. *Insect Conservation and Diversity*, *1*(2), pp.71-84.

Cardoso, P., Silva, I., De Oliveira, N.G. and Serrano, A.R., 2007. Seasonality of spiders (Araneae) in Mediterranean ecosystems and its implications in the optimum sampling period. *Ecological Entomology*, 32(5), pp.516-526.

Carvalho, J.C., Malumbres Olarte, J., Arnedo, M.A., Crespo, L.C., Domenech, M. and Cardoso, P., 2020. Taxonomic divergence and functional convergence in Iberian spider forest communities: *Insights from beta diversity partitioning. Journal of Biogeography*, 47(1), pp.288-300.

Cassis, G., Wall, M.A. and Schuh, R.T., 2007. Insect biodiversity and industrialising the taxonomic process: the plant bug case study (Insecta: Heteroptera: Miridae). *Systematics Association Special Volume*, *72*, p.193.

Catterall, W.A., Cestele, S., Yarov-Yarovoy, V., Frank, H.Y., Konoki, K. and Scheuer, T., 2007. Voltage-gated ion channels and gating modifier toxins. *Toxicon,* 49(2), pp.1-16.

Ceccarelli, F.S., 2008. Behavioral mimicry in Myrmarachne species (Araneae, Salticidae) from North Queensland, Australia. *The Journal of Arachnology*, *36*(2), pp.344-351.

Chagnon, M., Kreutzweiser, D., Mitchell, E.A., Morrissey, C.A., Noome, D.A. and Van der Sluijs, J.P., 2015. Risks of large-scale use of systemic insecticides to ecosystem functioning and services. *Environmental Science and Pollution Research*, *22*(1), pp.119-134.

Chand, R., Raju, S.S. and Pandey, L.M., 2008. Progress and potential of horticulture in India. *Indian Journal of Agricultural Economics*, 63(3), pp. 298-309.

Chao, A. and Jost, L., 2015. Estimating diversity and entropy profiles via discovery rates of new species. *Methods in Ecology and Evolution*, *6*(8), pp.873-882.

Chao, A. and Lee, S.M., 1992. Estimating the number of classes via sample coverage. *Journal of the American statistical Association*, *87*(417), pp.210-217.

Chao, A., Gotelli, N.J., Hsieh, T.C., Sander, E.L., Ma, K.H., Colwell, R.K. and Ellison, A.M., 2014. Rarefaction and extrapolation with Hill numbers: a framework for sampling and estimation in species diversity studies. *Ecological Monographs*, 84(1), pp.45-67.

Chao, A., 1984. Nonparametric estimation of the number of classes in a population. *Scandinavian Journal of statistics*, pp.265-270.

Chatterjee, S., Caleb, J.T., Tyagi, K., Kundu, S. and Kumar, V., 2017a. First report of *Menemerus nigli* (Araneae: Salticidae) from India. *Halteres*, *8*, pp.109-111.

Chatterjee, S., Caleb, J.T., Tyagi, K., Kundu, S. and Kumar, V., 2017b. First report of *Psechrus inflatus* Bayer (Araneae: Psechridae) from India. *Records of the Zoological Survey of India-A Journal of Indian Zoology*, *117*(4), pp.391-393.

Chaubey, S.N., 2019. Studies on habit and habitat, external morphology, feeding capacity and prey preference of two striped spider, *Telamonia dimidiata*. *Flora and Fauna*, 25(2), pp.204-208.

Chauhan, R., Sihag, V. and Singh, N.P., 2009. Distribution and biocontrol potential of chosen spiders. *Journal of Biopesticides*, *2*(2), pp.151-155.

Chen, K.C. and Tso, I.M., 2004. Spider diversity on Orchid Island, Taiwan: a comparison between habitats receiving different degrees of human disturbance. *Zoological Studies-Taipei*, *43*(3), pp.598-611.

Chetia, P. and Kalita, D.K., 2012. Diversity and distribution of spiders from gibbon wildlife sanctuary, Assam, India. *Indian Journal of Arachnology 1(1),* pp.130-142.

Choudhury, S.R., Siliwal, M. and Das, S.K., 2019. Spiders of Odisha: a preliminary checklist. *Journal of Threatened Taxa*, *11*(9), pp.14144-14157.

Chouhan, D., Das, P., Thatikonda, N., Nandi, S.K., Hedhammar, M. and Mandal, B.B., 2019. Silkworm silk matrices coated with functionalized spider silk accelerate healing of diabetic wounds. *ACS Biomaterials Science & Engineering*, *5*(7), pp.3537-3548.

Chouhan, D., Thatikonda, N., Nileback, L., Widhe, M., Hedhammar, M. and Mandal, B.B., 2018. Recombinant spider silk functionalized silkworm silk matrices as potential bioactive wound dressings and skin grafts. *ACS Applied Materials & Interfaces*, 10(28), pp.23560-23572.

Chowdhury, S., Boopathi, T., Chakraborty, A., Sontakke, P.P., Paul, T., Bhattacharjee, D., Dey, J.K. and Bhattacharjee, J., 2017. Diversity of predatory spider and their species composition in rice ecosystem in Kolasib district of Mizoram. *Innovative Farming*, *2*(1), pp.12-18.

Clough, Y., Kruess, A., Kleijn, D. and Tscharntke, T., 2005. Spider diversity in cereal fields: comparing factors at local, landscape and regional scales. *Journal of Biogeography*, 32(11), pp.2007-2014.

Coddington, J.A. and Levi, H.W., 1991. Systematics and evolution of spiders (Araneae). *Annual Review of Ecology and Systematics*, *22*(1), pp.565-592.

Coddington, J.A., 2005. Phylogeny and classification of spiders. *Spiders of North America: an identification manual*. American Arachnological Society, pp.18-24.

Conti, E., Costa, G., Liberatori, G., Vannuccini, M.L., Protano, G., Nannoni, F. and Corsi, I., 2018. *Ariadna* spiders as bioindicator of heavy elements contamination in the Central Namib Desert. *Ecological Indicators*, *95*, pp.663-672.

Corcuera, P., Valverde, P.L., Zavala-Hurtado, J.A., De la Rosa, G. and Gabriel-Duran, C., 2010. Non weaving spiders on native woodlands and Eucalyptus plantations in Western Mexico: diversity and distribution patterns. *Journal of Insect Conservation*, *14*(6), pp.711-719.

Costello, M.J. and Daane, K.M., 1999. Abundance of spiders and insect predators on grapes in central California. *Journal of Arachnology*, 27(2) pp.531-538.

Cronin, J.T., Haynes, K.J. and Dillemuth, F., 2004. Spider effects on planthopper mortality, dispersal, and spatial population dynamics. *Ecology*, *85*(8), pp.2134-2143.

Cushing, P.E., 1997. Myrmecomorphy and myrmecophily in spiders: a review. *Florida Entomologist*, pp.165-193.

Cushing, P.E., 1998. Population structure of the ant nest symbiont *Masoncus pogonophilus* (Araneae: Linyphiidae). *Annals of the Entomological Society of America*, *91*(5), pp.626-631.

Cushing, P.E., 2012. Spider-ant associations: an updated review of myrmecomorphy, myrmecophily, and myrmecophagy in spiders. *Psyche*,12 (2), pp. 1-23.

Darmawan, A., Wijayanti, H. and Ariyanti, Y., 2019. Arthropod diversity loss due to monoculture practice in south lampung, Indonesia. *BioWallacea: Scientific Journal of Biological Science*, 5(2), pp.69-73.

Davis, S., Sudhikumar, A.V., Jose, K.S. and Sebastian, P.A., 2005. New record of the Salticid Spider *Thiania bhamoensis* Thorell (Araneae: Salticidae) from Kerala, India with its redescription and field notes on behaviour. *Journal of Bombay Natural History Society*, *102*(2), pp.245-249.

De, K., Siliwal, M., Uniyal, V.P. and Hussain, S.A., 2021. Spiders as bio-indicators of habitat disturbance in the riparian zone of the Ganga river: a preliminary study. *Tropical Ecology*, pp.1-7.

Demir, H. and Seyyar, O., 2017. Annotated checklist of the spiders of Turkey. *Munis Entomology & Zoology*, *12*(2), pp.433-469.

Deng, L., Dai, J., Cao, H. and Xu, M., 2006. Effects of an organophosphorous insecticide on survival, fecundity, and development of *Hylyphantes graminicola* (Sundevall) (Araneae: Linyphiidae). *Environmental Toxicology and Chemistry: An International Journal*, *25*(11), pp.3073-3077.

Deshmukh, U.S. and Raut, N.M., 2014. Seasonal Diversity and Status of Spiders (Arachnida: Araneae) in Salbardi forest (Satpura Range), Maharashtra, India. *Journal of Entomology and Zoology Studies*, *2*(6), pp.278-281.

Deshpande, A. and Paul, R., 2016. Preliminary study on spiders of Gulbarga, Karnataka State. *International Journal of Environment, Agriculture and Biotechnology*, *1*(4), pp.680-686.

Devi, M.R., Singh, K.I. and Ray, D.C., 2018. Predators and parasitoids of rice insect pests under rice ecosystems of Manipur valley. *Indian Journal of Entomology*, 80(3), pp.789-793.

Devine, G.J. and Furlong, M.J., 2007. Insecticide use: Contexts and ecological consequences. *Agriculture and Human values*, *24*(3), pp.281-306.

Devotto, L., Carrillo, R., Cisternas, E. and Gerding, M., 2007. Effects of lambda-cyhalothrin and *Beauveria bassiana* spores on abundance of Chilean soil surface predators, especially spiders and carabid beetles. *Pedobiologia*, 51(1), pp.65-73.

Dey, A., Debnath, S., Debbarma, B. and Chaudhuri, P.S., 2013. A preliminary study on spider diversity from a household garden (artificial mixed plantation) in West Tripura, India. *Journal of Research in Biology*, *3*(5), pp.1009-1017.

Dhali, D.C., Sureshan, P.M. and Chandra, K., 2016. Diversity and distribution of Indian primitive spiders (Araneae: Opisthothelae: Mygalomorphae) in different state inculding an annotated checklist. *World Scientific News*, *37*, pp.88-100.

Dhaliwal, G.S., Jindal, V. and Dhawan, A.K., 2010. Insect pest problems and crop losses: changing trends. *Indian Journal of Ecology*, *37*(1), pp.1-7.

Dharmaraj, J., Gunasekaran, C. and Rajkumar, V., 2018. Diversity and plethora of spider fauna at different habitats of the Nilgiris, Tamilnadu south India. *International Journal of Recent Scientific Research*, *9*(3A), pp.23083-23086.

Dharmaraj, J., Gunasekaran, C., Rajkumar, V. and Chinnaraj, P., 2017. Diversity of spiders (Arachnida: Araneae) in Nilgiris, Tamilnadu. *International Journal of Advanced Research in Biological Sciences,* 4(5), pp.143-147.

Dinter, A., Mausch, H. and Brauckhoff, U., 1998. Risk assessments for the linyphiid spiders *Erigone atra* and *Oedothorax apicatus* and the pyrethroid Sumicidin 10 resulting from laboratory dose-response studies. *IOBC WPRS Bulletin*, *21*, pp.77-88.

Dippenaar-Schoeman, A.S. and Wassenaar, T.D., 2006. A checklist of spiders from the herbaceous layer of a coastal dune forest ecosystem at Richards Bay, KwaZulu-Natal, South Africa (Arachnida: Araneae). *African Invertebrates*, *47*(1), pp.63-70.

Dippenaar-Schoeman, A.S., Van den Berg, A.M., Lyle, R. and Haddad, C.R., 2013. Current knowledge of spiders in South African agroecosystems (Arachnida, Araneae). *Transactions of the Royal Society of South Africa*, *68*(1), pp.57-74.

Dow, G.K., Olewiler, N. and Reed, C., 2005. The transition to agriculture: Climate reversals, population density, and technical change. Population Density, and Technical Change online at http://ideas.repec.org/p/wpa/wuwpeh/ (accessed on 07.02.2024).

Drisya Mohan, O.M., Kashmeera, N.A. and Sudhikumar, A.V., 2019. Is cooperation in prey capture flexible in the Indian social spider *Stegodyphus sarasinorum*? *Arachnologische Mitteilungen*, *58*(1), pp.97-102.

Durkee, C.A., Weiss, M.R. and Uma, D.B., 2011. Ant mimicry lessens predation on a North American jumping spider by larger salticid spiders. *Environmental Entomology*, 40(5), pp.1223-1231.

Dubey, J.K. and Thakur, M., 2020. Pollution: Pesticides in Agro-Horticultural Ecosystems. In *Managing Global Resources and Universal Processes*, CRC Press, pp.99-109.

Durairaj, C., Shobanadevi, R., Suresh, S. and Natrajan, S., 2006. A non-chemical method for the management of leaf miner *Liriomyza trifolii* and whitefly *Bemisia tabaci* in brinjal. In *I International Conference on Indigenous Vegetables and Legumes. Prospectus for Fighting Poverty, Hunger and Malnutrition 752,* pp.527-530.

Edmunds, M., 1993. Does mimicry of ants reduce predation by wasps on salticid spiders? *Memoirs of the Queensland Museum. Brisbane*, 33(2), pp.507-512.

El-Karim, A., Hamdi, S., Rahil, A.A. and Rizk, M.A., 2016. The difference between organic and conventional cultivation on biodiversity activity of spiders (Araneae) in chamomile and chrysanthemum in Fayoum Governorate, Egypt. *Egyptian Academic Journal of Biological Sciences. A, Entomology*, 9(4), pp.83-95.

Encarnacao, J., Leitao, F., Range, P., Pilo, D., Chicharo, M.A. and Chícharo, L., 2015. Local and temporal variations in near shore macrobenthic communities associated with submarine groundwater discharges. *Marine Ecology*, 36(4), pp.926-941.

Engen, S., Lande, R., Walla, T. and DeVries, P.J., 2002. Analyzing spatial structure of communities using the two-dimensional Poisson lognormal species abundance model. *The American Naturalist*, *160*(1), pp.60-73.

Evans, H.C., 2013. Fungal pathogens of spiders. In *Spider ecophysiology* (pp.107-121). Springer, Berlin, Heidelberg.

Everts, J.W., Willemsen, I., Stulp, M., Simons, L., Aukema, B. and Kammenga, J., 1991. The toxic effect of deltamethrin on linyphiid and erigonid spiders in connection with ambient temperature, humidity, and predation. *Archives of Environmental Contamination and Toxicology*, 20(1), pp.20-24.

Fannes, W., De Bakker, D., Loosveldt, K. and Jocque, R., 2008. Estimating the diversity of arboreal oonopid spider assemblages (Araneae, Oonopidae) at Afrotropical sites. *The Journal of Arachnology*, 36(2), pp.322-330.

FAOSTAT. (2020). Data. [online] Available at: https://www.fao.org/fsnforum/resources/fao-flagships/world-food-and-agriculture-statistical-yearbook-2020 (accessed on 08.02. 2022).

FAOSTAT. (2021). Data. [online] Available at: https://www.fao.org/policy-support/tools-and-publications/resources-details/en/c/1458575/ (accessed on 08.02.2022).

Feber, R.E., Bell, J., Johnson, P.J., Firbank, L.G. and Macdonald, D.W., 1998. The effects of organic farming on surface-active spider (Araneae) assemblages in wheat in southern England, UK. *Journal of Arachnology*, pp.190-202.

Fernandez, R., Kallal, R.J., Dimitrov, D., Ballesteros, J.A., Arnedo, M.A., Giribet, G. and Hormiga, G., 2018. Phylogenomics, diversification dynamics, and comparative transcriptomics across the spider tree of life. *Current Biology*, *28*(9), pp.1489-1497.

Foord, S.H., Dippenaar-Schoeman, A.S. and Haddad, C.R., 2011. South African spider diversity: African perspectives on the conservation of a mega-diverse group. *Changing diversity in changing environment*, pp.163-182.

Foord, S.H., Fourie, R. and Dippenaar-Schoeman, A.S., 2015. Effects of a fast-burning spring fire on the ground-dwelling spider assemblages (Arachnida: Araneae) in a central South African grassland habitat. *African Zoology*, 50(4), pp.281-292.

Fritz, L.L., Heinrichs, E.A., Machado, V., Andreis, T.F., Pandolfo, M., de Salles, S.M., de Oliveira, J.V. and Fiuza, L.M., 2011. Diversity and abundance of arthropods in subtropical rice growing areas in the Brazilian south. *Biodiversity and Conservation,* 20(10), pp.2211-2224.

Garrison, N.L., Rodriguez, J., Agnarsson, I., Coddington, J.A., Griswold, C.E., Hamilton, C.A., Hedin, M., Kocot, K.M., Ledford, J.M. and Bond, J.E., 2016. Spider phylogenomics: untangling the Spider Tree of Life. *PeerJ*, *4*, pp.1-35.

Gartrell, B.A., Coleman, R., Efstathiou, E., Fizazi, K., Logothetis, C.J., Smith, M.R., Sonpavde, G., Sartor, O. and Saad, F., 2015. Metastatic prostate cancer and the bone: significance and therapeutic options. *European Urology*, *68*(5), pp.850-858.

Ghavami, S., 2008. The potential of predatory spiders as biological control agents of cotton pests in Tehran provinces of Iran. *Asian Journal of Experimental Sci*ence, *22*(3), pp.303-306.

Gibb, H., 2003. Dominant meat ants affect only their specialist predator in an epigaeic arthropod community. *Oecologia*, 136(4), pp.609-615.

Gilbert, R., Karp, R.D. and Uetz, G.W., 2016. Effects of juvenile infection on adult immunity and secondary sexual characters in a wolf spider. *Behavioural Ecology*, *27*(3), pp.946-954.

Gogoi, J. and Ningthoujam, K., 2021. Arthropod biodiversity in agricultural, horticultural and silvicultural ecosystems with special reference to spiders (Araneae) in mid-hills of Meghalaya, India. *Journal of Agriculture and Horticulture Research*, 6(2), pp. 244-262.

Gomes, D.G., Hesselberg, T. and Barber, J.R., 2020. Phantom river noise alters orb-weaving spider abundance, web size, and prey capture. *Functional Ecology*, *35(3)*, pp.717-726.

Graf, N., Battes, K.P., Cimpean, M., Dittrich, P., Entling, M.H., Link, M., Scharmuller, A., Schreiner, V.C., Szocs, E. and Schafer, R.B., 2019. Do agricultural pesticides in streams influence riparian spiders? *Science of the Total Environment*, *660*, pp.126-135.

Granados, C.E.F., Ibarra Nunez, G., Gomez Rodriguez, J.F. and Angulo Ordones, G.G., 2019. Spiders (Arachnida: Araneae) of the tropical mountain cloud forest from El Triunfo Biosphere Reserve, Mexico. *Acta Zoologica Mexicana*, *35,* pp. 1-19.

Grube, A., Donaldson, D., Kiely, T. and Wu, L., 2011. Pesticides industry sales and usage. *US Environmental Protection Aagency, Washington, DC,* pp. 1-41.

Guan, K.L., Liu, Y., Luo, X.J., Zeng, Y.H. and Mai, B.X., 2020. Short-and medium-chain chlorinated paraffins in aquatic organisms from an e-waste site: Biomagnification and maternal transfer. *Science of the Total Environment*, *708*, pp.1-29.

Gupta, A.K., 2004. Origin of agriculture and domestication of plants and animals linked to early Holocene climate amelioration. *Current Science*, 87 (1), pp.54-59

Hanelt, B., Thomas, F. and Schmidt-Rhaesa, A., 2005. Biology of the phylum Nematomorpha. *Advances in Parasitology*, *59*, pp.243-305.

Hanna, R., Zalom G.F. and Roltsch J.W., 2003. Relative impact of spider predation cover crop on population dynamics of *Erythroneura* variabilis in a raisin grape vineyard. *Entomol Exp Appl*. 107, pp. 109-116.

Harvey, M.S. and Edward, K.L., 2007. Three new species of cavernicolous goblin spiders (Araneae, Oonopidae) from Australia. *Records-Western Australian Museum*, 24(1), pp. 9-17.

Harvey, M.S., Sampey, A., West, P.L. and Waldock, J.M., 2000. Araneomorph spiders from the southern Carnarvon Basin, Western Australia: a consideration of regional biogeographic relationships. *Records of the Western Australian Museum, Supplement*, 61, pp.295-321.

Harwood, J.D., Sunderland, K.D. and Symondson, W.O.C., 2001. Living where the food is: web location by linyphiid spiders in relation to prey availability in winter wheat. *Journal of Applied Ecology*, *38*(1), pp. 88-99.

Haupt, J., 2003. The Mesothelae-a monograph of an exceptional group of-spiders (Araneae: Mesothelae). *Zoologica*, 154, pp. 1-102.Haupt, J., 2005. Taxonomy of spiders. *Toxin Reviews*, *24*(3-4), pp.249-256.

Hawkins, C.P. and MacMahon, J.A., 1989. Guilds: the multiple meanings of a concept. *Annual Review of Entomology,* 34(1), pp.423-451.

Hawlena, D. and Schmitz, O.J., 2010. Herbivore physiological response to predation risk and implications for ecosystem nutrient dynamics. *Proceedings of the National Academy of Sciences*, *107*(35), pp.15503-15507.

Hayasaka, D., Korenaga, T., Sánchez-Bayo, F. and Goka, K., 2012. Differences in ecological impacts of systemic insecticides with different physicochemical properties on biocenosis of experimental paddy fields. *Ecotoxicology*, *21*(1), pp.191-201.

He, X., Qiao, Y., Sigsgaard, L. and Wu, X., 2020. The spider diversity and plant hopper control potential in the long-term organic paddy fields in sub-tropical area, China. *Agriculture, Ecosystems & Environment*, 295, pp.1-8.

Hennecke, K., Redeker, J., Kuhbier, J.W., Strauss, S., Allmeling, C., Kasper, C., Reimers, K. and Vogt, P.M., 2013. Bundles of spider silk, braided into sutures, resist basic cyclic tests: potential use for flexor tendon repair. *PloS one*, 8(4), pp. 1-10.

Herzig, V., Sunagar, K., Wilson, D.T., Pineda, S.S., Israel, M.R., Dutertre, S., McFarland, B.S., Undheim, E.A., Hodgson, W.C., Alewood, P.F. and Lewis, R.J., 2020. Australian funnel-web spiders evolved human-lethal δ-hexatoxins for defense against vertebrate predators. *Proceedings of the National Academy of Sciences*, *117*(40), pp.24920-24928.

Heyborne, W.H., Miller, J.C. and Parsons, G.L., 2003. Ground dwelling beetles and forest vegetation change over a 17-year-period, in western Oregon, USA. *Forest Ecology and Management*, *179*(1-3), pp.123-134.

Hoefler, C.D., Chen, A. and Jakob, E.M., 2006. The potential of a jumping spider, *Phidippus clarus,* as a biocontrol agent. *Journal of Economic Entomology*, *99*(2), pp.432-436.

Hof, A., Heimann, D. and Rombke, J., 1995. Further development for testing the effects of pesticides on wolf spiders. *Ecotoxicology and Environmental Safety*, *31*(3), pp.264-270.

Hogg, B.N. and Daane, K.M., 2011. Ecosystem services in the face of invasion: the persistence of native and nonnative spiders in an agricultural landscape. *Ecological Applications*, 21(2), pp.565-576.

Hore, U. and Uniyal, V.P., 2008. Diversity and composition of spider assemblages in five vegetation types of the Terai Conservation Area, India. *The Journal of Arachnology*, 36(2), pp.251-258.

Hosseini, M.M.J. and Zamani, A., 2017. A checklist of subterranean arthropods of Iran. *Subterranean Biology*, *21*, pp.19-46.

Horticulture Statistics. 2018. Horticultural Statistics at a Glance. [Online] Available at: https://agricoop.nic.in/sites/default/files/Horticulture%20Statistics%20at%20a%20Glance-2018.pdf (accessed on 05.01.2022).

Hsieh, Y.L. and Linsenmair, K.E., 2012. Seasonal dynamics of arboreal spider diversity in a temperate forest. *Ecology and Evolution*, 2(4), pp.768-777.

Huby, N., Vie, V., Renault, A., Beaufils, S., Lefevre, T., Paquet-Mercier, F., Pezolet, M. and Beche, B., 2013. Native spider silk as a biological optical fiber. *Applied Physics Letters*, *102*(12), pp.1-8.

Huffaker, C.B. ed., 2012. Theory and practice of biological control. Elsevier, Publisher: Academic Press Inc., New York, pp.686-742.

Ivanov, V.V., 2013. The checklist of Belarusian spiders (Arachnida, Araneae). *Zoology and Ecology*, *23*(4), pp.293-311.

Jackson, R.R., Pollard, S.D., Nelson, X.J., Edwards, G.B. and Barrion, A.T., 2001. Jumping spiders (Araneae: Salticidae) that feed on nectar. *Journal of Zoology*, *255*(1), pp.25-29.

Jaga, K. and Dharmani, C., 2003. Sources of exposure to and public health implications of organophosphate pesticides. *Revista Panamericana de Salud Publica*, *14*, pp.171-185.

Jagers, G.A., Akkerhuis, O., Westerhof, R., Van Straalen, N.M. and Koeman, J.H., 1995. Water balance, respiration and immobilisation in relation to deltamethrin poisoning and physical conditions in the epigeal spider *Oedothorax apicatus*. *Pesticide Science*, *44*(2), pp.123-130.

Jangid, A.K., Dewasi, S.R., Kumar, L., Yadav, D., Sharma, V. and Upadhyay, M., 2019. Diversity of spiders (Arachnida: Araneae) from Central Aravalli Ranges, Rajasthan, India. *Serket* 17(1), pp.61-67.

Jastrzebski, P., 2007. Salticidae from the Himalayas. The genus *Epocilla* Thorell 1887 (Arachnida: Araneae). *Acta Arachnologica*, *56*(1), pp.15-19.

Jastrzbski, P., 1997. Salticidae from the Himalayas. Genus *Rhene* Thorell. 1g69 (Araneae: Salticidae). *Entomologica Basiliensia,* 20, pp.45-56.

Jastrzębski, P., 2010. Salticidae from the Himalayas. The genus *Hasarius* Simon, 1871 (Araneae: Salticidae). *Genus*, *21*(2), pp.319-323.

Jauharlina, J., Hasnah, H. and Taufik, M.I., 2019. Diversity and community structure of arthropods on rice ecosystem. *Agrivita, Journal of Agricultural Science*, *41*(2), pp.316-324.

Jayanthi PD, K., Aurade, R.M., Kempraj, V., Chakravarthy, A.K. and Verghese, A., 2015. Glimpses of semiochemical research applications in Indian horticulture: present status and future perspectives. *New horizons in insect science: Towards sustainable pest management*, pp.239-257.

Jayasree, S., Vismaya, R.S., SS, A. and Raju, A.M., 2023. Spider diversity (Arachnida: Araneae) in selected ten mixed agroecosystems of Palakkad district, Kerala, India. *International Journal of Advanced Research in Biological Sciences,* 10(8), pp.83-106.

Jeyaparvathi, S., Baskaran, S. and Bakavathiappan, G.A., 2013. Biological control potential of spiders on the selected cotton pests. *International Journal of Pharmacy & Life Sciences*, *4*(4) pp.2568-2572.

Jia, M., E, Z., Zhai, F. and Bing, X., 2020. Rapid multi-residue detection methods for pesticides and veterinary drugs. *Molecules*, *25*(16), p.3590.

John, S.J., 2020. Myrmecophily and kleptoparasitism of the weaver ant (*Oecophylla smaragdina*) by *Cosmophasis cf. bitaeniata* (Araneae: Salticidae: Chrysillini) in the Andaman Islands. *Peckhamia*, *219*(1), pp.1-9.

Jose, A.C., Sudhin, P.P., Prasad, P.M. and Sreejith, K.A., 2018. Spider diversity in Kavvayi river basin, Kerala, Southern India. *Current World Environment*, *13*(1), p.100-112.

Jose, K.S., 2014. First record of *Dolichognatha longiceps* (Thorell, 1895) from India (Araneae: Tetragnathidae), *Munis Entomology and Zoology*, 9 (1), pp.473-477.

Jose, K.S. and Sebastian, P. A. 2001, New report on some crab spiders (Araneae: Thomisidae) from Kerala, India, *Entomon*, vol. 26, (2), pp.183-190.

Jose. K. S., Sudhikumar, A., Davis, S. and Sebastian, P.A., 2008. Preliminary studies on the diversity of spider fauna (Araneae: Arachnida) in Parambikulam Wildlife Sanctuary in Western Ghats, Kerala, India. *Journal of the Bombay Natural History Society*, *105*(3), pp.264-273.

Jost, L., 2006. Entropy and diversity. *Oikos*, *113*(2), pp.363-375.

Jost, L., 2007. Partitioning diversity into independent alpha and beta components. *Ecology*, *88*(10), pp.2427-2439.

Kamble, S.S., Bodkhe, A.K., Sarkar, I.D. and Kale, S.S., 2020. First record of *Pritha nana* Simon, 1868 of (Aranae: Filistatidae) from India. Biodiversity and Bioprospects, Indian Scenario and Perspectives, pp.145-154.

Kananbala, A., Bhubaneshwari, M. and Siliwal, M., 2018. A checklist of spiders (Arachnidae: Araneae) of Manipur, India with some first records and a new species *Conothele khunthokhanbi* (Family: Ctenizidae). *Journal of Entomology and Zoology Studies*, *6*(5), pp.2209-2214.

Karami-Mohajeri, S. and Abdollahi, M., 2011. Toxic influence of organophosphate, carbamate, and organochlorine pesticides on cellular metabolism of lipids, proteins, and carbohydrates: a systematic review. *Human & Experimental Toxicology*, *30*(9), pp.1119-1140.

Karthikeyani, R. and Kannan, S., 2012. Diversity and bio-control Potential of huntsman spider *Heteropoda venatoria* Linnaeus (Araneae: Sparassidae). *Journal of Biosciences Research*, *3*(4), pp.240-244.

Karthikeyani, R., Caleb, J.T.D., Gajbe, U.A. and Muthuchelian, K., 2017. Checklist of spiders (Arachnida: Araneae) of the state of Tamil Nadu, India. *Munis Entomology & Zoology Journal*, *12*(1), pp.180-193.

Karuppuchamy, P. and Venugopal, S., 2016. Integrated pest management. In *Ecofriendly pest management for food security* (pp.651-684). Academic Press, pp.651-684.

Kashmeera, N.A. and Sudhikumar, A.V., 2019. A checklist of spider fauna of Rajasthan, India. *Journal of Threatened Taxa*, *11*(1), pp.13184-13187.

Kashmeera, N.A., Drisya-Mohan, O.M. and Sudhikumar, A.V., 2020. Spiders of rocky desert in Kailana, Rajasthan, India. *Serket*, *17*, pp.201-206.

Kashmeera, N.A. and Sharma I., 2023. Dominance structure and guild composition of spider assemblages in the Purna Wildlife Sanctuary, Gujarat, India. *Serket*, 19(4), pp. 365-372.

Kaur, M., Das, S.K., Anoop, K.R. and Siliwal, M., 2014. Preliminary checklist of spiders of Keoladeo National Park, Bharatpur, Rajasthan with first record of *Ptocasius strupifer* Simon, 1901 (Araneae: Salticidae) from India. *Munis Entomology and Zoology*, *9*(1), pp.501-509.

Keswani S., Hadole P. and Rajoria A., 2012. Checklist of spiders (Arachnida: Araneae) from India. *Indian Journal of Arachnology.* 1(1), pp.1-129.

Keswani, S. and Vankhede, G., 2014. Diversity, population and habitat used by spiders in banana agro ecosystem. *Indian Journal of Arachnology*, *3*(1), pp.35-40.

Keyserling, E., 1882. Die Arachniden Australiens. *Nunberg*, *1*, pp.1325-1420.

Khan, A.A. and Rather, A.Q., 2012. Diversity and foraging behaviour of spider (Arachnida: Araneae) in the temperate maize ecosystem of Kashmir. *Journal of Biological Control*, *26*(2), pp.85-95.

Khan, A.A., 2006. Relative abundance of spider fauna in rice ecosystem. *SAARC Journal of Agriculture*, *4*, pp.159-166.

Khan, A.A., 2009. Biodiversity of spider fauna (Arachnida: Araneae) in horticultural ecosystem of Kashmir. *Indian Journal of Ecology*, *36*(1), pp.59-64.

Khan, A.A., 2011. Spider fauna on temperate rice in Kashmir. *Oryza-An International Journal on Rice*, *48*(2), pp.147-153.

Khofar, P.N., Kurahashi, H., Zainal, N.S., Isa, M.S. and Heo, C.C., 2019. Diversity of Coprophilic Diptera associated with buffalo dung in Selangor, Malaysia. *Journal of Wildlife and Parks*, *34*, pp.63-80.

Kielhorn, K.H., 2008. A glimpse of the tropics–spiders (Araneae) in the greenhouses of the Botanic Garden Berlin-Dahlem. *Arachnologische Mitteilungen*, *36*, pp.26-34.

Kobayashi, T., Takada, M., Takagi, S., Yoshioka, A. and Washitani, I., 2011. Spider predation on a mirid pest in Japanese rice fields. *Basic and Applied Ecology*, *12*(6), pp.532-539.

Komnenov, M., 2010. Checklist of spiders (Araneae) of Bosnia and Herzegovina. *Uzizaz i Biospeld*, *5*(2009), pp.52-69.

Korenko, S., 2017. First record from Italy of *Zatypota anomala* (Ichneumonidae, Ephialtini), a parasitoid of the cribellate spider *Dictyna pusilla* (Araneae, Dictynidae). *Arachnologische Mitteilungen*, 54, pp.1-4.

Krishnaveni, K. and Kandeepan, C., 2017. Diversity and structure of spider assemblages in Sirumalai Hills, Dindigul district, Tamil Nadu. *International Journal of Life Sciences Research* 7(3), pp:61-66.

Kumar, A., Kanaujia, A., Kumar, A., Kumar, V. and Mishra, H., 2017a. Araneofauna of Nawabganj bird sanctuary, Unnao, Uttar Pradesh, India. *Journal of Entomology and Zoology Studies*, *5*(4), pp.1952-1955.

Kumar, A., Kanaujia, A., Kumar, A., Kumar, V. and Mishra, H., 2017b. Diversity of spiders in Kukrail Reserve Forest, Lucknow, Uttar Pradesh, India. *Journal of Environmental Science and Technology*, *4*(5), pp.101-104.

Kumari, V., Saini, K.C. and Singh, N.P., 2017. Diversity and distribution of spider fauna in arid and semi-arid region of Rajasthan. *Journal of Biopesticides*, *10*(1), pp.17-24.

Kumari, V., Singh, N.P., Meena, S. and Lata, R.K., 2019. Toxicity of biological and chemical insecticides on spiders. *Journal of Himalayan Ecology and Sustainable Development*, 14, pp.79-87.

Lavery, A., 2019. A revised checklist of the spiders of Great Britain and Ireland. *Arachnology*, *18*(3), pp.196-212.

Lawania, K.K. and Mathur, P., 2018. Seasonal abundance and population indices of spider fauna in monsoon seasons of the years 2013 to 2016 from different habitats of eastern region of Rajasthan, India. *Munis Entomology and Zoology,* 13(1), pp.172-180.

Lawler, S.P., 2001. Rice fields as temporary wetlands: a review. *Israel Journal of Zoology*, 47(4), pp.513-528.

Lazarov, S., 2009. *Harpactea konradi*, a new spider species from Bulgaria, (Araneae, Dysderidae). *Zootaxa*, *2140*(1), pp.33-37.

Lefebvre, M., Franck, P., Olivares, J., Ricard, J.M., Mandrin, J.F. and Lavigne, C., 2017. Spider predation on rosy apple aphid in conventional, organic and insecticide-free orchards and its impact on aphid populations. *Biological Control*, 104, pp.57-65.

Lenoir, L., Bengtsson, J. and Persson, T., 2003. Effects of Formica ants on soil fauna-results from a short-term exclusion and a long-term natural experiment. *Oecologia*, *134*(3), pp.423-430.

Liu, P.W. and Bean, B.P., 2014. Kv2 channel regulation of action potential repolarization and firing patterns in superior cervical ganglion neurons and hippocampal CA1 pyramidal neurons. *Journal of Neuroscience*, *34*(14), pp.4991-5002.

Liu, S., Li, Z., Sui, Y., Schaefer, D.A., Alele, P.O., Chen, J. and Yang, X., 2015. Spider foraging strategies dominate pest suppression in organic tea plantations. *BioControl*, *60*(6), pp.839-847.

Liu, Z., Deng, M., Xiang, J., Ma, H., Hu, W., Zhao, Y., Li, D.C. and Liang, S., 2012. A novel spider peptide toxin suppresses tumor growth through dual signaling pathways. *Current Molecular Medicine*, *12*(10), pp.1350-1360.

Lo Man Hung, N.F., Marichal, R., Candiani, D.F., Carvalho, L.S., Indicatti, R.P., Bonaldo, A.B., Cobo, D.H., Feijoo M, A., Tselouiko, S., Praxedes, C. and Brown, G., 2011. Impact of different land management on soil spiders (Arachnida: Araneae) in two Amazonian areas of Brazil and Colombia. *Journal of Arachnology*, pp.296-302.Lopes, R.E.N., Mendonca, M.S., Rosado, J.L.O. and Loeck, A.E., 2010. Soil

spiders in differing environments: Eucalyptus plantations and grasslands in the Pampa biome, southern Brazil. *Revista Colombiana de Entomología*, 36(2), pp.277-284.

Luddecke, T., Herzig, V., Von Reumont, B.M. and Vilcinskas, A., 2022. The biology and evolution of spider venoms. *Biological Reviews*, *97*(1), pp.163-178.

Maelfait, J.P. and Hendrickx, F., 1998. Spiders as bio-indicators of anthropogenic stress in natural and semi-natural habitats in Flanders (Belgium): some recent developments. In *Proceedings of the 17th European Colloquium of Arachnology*, Dorset Press, Dorchester, pp.293-300.

Maes, J., Burkhard, B. and Geneletti, D., 2018. Ecosystem services are inclusive and deliver multiple values. A comment on the concept of nature's contributions to people. *One Ecosystem 3*, pp.1-5.

Magurran, A.E., 1988. *Ecological diversity and its measurement*. Princeton university press, New Jersey, pp.61-81.

Mahalakshmi, R. and Jeyaparvathi, S., 2014. Diversity of spider fauna in the cotton field of Thailakulam, Virudhunagar district, Tamil Nadu, India. *Journal of Zoology Studies*, *1*(1), pp.12-18.

Mahto, T.P. and Yadav, R.P., 2009. Effect of manuring with Oilcake based vermicompost on incidence of red spider mite in okra crop. *Annals of Plant Protection Sciences*, *17*(1), pp.40-45.

Malhotra, S.K. and Srivastava, A.K., 2015. Fertilizer requirement of Indian horticulture–An analysis. *Indian Journal of Fertilizer*, 11(7), pp.16-25.

Malhotra, G.S., Neera, K. and Saxena, M.M., 2019. Spider diversity and abundance in different habitats of Upper-Northern Rajasthan. *Essence International Journal for Environmental Rehabilitation and Conservation*, *10*(1), pp.1-14.

Malik, S., Das, S.K. and Siliwal, M., 2015. Spider (Arachnida: Araneae) fauna of Delhi with first report of cobweb spider *Argyrodes bonadea* (Karsch, 1881) from India. *Indian Journal of Arachnology*, 4(2), pp.31-36.

Malik, V. and Goyal, V., 2017. Biodiversity of spiders in different habitats of Western Haryana, India. *Journal of Entomology and Zoology Studies*, *5*(4), pp.822-825.

Maloney, D., Drummond, F.A. and Alford, R., 2003. Spider predation in agroecosystems: can spiders effectively control pest population? *Maine Agricultural and Forest Experiments Station Technical Bulletin*, 190, Maine Agricultural and Forest Experiment Station, The University of Maine, Orono, pp. 1-32.

Mammola, S., Michalik, P., Hebets, E.A. and Isaia, M., 2017. Record breaking achievements by spiders and the scientists who study them. *PeerJ*, 5, pp.1-50.

Mansour, F., 1987. Effect of pesticides on spiders occurring on apple and citrus in Israel. *Phytoparasitica*, *15*(1), pp.43-50.

Mansour, F., 1988. Spiders as biocontrol agents in a citrus grove and their susceptibility to different pesticides. In *Proceedings of the Sixth International Citrus Congress, ed. by R Goren and K Mendel. Balaban Publishers, Philadelphia, PA,* pp. 1215–1221.

Marquez, T. J., Torres, R.A. and Alvarez-Garcia, D.M., 2021. Diversity of orb-weaving spiders (Arachnida: Araneae) from tropical dry forest in Northern Colombia, with eleven new records for the country. *Journal of Natural History*, 55(19-20), pp.1237-1250.

Marko, V., Keresztes, B., Fountain, M.T. and Cross, J.V., 2009. Prey availability, pesticides and the abundance of orchard spider communities. *Biological Control*, *48*(2), pp.115-124.

Marusik, Y.M., 2009. A checklist of spiders (Aranei) from the Lazo Reserve, Maritime Province, Russia. *Arthropoda Selecta*, 18(1/2), pp.95-109.

Mathew, E.V., Sudhikumar, A. and Sebastian, P.A., 2014. Vertical stratification of spiders in Kuttanad rice agroecosystem, Kerala. *Journal of Biological Control*, *28*(2), pp.62-67.

McGeoch, M.A., 1998. The selection, testing and application of terrestrial insects as bioindicators. *Biological Reviews*, *73*(2), pp.181-201.

Meehan, C.J., Olson, E.J., Reudink, M.W., Kyser, T.K. and Curry, R.L., 2009. Herbivory in a spider through exploitation of an ant–plant mutualism. *Current Biology*, *19*(19), pp.892-893.

Mehmood, S., Tahir, H.M., Summer, M., Sherawat, S.M., Ali, S. and Naseem, S., 2021. Diversity of spiders in rice ecosystems of Punjab, Pakistan. *Punjab University Journal of Zoology*, *36*(1), pp.9-20.

Merrett, P., Locket, G.H. and Millidge, A.F., 1985. A check list of British spiders. *Bulletin of the British Arachnological Society*, *6*(9), pp.381-403.

Merrett, P. and Murphy, J.A., 2000. A revised check list of British spiders. *Bulletin of British Arachnological Society*, *11*(9), pp.345-357.

Michalko, R. and Pekar, S., 2015. The biocontrol potential of *Philodromus* (Araneae, Philodromidae) spiders for the suppression of pome fruit orchard pests. *Biological Control*, *82*, pp.13-20.

Michalko, R. and Kossulic, O., 2016. Temperature-dependent effect of two neurotoxic insecticides on predatory potential of *Philodromus* spiders. *Journal of Pest Science*, 89, pp.517-527.

Michalko, R., Pekar, S., Dula, M. and Entling, M.H., 2019. Global patterns in the biocontrol efficacy of spiders: A meta-analysis. *Global Ecology and Biogeography*, *28*(9), pp.1366-1378.

Mineo, M.F., Del-Claro, K. and Brescovit, A.D., 2010. Seasonal variation of ground spiders in a Brazilian Savanna. *Zoologia (curitiba)*, *27*, pp.353-362.

Mirshamsi, O., Marusik, Y.M., Zamani, A., Moradmand, M. and Kashefi, R., 2015. Annotated checklist of the spiders of Iran (Arachnida: Araneae). *Iranian Journal of Animal Biosystematics*, *2015*(1), pp.1-108.

Mnif, W., Hassine, A.I.H., Bouaziz, A., Bartegi, A., Thomas, O. and Roig, B., 2011. Effect of endocrine disruptor pesticides: a review. *International Journal of Environmental Research and Public Health*, *8*(6), pp.2265-2303.

Mohsin, S.B., Yi-jing, L., Li-jie, T., Maqsood, I., Ma-sun, T., Le-meng, H., Khalil, U.R., Andleeb, S., Muhammad, S.K. and Saleem, M.A., 2015. Predatory efficacy of cotton inhabiting spiders on *Bemisiatabaci*, *Amrascadevastans thripstabaci* and *Helicoverpa armigera* in laboratory conditions. *Journal of Northeast Agricultural University (English Edition)*, *22*(3), pp.48-53.

Montgomery and David R. 2012. *The erosion of civilizations*. University of California press, Los Angels, California, pp. 233-247.

Moses, S., Kishor, D.R., Misra, A.K. and Ahmad, M.A., 2019. Monitoring of important predators associated with major insect pests of rice during kharif season 2017 at Pusa, Samastipur. *Journal of Entomology and Zoology Studies*, 7(1) pp.476-478.

Mukhtar, M.K. and Mushtaq, S., 2005. Spiders of the genus Clubiona (Araneae: Clubionidae) from Punjab, Pakistan. *Pakistan Journal of Zoology*, *37*(3), pp.169-174

Mullie, W.C. and Everts, J.W., 1991. Uptake and elimination of [14C] Deltamethrin by *Oedothorax apicatus* (Arachnida; Erigonidae) with respect to bioavailability. *Pesticide Biochemistry and Physiology*, *39*(1), pp.27-34.

Munevar, A., Cardoso, P. and Zurita, G.A., 2022. From forest to forestry: Reassembly of spider communities after native forest replacement by pine monocultures. *Ecological Entomology*, 47(3), pp.400-410.

Muniappan, R., Shepard, B. M., Carner, G. R., & Ooi, P. A. C. 2012. *Arthropod Pests of Horticultural Crops in Tropical Asia*. Wallingford, Oxfordshire: CABI, pp.1-4.

Muthukumaravel, K., Amsath, A. and Raja, R.B., 2013. A preliminary investigation of spider fauna in associated mangroves of Muthupet at Adirampattinam Coast, Tamil Nadu, India. *International Journal of Pure and Applied Zoology*, 1(4), pp.304-309.

Nakambam, S., Ningthoujam, K., Biswas, D. and Singh, Y.S., 2021. Studies on diversity of spider fauna in rice agroecosystem in mid-hills of Meghalaya. *J Ent Zool St*, 9(1), pp.1615-1620.

Namkung, J., Im, M.S., Kim, S.T. and Lee, J.H., 2002. Spider Fauna of Jeju Island in Korea. *Journal of Asia-Pacific Entomology*, *5*(1), pp.55-74.

Namkung, J., Yoo, J.S., Lee, S.Y., Lee, J.H., Paek, W.K. and Kim, S.T., 2009. Bibliographic checklist of Korean spiders (Arachnida: Araneae). *Journal of Korean Nature*, *2*(3), pp.191-285.

Nathan, K.K., 2000. Characteristics of drought in Kerala, India. *Drought Network News* (1994-2001), 12(1) pp. 3-5.

Nayak, P. and Solanki, H., 2021. Pesticides and Indian agriculture—a review. *International Journal of Research- Granthaalayah*, *9*, pp.250-63.

Nelson, X.J., Jackson, R.R., Li, D., Barrion, A.T. and Edwards, G.B., 2006. Innate aversion to ants (Hymenoptera: Formicidae) and ant mimics: experimental findings from mantises (Mantodea). *Biological Journal of the Linnaean Society*, *88*(1), pp.23-32.

Nelson, X.J. and Jackson, R.R., 2009. Collective Batesian mimicry of ant groups by aggregating spiders. *Animal Behaviour*, *78*(1), pp.123-129.

Nelson, X.J., 2012. A predator's perspective of the accuracy of ant mimicry in spiders. *Psyche*, 12(1), pp. 1-5.

Nepal, T.K., 2005. Spiders of Bhutan. *International Journal of Zoological Studies*, 6(4), pp.36-42.

Niedobova, J., Hula, V. and Michalko, R., 2016. Sublethal effect of agronomical surfactants on the spider *Pardosa agrestis*. *Environmental Pollution*, *213*, pp.84-89.

Norma, R.Y., Zainudin, M.A.W., Dzulhelmi, M.N. and Masduki, N., 2014. Spiders as potential ecofriendly predators against pests. *Basic and Applied Aspects of Biopesticides*, Springer, New Delhi, pp.245-254.

Novak, K., 2001. Spider venom helps hearts keep their rhythm. *Nature Medicine*, *7*(2), pp.155-155.

Ntzani, E.E., Ntritsos G, C.M., Evangelou, E. and Tzoulaki, I., 2013. Literature review on epidemiological studies linking exposure to pesticides and health effects. *EFSA Supporting Publications*, *10*(10), pp.1-159.

Nyffeler, M. and Birkhofer, K., 2017. An estimated 400–800 million tons of prey are annually killed by the global spider community. *The Science of Nature* 104(30), pp. 1-12.

Nyffeler, M. and Gibbons, J.W., 2022. Spiders feeding on vertebrates is more common and widespread than previously thought, geographically and taxonomically. *The Journal of Arachnology*, *50*(2), pp.121-134.

Oberg, S. and Ekbom, B., 2006. Recolonisation and distribution of spiders and carabids in cereal fields after spring sowing. *Annals of Applied Biology*, 149(2), pp.203-211.

Oberg, S., 2007. Spiders in the Agricultural Landscape: Diversity, Recolonisation, and Body Condition, *Doctoral Thesis, Department of Ecology, Faculty of Natural Resources and Agricultural Sciences, Swedish University of Agricultural Sciences, Uppsala*, pp.1-12

Oerke, E.C., 2006. Crop losses to pests. *The Journal of Agricultural Science*, *144*(1), pp.31-43.

Ossamy, S., Elbanna, S.M., Orabi, G.M. and Semida, F.M., 2016. Assessing the potential role of spider as bioindicators in Ashtoum el Gamil Natural Protected Area, Port Said, Egypt. *Indian Journal of Arachnology*, *5*(1-2), pp.100-112.

Ovtcharenko, V.I., Tanasevitch, A.V. and Zakharov, B.P., 2014. A survey of the spiders of Black Rock Forest preserve in New York (Arachnida: Araneae). *Entomologica Americana*, 120(1), pp.24-38.

Oxbrough, A.G., Gittings, T., O'Halloran, J., Giller, P.S. and Kelly, T.C., 2007. Biodiversity of the ground-dwelling spider fauna of afforestation habitats. *Agriculture, Ecosystems & Environment*, *120*(2-4), pp.433-441.

Oxbrough, A.G., Gittings, T., O'Halloran, J., Giller, P.S. and Smith, G.F., 2005. Structural indicators of spider communities across the forest plantation cycle. *Forest Ecology and Management*, 212(1-3), Pp.171-183.

Palem, H., Kanike, S. and Purushottam, V.R.S., 2017. Diversity of spider fauna (Arachnida: Araneae) in different ecosystems, Eastern Ghats, Southern Andhra Pradesh, India. *S*outh *Asian Journal of Life Sciences*, *4*(2), pp.51-60.

Pandey, S.P. and Mohanty, B., 2015. The neonicotinoid pesticide imidacloprid and the dithiocarbamate fungicide mancozeb disrupt the pituitary–thyroid axis of a wildlife bird. *Chemosphere*, *122*, pp.227-234.

Pandit, R. and Pai, I.K., 2017. Spiders of Taleigao Plateau, Goa, India. *Journal of Environmental Science and Public Health,1 (4), pp.240-252.*

Pandit, A.K., 2019. Diversity of common garden and house spider in Tinsukia district. *Journal of Entomological and Zoological Studies*, *7*(4), pp.1432-1439.

Paquin, P., Buckle, D.J., Duperre, N. and Dondale, C.D., 2010. Checklist of the spiders (Araneae) of Canada and Alaska. *Zootaxa*, *2461*(1), pp.1-170.

Park, Y.C., Yoo, J.S. and Kim, J.P., 2007. Diversity of spider communities in a pesticide-treated pine (*Pinus densiflora*) forest. *Journal of Ecology and Environment*, *30*(2), pp.179-186.

Parmar, B.M., 2020. The diversity of spiders from the vicinity of Dharoi Reservoir, North Gujarat, India. *Serket*, *17*(3), pp.194-200.

Pascale, M., Azinwi, C.N., Marongiu, B., Pesce, G., Stoffel, F. and Roggero, E., 2017. The outcome of prostate cancer patients treated with curative intent strongly depends on survival after metastatic progression. *BMC Cancer*, *17*(1), pp.1-8.

Patel, B.H., 2003. Spiders of Vansda National Park, Gujarat. *Zoos' Print Journal*, *18*(4), pp.1079-1083.

Patil, S.K. and Jamadagni, B.M., 2008. Efficacy and economics of some insecticides against pod borers in black gram. *Annals of Plant Protection Sciences*, *16*(2), pp.347-349.

Patil, S.R., Sambath, S. and Bhandari, R., 2013. Preliminary Study on Spider Fauna (Arachnida: Araneae) of Singhori Wildlife Sanctuary, District Raisen, Madhya Pradesh, India. *Bugs R All*, (20), pp.8-11.

Patil, S.R., 2012. Spiders of Jabalpur district (Arachnida: Araneae): updated checklist 2011. *Indian Journal of Arachnology*, *1*(1), pp.143-149.

Paul, A.V.N. and Thygarajan, K.S., 1992. Toxicity of pesticides to natural enemies of crop pests in India. *Pest management and pesticides: Indian scenario*. Narmrutha Publications, Madras, pp.158-176.

Pawar, K., Welzel, G., Haynl, C., Schuster, S. and Scheibel, T., 2019. Recombinant spider silk and collagen-based nerve guidance conduits support neuronal cell differentiation and functionality in vitro. *ACS Applied Biomaterials*, *2*(11), pp.4872-4880.

Pearce, J.L. and Venier, L.A., 2006. The use of ground beetles (Coleoptera: Carabidae) and spiders (Araneae) as bioindicators of sustainable forest management: a review. *Ecological Indicators*, *6*(4), pp.780-793.

Pechmann, M., Khadjeh, S., Sprenger, F. and Prpic, N.M., 2010. Patterning mechanisms and morphological diversity of spider appendages and their importance for spider evolution. *Arthropod Structure & Development*, 39(6), pp.453-467.

Pedersen, L.F., Dall, L.G., Sorensen, B.C., Mayntz, D. and Toft, S., 2002. Effects of hunger level and nutrient balance on survival and acetylcholinesterase activity of dimethoate exposed wolf spiders. *Entomologia Experimentalis et Applicata*, *103*(3), pp.197-204.

Peedikayil, A.C., Kunnath, S.M., Rajeevan, S., Prasadan, P.K., Sudhin, P.P. and Sudhikumar, A., 2021. Spider diversity (Arachnida: Araneae) in selected sacred groves of the Kannur district, India. *Acta Zoologica Bulgarica*, *73*(2), pp.233-252.

Pekar, S. and Kocourek, F., 2004. Spiders (Araneae) in the biological and integrated pest management of apple in the Czech Republic. *Journal of Applied Entomology*, *128*(8), pp.561-566.

Pekar, S., 1998. Effect of selective insecticides on the beneficial spider community of a pear orchard in the Czech Republic. In *Proceedings of the 17th European colloquium of arachnology, Edinburgh*, BAS, Burnham Beeches, pp.338-342.

Pekar, S., 1999. Effect of IPM practices and conventional spraying on spider population dynamics in an apple orchard. *Agriculture, Ecosystems & Environment*, *73*(2), pp.155-166.

Pekar, S., 2012a. Side effect of synthetic pesticides on spiders. *In Spider ecophysiology* Berlin, Heidelberg: Springer Berlin Heidelberg, pp.415-427.

Pekar, S., 2012b. Spiders (Araneae) in the pesticide world: an ecotoxicological review. *Pest Management Science*, 68(11), pp.1438-1446.

Peng, Y., Shao, X.L., Hose, G.C., Liu, F.X. and Chen, J., 2010. Dimethoate, fenvalerate and their mixture affects *Hylyphantes graminicola* (Araneae: Linyphiidae) adults and their unexposed offspring. *Agricultural and Forest Entomology*, *12*(4), pp.343-351.

Penney, D. and Selden, P.A., 2007. Spinning with the dinosaurs: the fossil record of spiders. *Geology Today*, *23*(6), pp.231-237.

Pennington, M.W., Czerwinski, A. and Norton, R.S., 2018. Peptide therapeutics from venom: Current status and potential. *Bioorganic & Medicinal Chemistry*, 26(10), pp.2738-2758.

Peshin, R., Kranthi, K.R. and Sharma, R., 2014. Pesticide use and experiences with integrated pest management programs and Bt cotton in India. In *Integrated Pest Management* Springer, Dordrecht, pp.269-306.

Peter, K.V., Bonny, B. and Pradeepkumar, T., 2015. *Horticulture Science and Profession*. New India Publishing Agency, New Delhi, pp. 5-24.

Piel, W.H., 2018. The global latitudinal diversity gradient pattern in spiders. *Journal of Biogeography*, *45*(8), pp.1896-1904.

Pillai, A.K., Kumar, M.G. and Kuttalam, S., 2017. Computation of arthropod biodiversity in grapes ecosystem. *Entomol Journal,* 5(5), pp.447-454

Pineda, S.S., Chin, Y.K.Y., Undheim, E.A., Senff, S., Mobli, M., Dauly, C., Escoubas, P., Nicholson, G.M., Kaas, Q., Guo, S. and Herzig, V., 2020. Structural venomics reveals evolution of a complex venom by duplication and diversification of an ancient peptide-encoding gene. *Proceedings of the National Academy of Sciences*, *117*(21), pp.11399-11408.

Plotkin, J.B. and Muller-Landau, H.C., 2002. Sampling the species composition of a landscape. *Ecology*, *83*(12), pp.3344-3356.

Poinar Jr, G., 2000. *Heydenius araneus* n. sp. (Nematoda: Mermithidae), a parasite of a fossil spider, with an examination of helminths from extant spiders (Arachnida: Araneae). *Invertebrate Biology*, *119*(4), pp.388-393.

Polchaninova, N. and Prokopenko, E., 2019. An updated checklist of spiders (Arachnida: Araneae) of Left-Bank Ukraine. *Arachnologische Mitteilungen*, *57*(1), pp.60-64.

Polchaninova, N., 2021. Spiders (Arachnida: Araneae) in dry grasslands of South Ukraine: a case study of Yelanetskyi Steppe Natural Reserve. *Arachnologische Mitteilungen*, *61*(1), pp.27-35.

Polchaninova, N., Gnelitsa, V., Terekhova, V. and Iosypchuk, A., 2021. New and rare spider species (Arachnida, Araneae) from Ukraine. *Zoodiversity*, *55*(2), pp.95-112.

Post, W.M. and Riechert, S.E., 1977. Initial investigation into the structure of spider communities. *Journal of Animal Ecology*, pp.729-749.

Prabawati, G., Herlinda, S. and Pujiastuti, Y., 2019. The abundance of canopy arthropods in South Sumatra (Indonesia) freshwater swamp main and ratooned rice applied with bioinsecticides and synthetic insecticide. Biodiversitas Journal of Biological Diversity, 20(10), pp.2921-2930.

Prasanth, M.T. and Jose, K.S., 2014. A new species of the genus *Haploclastus* from Western Ghats, India (Araneae: Theraphosidae). *Munis Entomology and Zoology*, *9*(1), pp.494-500.

Preetha, G., 2023. Toxicity of insecticides to wolf spider (*Pardosa pseudoannulata*) and rice leaf folder (*Cnaphalocrocis medinalis*): assessing the risk of insecticides on spiders in the rice ecosystem. *International Journal of Pest Management*, pp.1-10.

Privet, K. and Pétillon, J., 2020. Comparative patterns in taxonomic and functional spider diversities between tropical vs. temperate forests. *Ecology and Evolution*, 10(23), pp.13165-13172.

Priyadarshini, D. and Mahapatra, P.K., 2023. Effect of abiotic factors and seasonal influence on spider diversity in rice agroecosystem of Bargarh district, Odisha, India. *Nova Geodesia*, 3(4), pp.146-146.

Purgat, P., Krumpalova, Z., Lelovicsova, S. and Petrovicova, K., 2020. Spreading of spiders (Araneae) in the urban environment as an impact of human activities. *Public Recreation and Landscape Protection*, p.430-434.

Raghu, S. and Kumar, K., 2022. Diversity and population dynamics of spiders in agroecosystems, *Indian Journal of Entomology*, 84(3), pp. 670-673.

Raja, R.B., Muthukumaravel, K., Selvan, K.M., Pradhoshini, K.P., Ahmed, M.S., Musthafa, M.S., Burgos-Aceves, M.A. and Faggio, C., 2023. Seasonal variation in spider abundance in Muthupet mangroves, Southeast coast of Tamilnadu, India. *Environmental Monitoring and Assessment*, pp.1-26.

Rajeevan, S., Kunnath, S.M., Varghese, T. and Kandambeth, P.P., 2019. Spider diversity (Arachnida: Araneae) in different ecosystems of the Western Ghats, Wayanad region, India. *South Asian Journal of Life Science*, *7*(2), pp.29-39.

Rajeswaran, J., Duraimurugan, P. and Shanmugam, P.S., 2005. Role of spiders in agriculture and horticulture ecosystem. *Journal of Food Agriculture and Environment*, *3*(3/4), pp.147-152.

Rathee, M. and Dalal, P., 2018. Emerging insect pests in Indian agriculture. *Indian Journal of Entomology*, 80(2), pp.267-281.

R Core Team., 2020. R: A language and environment for statistical computing. Vienna, Austria: R Foundation for Statistical Computing. Retrieved from https://www.R-project.org/.

Relyea, R.A. and Hoverman, J.T., 2008. Interactive effects of predators and a pesticide on aquatic communities. *Oikos*, *117*(11), pp.1647-1658.

Rendon, M.A.P., Ibarra-Nunez, G., Parra-Tabla, V., García-Ballinas, J.A. and Henaut, Y., 2006 a. Spider diversity in coffee plantations with different management in Southeast Mexico. *Journal of Arachnology*, pp.104-112.

Rendon, M.A.P., Leon Cortes, J.L. and Ibarra-Nunez, G., 2006 b. Spider diversity in a tropical habitat gradient in Chiapas, Mexico. *Diversity and Distributions*, 12(1), pp.61-69.

Rezac, M., Glorikova, N., Wilder, S.M. and Heneberg, P., 2021. The sublethal effects of neonicotinoids on spiders are independent of their nutritional status. *Scientific Reports*, *11*(1), pp.1-11.

Rezac, M., Pekar, S. and Stara, J., 2010. The negative effect of some selective insecticides on the functional response of a potential biological control agent, the spider *Philodromus cespitum*. *BioControl*, 55(4), pp.503- 511.

Rivera-Quiroz F.A., Petcharad B., Miller J.A., 2021. First records and three new species of the family Symphytognathidae (Arachnida, Araneae) from Thailand, and the circumscription of the genus Crassignatha Wunderlich, 1995. *ZooKeys*, 1012, pp. 21-53.

Rodriguez, R.S.E., Solís-Catalan, K.P. and Valdez-Mondragon, A., 2015. Diversity and seasonal abundance of anthropogenic spiders (Arachnida: Araneae) in different urban zones of the city of Chilpancingo, Guerrero, Mexico. *Revista Mexicana de Biodiversidad*, 86(4), pp.962-971.

Roessink, I., Merga, L.B., Zweers, H.J. and Van den Brink, P.J., 2013. The neonicotinoid imidacloprid shows high chronic toxicity to mayfly nymphs. *Environmental Toxicology and Chemistry*, *32*(5), pp.1096-1100.

Roloff, F., Straub, S., Vogt, P.M., Bicker, G. and Radtke, C., 2014. Spider silk as guiding biomaterial for human model neurons. *BioMed Research International*, *pp. 1-8*.

Root, R.B., 1967. The niche exploitation pattern of the blue-grey gnatcatcher. *Ecological Monographs*, *37*(4), pp.317-350.

Rosa, R., Materatski, P., Moreira Santos, M., Sousa, J.P. and Ribeiro, R., 2012. A scaled-up system to evaluate zooplankton spatial avoidance and the population immediate decline concentration. *Environmental Toxicology and Chemistry*, *31*(6), pp.1301-1305.

Roschewitz, I., Thies, C. and Tscharntke, T., 2005. Are landscape complexity and farm specialisation related to land-use intensity of annual crop fields? *Agriculture, Ecosystems & Environment*, *105*(1-2), pp.87-99.

Rubio, G.D., Corronca, J.A. and Damborsky, M.P., 2008. Do spider diversity and assemblages change in different contiguous habitats? A case study in the protected habitats of the Humid Chaco Ecoregion, Northeast Argentina. *Environmental Entomology*, *37*(2), pp.419-430.

Rypstra, A.L. and Buddle, C.M., 2013. Spider silk reduces insect herbivory. *Biology Letters*, *9*(1), pp.1-4.

Saengyot, S. and Napompeth, B., 2008. Spiders in paddy fields in northern Thailand. *The International Society for Southeast Asian Agricultural Sciences*, 14(1), pp.60-66.

Saez, N.J., Senff, S., Jensen, J.E., Er, S.Y., Herzig, V., Rash, L.D. and King, G.F., 2010. Spider-venom peptides as therapeutics. *Toxins*, 2(12), pp.2851-2871.

Saha, S., Bhadra, A. and Raychaudhuri, D., 2020. Diversity spectrum of spider fauna in backyard rice agroecosystem, Narendrapur, West Bengal, India. *World Scientific News*, *147*, pp.61-75.

Saha, S., Roy, T. K., and Raychaudhuri, D. 2016. Survey on spider faunal diversity of Darjeeling tea plantations. *Munis Entomology & Zoology*, *11*(2), 622-635.

Samiayyan, K., 2014. Spiders–The generalist super predators in agro-ecosystems. *Integrated Pest Management* ,Academic Press, pp. 283-310.

Samu, F. and Szinetar, C., 2002. On the nature of agrobiont spiders. *The Journal of Arachnology*, *30*(2), pp.389-402.

Samu, F. and Vollrath, F., 1992. Spider orb web as bioassay for pesticide side effects. *Entomologia Experimentalis et Applicata*, *62*(2), pp.117-124.

Sanchez-Bayo, F., Tennekes, H.A. and Goka, K., 2013. Impact of systemic insecticides on organisms and ecosystems. *Insecticides-development of safer and more effective technologies*, pp.365-414.

Sanders, D. and Platner, C., 2007. Intraguild interactions between spiders and ants and top-down control in a grassland food web. *Oecologia*, 150(4), pp.611-624.

Santana, R.C., Perez, D., Dobson, J., Panagides, N., Raven, R.J., Nouwens, A., Jones, A., King, G.F. and Fry, B.G., 2017. Venom profiling of a population of the theraphosid spider *Phlogius crassipes* reveals continuous ontogenetic changes from juveniles through adulthood. *Toxins*, *9*(4), pp.1-13.

Santos, S.A., Pereira, J.A., Torres, L.M. and Nogueira, A.J., 2007. Evaluation of the effects, on canopy arthropods, of two agricultural management systems to control pests in olive groves from north-east of Portugal. *Chemosphere*, *67*(1), pp.131-139.

Saqib, H.S.A., Liang, P., You, M. and Gurr, G.M., 2021. Molecular gut content analysis indicates the inter and intra guild predation patterns of spiders in conventionally managed vegetable fields. *Ecology and Evolution*, 11(14), pp.9543-9552.

Scharff, N., Coddington, J.A., Griswold, C.E., Hormiga, G. and de Place Bjørn, P., 2003. When to quit? Estimating spider species richness in a northern European deciduous forest. *The Journal of Arachnology*, *31*(2), pp.246-273.

Schmidt, M.H., Roschewitz, I., Thies, C. and Tscharntke, T., 2005. Differential effects of landscape and management on diversity and density of ground dwelling farmland spiders. *Journal of Applied Ecology*, 42(2), pp.281-287.

Schmitz, O.J., 2005. Behaviour of predators and prey and prey and links with population-level processes. *Ecology of predator-prey interactions*, 256, Oxford University Press, pp.256-278.

Scholz, N.L., Fleishman, E., Brown, L., Werner, I., Johnson, M.L., Brooks, M.L., Mitchelmore, C.L. and Schlenk, D., 2012. A perspective on modern pesticides, pelagic fish declines, and unknown ecological resilience in highly managed ecosystems. *Bioscience*, *62*(4), pp.428-434.

Sebastian, P.A., Mathew, M.J., Beevi, S.P., Joseph, J. and Biju, C.R., 2005. The spider fauna of the irrigated rice ecosystem in central Kerala, India across different elevational ranges. *The Journal of Arachnology*, *33*(2), pp.247-255.

Sebastian, P.A., Murugesan, S., Mathew, M.J., Sudhikumar, A.V. and Sunish, E., 2005. Spiders in Mangalavanam, an ecosensitive mangrove forest in Cochin, Kerala, India (Araneae). *European Arachnology-Acta Zoologica Bulgarica*, *1*, pp.315-318.

Sebastian, P.A., Sudhikumar, A.V., Mathew, M.J. and Sunish, E., 2012. Diversity of spiders (Araneae) in the Western Ghats–an overview. *Invertebrate diversity and conservation in the Western Ghats*, pp.235-247.

Selden, P.A. and Penney, D., 2010. Fossil spiders. *Biological Reviews*, *85*(1), pp.171-206.

Sengonca C., and Liu B., 2002. Effect of GCSC-BtA biocide on population dynamics of cabbage pests and their natural enemies from fields in southeastern China. *Anz Schaedlkd* 75(2), pp. 46–50.

Sereda, E., Blick, T., Dorow, W.H., Wolters, V. and Birkhofer, K., 2014. Assessing spider diversity on the forest floor: expert knowledge beats systematic design. *Journal of Arachnology*, pp.44-51.

Seyyar, O., Demir, H., Kar, M., & Duman, F., 2010. *Argyroneta aquatica* (Clerck, 1757) (Araneae: Cybaeidae) as a biological indicator for environmental pollution of Sultan Marsh National Park, Turkey. *Acta Zoologica Bulgarica*, 62(1), pp.107-112.

Shankar, U. and Raju, S.V.S., 2012. Integrated pest management in vegetable eco-system. *Ecologically Based Integrated Pest Management, New India Publishing House, New Delhi, India, pp–619–650*.

Sharma, A., Singh, G. and Singh, R., 2021. Faunal diversity of spider families Dictynidae, Dysderidae, Eresidae and Filistatidae (Araneomorphae: Araneae: Arachnida) in India. *International Journal of Zoology and Applied Biosciences*, *6*(1), pp.1-9.

Sharma, L.S., 2015. Horticulture for Improving the Economic Condition of Mizo Farmers: Problems and Prospects. *Horticulture*, *6*(2), pp.13-20.

Sharma, P.P., 2018. Chelicerates. *Current Biology*, *28*(14), pp.774-778.

Sharma, S., 2014. A study on spiders as predators in the agroecosystems. *Munis Entomology & Zoology*, 9(1), pp.80-83.

Shaw, E.M., Waddicor, M. and Langan, A.M., 2006. Impact of cypermethrin on feeding behaviour and mortality of the spider *Pardosa amentata* in arenas with artificial vegetation. *Pest Management Science: formerly Pesticide Science*, *62*(1), pp.64-68.

Sherawat, S.M., Butt, A. and Tahir, H.M., 2015. Effects of Pesticides on Agrobiont Spiders in Laboratory and Field. *Pakistan Journal of Zoology*, 47(4), pp. 1089-1095.

Shetty, P.K., 2004. Socio-ecological implications of pesticide use in India. *Economic and Political Weekly*, pp.5261-5267.

Shimadzu, H., Dornelas, M., Henderson, P.A. and Magurran, A.E., 2013. Diversity is maintained by seasonal variation in species abundance. *BMC Biology*, *11*(1), pp.1-9

Shimazaki, A. and Miyashita, T., 2005. Variable dependence on detrital and grazing food webs by generalist predators: aerial insects and web spiders. *Ecography*, *28*(4), pp.485-494.

Shivalingaswamy, T.M., Satpathy, S. and Banerjee, M.K., 2002. Estimation of crop losses due to insect pests in vegetables. *Resources management in plant protection during twenty first century, Hyderabad, India, 14-15 November 2002. Volume I*, pp.24-31.

Shochat E., Stefanov W.L., Whitehouse M.E. and Faeth S.H., 2008. Urbanization and spider diversity: influences of human modification of habitat structure and productivity. *Urban Ecology*: *An International Perspective on the Interaction Between Humans and Nature*, pp.455-472.

Shrestha, B., Kubatova, A., Tanaka, E., Oh, J., Yoon, D.H., Sung, J.M. and Sung, G.H., 2019. Spider-pathogenic fungi within Hypocreales (Ascomycota): their current nomenclature, diversity, and distribution. *Mycological Progress*, *18*(8), pp.983-1003.

Sial, N., Ruby, T., Malik, S. and Mushtaq, S., 2012. A checklist of the spiders of Cholistan and neighbouring areas. *Pakistan Journal of Agricultural Science*, *49*, pp.301-304.

Siegfried, B.D. and Scharf, M.E., 2001. Mechanisms of organophosphate resistance in insects. In *Biochemical sites of insecticide action and resistance,* Springer, Berlin, Heidelberg, pp. 269-291.

Siliwal, M. and Molur, S. 2006. Checklist of spiders (Arachnida: Araneae) of South Asia including the 2006 update of Indian spider check list. *Zoos' Print Journal*, 22(2), pp.2551-2597.

Siliwal, M., Molur, S. and Biswas, B.K., 2005. Indian spiders (Arachnida: Araneae): updated checklist 2005. *Zoos' Print Journal*, 20(10), pp.1999-2049

Singh, B., Gaur, R.K., & Jakhar, A. 2021a. Relative Safety of Newer Insecticides to Spiders in Okra Ecosystem. *International Journal of Theoretical & Applied Sciences*, 13(2), pp. 42-45.

Singh, B.B., Singh, R. and Singh, G., 2021b. Faunal diversity of spitting spiders (Scytodidae: Araneomorphae: Araneae: Arachnida) in India. *World Journal of Pharmaceutical & Life Sciences,* 7(3), pp.82-89.

Singh, B.B. and Singh, R., 2014. Incidence and biodiversity of rice land spiders (Arthropoda: Arachnida) in northeastern Uttar Pradesh, India. *Indo-American Journal of Life Sciences and Biotechnology*, *2*(1), pp.64-89.

Singh, G., Singh, D.V., Singh, G., Singh, H., Mishra, P. and Kumar, A., 2020a. Effect of different insecticides on natural enemies' spider in brinjal ecosystem. *J. Entomol. Zool. Stud*, 8(6), pp.1186-1192.

Singh, R., Singh, G. and Sharma, A. 2020b. Diversity of yellow sac spiders (Cheiracanthiidae: Araneae: Arachnida) in India. *Journal of Entomology and Zoology Studies*. 8(6), pp.118-126.

Singh, R. and Singh, G., 2021. Updated checklist of Philodromidae (Araneae: Arachnida) from India. *World Journal of Pharmaceuticals & Life Sciences*, *7*(2), pp.129-139.

Singh, R., 2023. An updated checklist of the spider fauna (Arachnida: Araneae) in different districts of Kerala state of India. *Serket.* 19(3), pp.267-318.

Singh, R. and Singh S, 2020. Diversity of mygalomorph spiders (Aranae: Opisthothelae) in India. *IJBI.* 2 (2), pp 178-201.

Singh, R., Singh, G. and Singh, B.B., 2020. Diversity of Amycoida and Astioida (Arachnida: Araneae: Salticidae: Salticinae) in India. *Journal of Entomology and Zoology Studies*, *8*(5), pp.1478-1488.

Singh, S. and Goswami, P., 2023. Seasonal Diversity of spiders (Arachnida: Araneae) and collection methods in Barpeta district, Assam, India. *Journal of Advanced Zoology*, 44(2), pp.233-239.

Slowik, J. and Blagoev, G.A., 2012. 0251. A survey of spiders (Arachnida: Araneae) of Prince of Wales Island, Alaska; combining morphological and DNA barcode identification techniques. *Insecta mundi*, pp.1-12.

Smith, H. S., 1919. On some phases of insect control by the biological method. *J. econ. Ent.* 12, pp. 288–92.

Smith, R.B. and Mommsen, T.P., 1984. Pollen feeding in an orb-weaving spider. *Science*, *226*(4680), pp.1330-1332.

Smitha, M.S. and Sudhikumar, A.V., 2020. A diversity of spiders (Arachnida: Araneae) from a cashew ecosystem in Kerala, India. *Journal of Threatened Taxa*, *12*(13), pp.16879-16884.

Solanki, R. and Kumar, D., 2014. Effect of pesticides on spider population in cotton agro system of Vadodara (Gujarat). *The IIS University Journal of Science & Technology*, *3*(1), pp.48-52.

Song, X., Yang, T., Xu, X. and Zhong, Y., 2020. A checklist of spiders in tea plantations of China. *Biodiversity Data Journal*, *8,* pp. 1-11.

Sorensen, L.L., 2004. Composition and diversity of the spider fauna in the canopy of a montane forest in Tanzania. *Biodiversity & Conservation*, *13*(2), pp.437-452.

Stojanowska, A., Rybak, J., Bożym, M., Olszowski, T. and Bihałowicz, J.S., 2020. Spider webs and lichens as bioindicators of heavy metals: A comparison study in the vicinity of a copper smelter (Poland). *Sustainability*, *12*(19), pp.2-13.

Stowe, Mark K., James H. Tumlinson, and Robert R. H. 1987. Chemical mimicry: bolas spiders emit components of moth prey species sex pheromones. *Science* 236.4804: 964-967.

Stuart, A.J., Sulerzhitsky, L.D., Orlova, L.A., Kuzmin, Y.V. and Lister, A.M., 2002. The latest woolly mammoths (*Mammuthus primigenius* Blumenbach) in Europe and Asia: a review of the current evidence. *Quaternary Science Reviews, 21(14-15)*, pp.1559-1569.

Sudhikumar, A.V. and Nafin, K.S., 2020. Diversity of spiders in the organically cultivated paddy fields of Muriyad kol wetlands, Kerala, India. *Perspectives on biodiversity of India*, pp.232-234

Sudhikumar, A.V., 2015. Distribution pattern of spiders along an elevational gradient in Nelliyampathy Hill Ranges of the Western Ghats, Kerala, India. *International Journal of Science and Research*, *4*(7), pp.170-173.

Sudhikumar, A.V., Jocque, R. and Sebastian, P.A., 2009. A new species of the ant spider genus *Suffasia* (Araneae: Zodariidae) from the Western Ghats, India, with a key to the species of the genus. *Zootaxa*, *2203*(1), pp.59-64.

Sudhikumar, A.V., Mathew, M.J., Sunish, E. and Sebastian, P.A., 2005a. Seasonal variation in spider abundance in Kuttanad rice agroecosystem, Kerala, India (Araneae). *European Arachnology*, *1*, pp.181-190.

Sudhikumar, A.V., Mathew, M.J., Sunish, E., Murugesan, S. and Sebastian, P.A., 2005b. Preliminary studies on the spider fauna in Mannavan shola forest, Kerala, India (Araneae). *European Arachnology Supplement*, *1*, pp.319-327.

Sudhikumar, A.V., Mathew, M.J., Sunish, E. and Sebastian, P.A., 2006. Synanthropic spiders of Kerala, India. *Science and Technology for Sustainable Development*, *1*, pp.27-32.

Sudhin, P. P., Nafin, K. S., Sumesh, N. V., & Sudhikumar, A. V., 2019. A new spider species of the genus *Cocalus* C.L. Koch, 1846 (Araneae: Salticidae: Spartaeinae) from Western Ghats of India, *Arthropoda Selecta*, 28, (1), pp.125-130.

Sudhin, P.P., Nafin, K.S. and Sudhikumar, A.V., 2020. Effect of elevational gradient on diversity of spiders-a case study from Wayanad wildlife sanctuary, Kerala, India. *Perspectives on biodiversity of India*, pp.235-238.

Sudhin, P.P., Nafin, K.S., Benjamin, S.P. and Sudhikumar, A.V., 2019. Two new species of the genus *Marengo* Peckham et Peckham, 1892 (Araneae: Salticidae) from Western Ghats of India. *Arthropoda Selecta, 28*(3), pp.435-444.

Suenaga, H. and Hamamura, T., 2015. Effects of manipulated density of the wolf spider, *Pardosa astrigera* (Araneae: Lycosidae), on pest populations and cabbage yield: a field enclosure experiment. *Applied Entomology and Zoology*, *50*(1), pp.89-97.

Sugumaran, M.P. and Duraimurugan, B., 2019. Arthropod diversity in horticultural ecosystems in Keelaiyur block, Nagapattinam district, Tamil Nadu. *Indian Journal of Ecology*, *46*(4), pp.889-891.

Sugumaran, M.P., Soundararajan, R.P. and Lakshmanan, V., 2007. Spider fauna in Horticultural crops of Yercaud Hills. *Zoos' Print Journal*, *22*(6), pp.2721-2722.

Sumesh, N.V. and Sudhikumar, A.V., 2020a. Checklist of spiders from the sacred groves of Northern Kerala, India. *Uttar Pradesh Journal of Zoology*, 41(9), pp.104-115.

Sumesh, N.V. and Sudhikumar, A.V., 2020b. Diversity and guild structure of spiders in a sacred grove of Kerala, India. *Perspectives on biodiversity of India*, p.239-241.

Sunderland, K., 1999. Mechanisms underlying the effects of spiders on pest populations. *Journal of Arachnology*, pp.308-316.

Symondson, W.O.C., Sunderland, K.D. and Greenstone, M.H., 2002. Can generalist predators be effective biocontrol agents. *Annu. Rev. Entomol.*, 47, pp.561-94.

Tahir, H.M. and Butt, A., 2009. Predatory potential of three hunting spiders inhabiting the rice ecosystems. *Journal of Pest Science*, *82*(3), pp.217-225.

Tahir, H.M., Basheer, T., Ali, S., Yaqoob, R., Naseem, S. and Khan, S.Y., 2019. Effect of pesticides on biological control potential of *Neoscona theisi* (Araneae: Araneidae). *Journal of Insect Science*, 19(2), pp.1-6.

Tahir, H.M., Yaqoob, R., Naseem, S. and Zahra, K., 2015. Effects of insecticides on predatory performance of spiders. *Biologia*, 61, pp.127-131.

Tanaka, K. and Watanabe, M., 2003. Transmission of ice-nucleating active bacteria from a prey reduces cold hardiness of a predator (Araneae: Theridiidae). *Naturwissenschaften*, *90*(10), pp.449-451.

Tanaka, K., Endo, S. and Kazano, H., 2000. Toxicity of insecticides to predators of rice planthoppers: spiders, the mirid bug and the dryinid wasp. *Applied Entomology and Zoology*, *35*(1), pp.177-187.

Tang, J., Liang, W., Shi, H., Gao, C., Li, S. and Zheng, G., 2021. A checklist of spiders from Yongxing Island, South China Sea, with taxonomic notes on four species of goblin spiders. *Biodiversity Data Journal*, *9*, pp. 1-17.

Taylor, R.M. and Foster, W.A., 1996. Spider nectarivory. *American Entomologist*, *42*(2), pp.82-86.

Taylor, R.M. and Pfannenstiel, R.S., 2008. Nectar feeding by wandering spiders on cotton plants. *Environmental Entomology*, *37*(4), pp.996-1002.

Tiemann, U., 2008. In vivo and in vitro effects of the organochlorine pesticides DDT, TCPM, methoxychlor, and lindane on the female reproductive tract of mammals: a review. *Reproductive Toxicology*, *25*(3), pp.316-326.

Tietjen, W.J., 2006. Pesticides affect the mating behaviour of *Rabidosa rabida* (Araneae, Lycosidae). *The Journal of Arachnology*, 34(2), pp.285-288.

Tischler, W., 1949. Grundzuge der terrestrischen Tierokologie–Braunschweig. *Friedrich Vieweg und Sohn*,219, pp.52-57.

Tiwari, A.K., Singh, G. and Singh, R., 2021. Biodiversity of some poorly known families of spiders (Areneomorphae: Araneae: Arachnida) in India. *Journal of Global Biosciences,* 10(1), pp. 8352-8371.

Tokeshi, M., 1990. Niche apportionment or random assortment: species abundance patterns revisited. *The Journal of Animal Ecology*, 59(3), pp.1129-1146.

Toledo, M.I., Torres, P., Díaz, C., Zamora, V., López, J. and Olivares, G., 2020. Ecological succession of benthic organisms on niche-type artificial reefs. *Ecological Processes*, 9(1), pp.1-10.

Tong, Y. and Li, S., 2014. A survey of oonopid spiders in Taiwan with descriptions of three new species. *ZooKeys*, (396), pp.67-86.

Tovar M. J., Torres, R.A. and Alvarez-Garcia, D.M., 2021. Diversity of orb-weaving spiders (Arachnida: Araneae) from tropical dry forest in Northern Colombia, with eleven new records for the country. *Journal of Natural History*, *55*(19-20), pp.1237-1250.

Trinkaus, E., 2005. Early modern humans. *Annu. Rev. Anthropol. 34*, pp.207-230.

Tscharntke, T. and Brandl, R., 2004. Plant-insect interactions in fragmented landscapes. *Annual Reviews in Entomology*, 49(1), pp.405-430.

Tuomisto, H., 2010. A consistent terminology for quantifying species diversity? Yes, it does exist. *Oecologia*, *164*(4), pp.853-860.

Tuomisto, H., 2011. Commentary: do we have a consistent terminology for species diversity? Yes, if we choose to use it. *Oecologia*, *167*(4), pp.903-911.

Uetz, G.W., 1977. Coexistence in a guild of wandering spiders. *The Journal of Animal Ecology*, 46(2), pp.531-541.

Uetz, G.W., Halaj, J. and Cady, A.B., 1999. Guild structure of spiders in major crops. *Journal of Arachnology*, 27, pp.270-280.

Vairale, A.B., 2019. Diversity of spiders in agro-ecosystems of tahsil Anjangaon-Surji district Amravati (ms). *Vidyabharati International Interdisciplinary Research Journal*, 9(2), pp.158-161.

Valence, L., Nguema, A.M.N., Ndiaye, A., Morel, L. and Ysnel, F., 2022. Taxonomic diversity and functional redundancy of spider communities in African savannas. *Journal of Animal and Plant Sciences,*53 (1), pp. 9566-9579.

Van Erp, S., Booth, L., Gooneratne, R. and O'Halloran, K., 2002. Sublethal responses of wolf spiders (Lycosidae) to organophosphorous insecticides. *Environmental Toxicology: An International Journal*, *17*(5), pp.449-456.

Vehvilainen, H., Koricheva, J. and Ruohomaki, K., 2008. Effects of stand tree species composition and diversity on abundance of predatory arthropods. *Oikos*, 117(6), pp.935-943.

Vergnes, A., Pellissier, V., Lemperiere, G., Rollard, C. and Clergeau, P., 2014. Urban densification causes the decline of ground-dwelling arthropods. *Biodiversity and Conservation*, *23*(8), pp.1859-1877.

Vetter, R.S., 2011. Scavenging by spiders (Araneae) and its relationship to pest management of the brown recluse spider. *Journal of Economic Entomology*, 104(3), pp.986-989.

Vetter, R.S., Khan, S.Z., Arif, M.J., Hoddle, C. and Hoddle, M.S., 2013. Spiders (Araneae) surveyed from unsprayed citrus orchards in Faisalabad, Pakistan and their potential as biological control agents of *Diaphorina citri* (Hemiptera: Liviidae). *Pak. Entomol*, *35*, pp.61-69.

Vickerman, G.P. and Sunderland, K.D., 1977. Some effects of dimethoate on arthropods in winter wheat. *Journal of Applied Ecology*, pp.767-777.

Vijaykumar, and Patil B.V. 2004, Spider fauna of paddy ecosystem in selected areas of Tungabhadra project in Karnataka, University of Agricultural Sciences, Dharwad, India. *Karnataka Journal of Agricultural Sciences*, vol. 17(3), pp. 584-585.

Vishnudas, E.H. and Sudhikumar A.V., 2021. First report of the small daddy long leg spider *Micropholcus fauroti* (Simon, 1887) (Araneae: Pholcidae) female from India with redescription of the male. *Serket*, 18(1), pp.59-63.

Vishnudas, E.H., Ajitha, V.S. and Sudhikumar A.V., 2021. Diversity of spiders in Poovar mangrove ecosystem, Kerala, India. *Serket*, 18(1), pp.53-58.

Volkmar, C., Schumacher, K. and Freier, B., 2008. Araneae as indicators in low-input strategies in crop protection. *Mitt. Dtsch. Ges. Allg. Angew. Entomol*. 16, pp.301–304.

Vollrath, F., and Selden P., 2007. The role of behaviour in the evolution of spiders, silks, and webs. *Annual Review of Ecology, Evolution, and Systematics*.38, pp. 819-846.

Von Baeyer, and Edwinna. 2010. *The development and history of horticulture*. Oxford, United Kingdom: Eolss Publishers, pp.1-10.

Wagh, R. and Dongre, A.P., 2016. Agricultural sector: status, challenges and its role in Indian economy. *Journal of Commerce and Management Thought*, *7*(2), pp.209-218.

Wang, L.Y., Chen, H.M., Zhou, K.X., Zhang, F. and Zhang, Z.S., 2015. Diversity of spiders in Fanjing Mountain Nature Reserve, Guizhou, China, I: Six new species of Phrurolithidae (Araneae). *Zootaxa*, *4012*(3), pp.447-464.

Wang, B., Dunlop, J.A., Selden, P.A., Garwood, R.J., Shear, W.A., Müller, P. and Lei, X., 2018. Cretaceous arachnid *Chimerarachne yingi* gen. et sp. nov. illuminates spider origins. *Nature ecology & evolution*, *2*(4), pp.614-622.

Wang, X., Zhong, W., Xiao, B., Liu, Q., Yang, L., Covaci, A. and Zhu, L., 2019. Bioavailability and biomagnification of organophosphate esters in the food web of Taihu Lake, China: Impacts of chemical properties and metabolism. *Environment International*, *125*, pp.25-32.

Warra, A.A. and Prasad, M.N.V., 2020. African perspective of chemical usage in agriculture and horticulture-their impact on human health and environment. In *Agrochemicals detection, treatment and remediation* (pp.401-436). Butterworth-Heinemann.

Webster, J., and Richard T. W., 2002. Analyzing the past to Prepare for the Future: Writing a Literature Review. *MIS Quarterly* 26, no. 2: xiii–xxiii. http://www.jstor.org/stable/4132319.

Wendt, H., Hillmer, A., Reimers, K., Kuhbier, J.W., Schäfer-Nolte, F., Allmeling, C., Kasper, C. and Vogt, P.M., 2011. Artificial skin–culturing of different skin cell lines for generating an artificial skin substitute on cross-weaved spider silk fibres. *PloS one*, *6*(7), pp.1-10.

Werner, S.M. and Raffa, K.F., 2000. Effects of forest management practices on the diversity of ground-occurring beetles in mixed northern hardwood forests of the Great Lakes Region. *Forest Ecology and Management*, *139*(1-3), pp.135-155.

Wheeler, W.C., Coddington, J.A., Crowley, L.M., Dimitrov, D., Goloboff, P.A., Griswold, C.E., Hormiga, G., Prendini, L., Ramírez, M.J., Sierwald, P. and Almeida Silva, L., 2017. The spider tree of life: phylogeny of Araneae based on target gene analyses from an extensive taxon sampling. *Cladistics*, *33*(6), pp.574-616.

Whitmore, C., Slotow, R., Crouch, T.E. and Dippenaar-Schoeman, A.S., 2002. Diversity of spiders (Araneae) in a savanna reserve, Northern Province, South Africa. *The Journal of Arachnology*, *30*(2), pp.344-356.

Wise, D.H., Snyder, W.E., Tuntibunpakul, P. and Halaj, J., 1999. Spiders in decomposition food webs of agroecosystems: theory and evidence. *Journal of Arachnology*, pp.363-370.

Wolak, M., 2002. The spider fauna of balks, *Proceedings of the 19th European Colloquium of Arachnology*. Aarhus University Press, Aarhus pp.229-326.

Wongprom, P. and Kosulic, O., 2016. First data on spiders (Arachnida: Araneae) from dry dipterocarp forests of Thailand. *Check List*, *12*(6), p.1996.

World Spider Catalog, 2024. World Spider Catalog. Version 22.5. Natural History Museum Bern, online at http://wsc.nmbe.ch , (accessed on 28.01.2024).

Wu, C.H. and Elias, D.O., 2014. Vibratory noise in anthropogenic habitats and its effect on prey detection in a web-building spider. *Animal Behaviour*, *90*, pp.47-56.

Wunderlich, J., 2000. Ant mimicry by spiders and spider-mite interactions preserved in Baltic amber (Arachnida: Acari, Araneae). *European Arachnol*, *2000*, pp.355-358.

Yadav, A., Solanki, R., Siliwal, M. and Kumar, D., 2017. Spiders of Gujarat: a preliminary checklist. *Journal of Threatened Taxa*, *9*(9), pp.10697-10716.

Yoo, J.S., Lee, S.Y., Im, M.S. and Kim, S.T., 2015. Bibliographic checklist of Korean spiders (Arachnida: Araneae). *Journal of Species Research*, *4*(spc), pp.1-112.

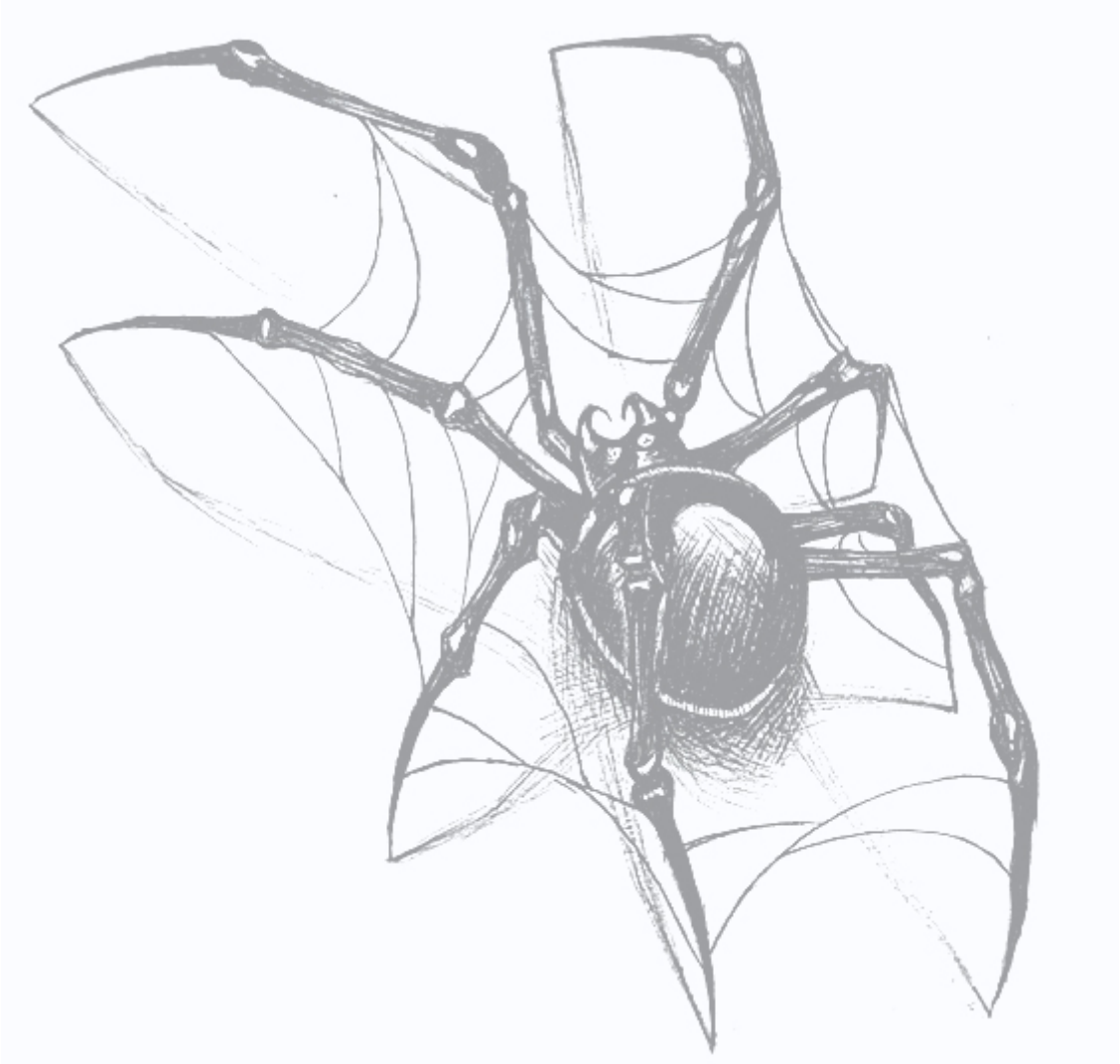
Zamani A., Seiedy M., Saboori A. and Marusik Y. M.,2018. The spider genus *Pterotricha* in Iran, with the description of a new genus (Araneae, Gnaphosidae). *ZooKeys*, 777, pp. 17–41.

Zare, R., and Gams, W., 2001. The genus *Haptocillium*. *Nova Hedwigia*, 73, pp.271-292.

Zhao, Q. and Li, S., 2014. A survey of linyphiid spiders from Xishuangbanna, Yunnan Province, China (Araneae, Linyphiidae). *ZooKeys*, (460), p.1-181

Zhu, M.S. and Ono, H., 2007. New record of the spider genus *Talaus* from South China, with description of a new species (Araneae: Thomisidae). *Acta Arachnologica*, *56*(2), pp.81-83.

Zimmermann, M. and Spence, J.R., 1989. Prey use of the fishing spider *Dolomedes triton* (Pisauridae, Araneae): an important predator of the neuston community. *Oecologia*, 80, pp.187-194.



PUBLICATIONS

PUBLICATIONS

1. **Naduvath Mana Krishnan Namboothiri Prasad**, Ambalath Veettil Saidu Mohamed Shihabudeen & Ambalaparambil Vasu Sudhikumar, 2022. Araneofauna associated with the horticultural ecosystems of Thrissur District, Kerala, India. Serket, vol. 18(3): 305-313.

2. Ambalath Veetil Saidu Mohamed Shihabudeen, **Naduvath Mana Krishnan Namboothiri Prasad** & Ambalaparambil Vasu Sudhikumar, 2022. Diversity of spiders in riparian habitats of Kalpathipuzha, Palakkad, Kerala, India. Serket,vol. 18(3): 314-320.

PUBLICATIONS IN PROCEEDINGS

1. **Naduvath Krishnan Namboodiri Prasad**, Ambalath Veettil Saidu Mohamed Shihabudeen & Ambalaparambil Vasu Sudhikumar, 2019. Assessment of biocontrol potential of selected spiders. Proceedings of International seminar organized by Department of Zoology, KKTM Government College, Pullut. ISBN: 978 81 7255130 8.

2. **Naduvath Krishnan Namboodiri Prasad**, Ambalath Veettil Saidu Mohamed Shihabudeen & Ambalaparambil Vasu Sudhikumar, 2023.Impact of agricultural practices in selected horticultural ecosystems in Thrissur District, Kerala. Proceedings of National seminar organized by Department of Zoology, SNGS College, Pattambi. ISBN: 978 81 7255173 5.

3. Ambalath Veettil Saidu Mohamed Shihabudeen , **Naduvath Krishnan Namboodiri Prasad** & Ambalaparambil Vasu Sudhikumar, 2023.Study of

seasonal variation in the occurrence of jumping spiders (Salticidae) in the selected riparian habitats of Bharatapuzha. Proceedings of the two-day International seminar organized by Department of Zoology, KKTM Government College, Pullut. ISBN: 978-81-7255-172-8.

4. Ambalath Veettil Saidu Mohamed Shihabudeen, **Naduvath Krishnan Namboodiri Prasad** & Ambalaparambil Vasu Sudhikumar, 2019. A comparative study of spider diversities associated with Chitturpuzha, Kerala, India, before and after the deluge of August 2019. Proceedings of International seminar organized by Department of Zoology, KKTM Government College, Pullut. ISBN: 978 81 7255130 8.

PRESENTATIONS

1. Presented a paper on "Assessment of biocontrol potential of selected spiders". International seminar held on 30th October 2019, organized by Department of Zoology, KKTM Government College, Pullut.

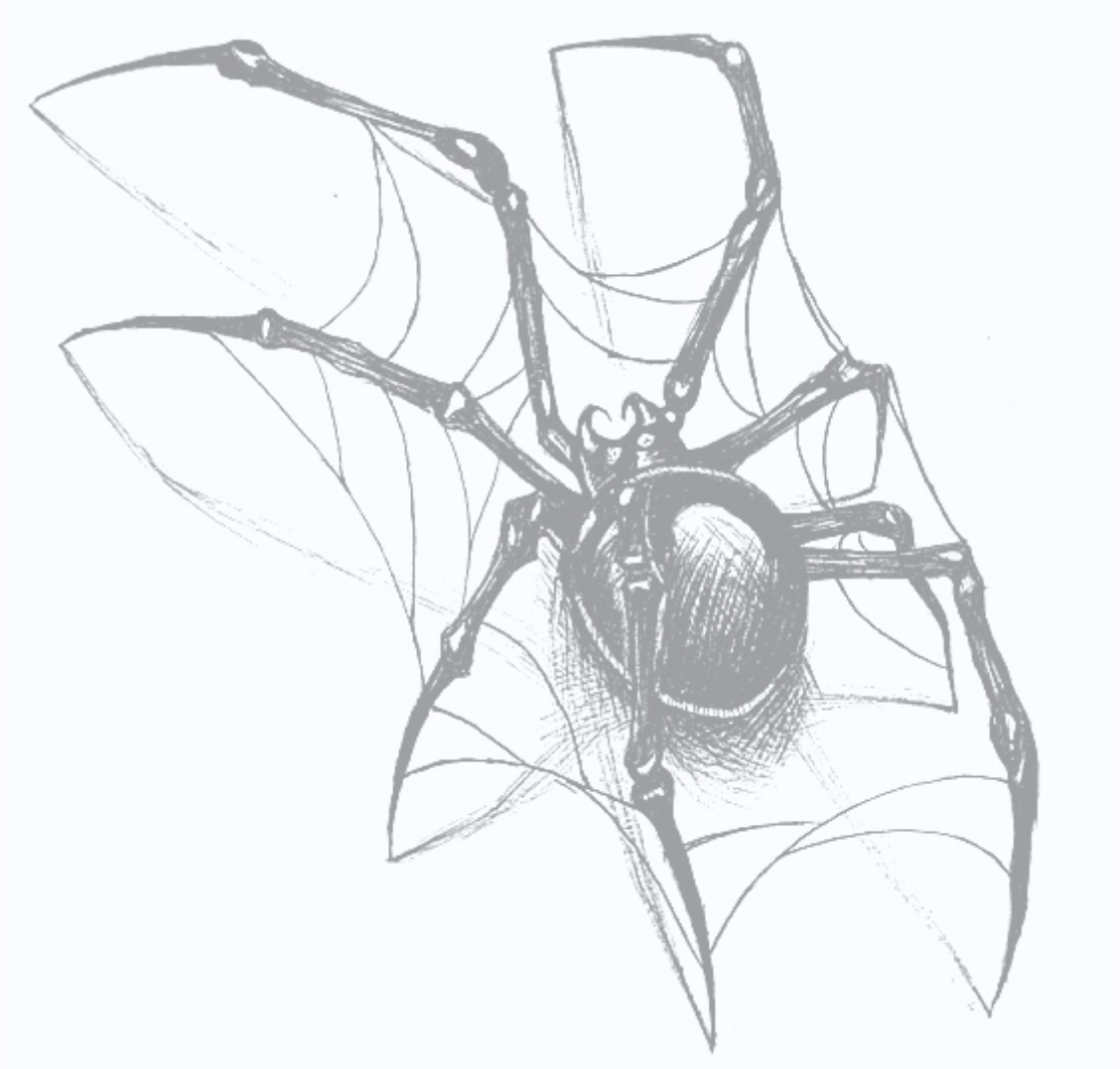
2. Presented a paper on "Araneofauna associated with banana cropland in Narayanamangalam, Thrissur district, Kerala, India". National seminar held on November 15 organized by Department of Zoology, University College Trivandrum.

3. Presented a paper on "Comparison of spider fauna in banana croplands of Kadalayi and Nenmanikkara, Thrissur district, Kerala, India". National seminar held on 25th and 26th November 2019, organized by department of Zoology, Maharajas College, Ernakulam.

4. Presented a paper on "Impact of agricultural practises on Araneid spiders in selected horticultural ecosystems in Thrissur District, Kerala.". National seminar

held on 14th, 15th and 16th November 2023, organized by Department of Zoology, SNGS College, Pattambi.

5. Presented a paper on “Arachnids in Agriculture fields: A Study of Seasonal Spider Diversity in Narayanamangalam, Thrissur, Kerala India"”. International seminar held on 22nd and 23rd November 2023, organized by Department of Zoology, KKTM Government College, Pullut.



PLATES

STUDY AREAS

PLATE 1- BHARATA

PLATE 2-CHELAKKARA








PLATE 3-KUZHUR








PLATE 4-NARAYANAMANGALAM








PLATE 5-NENMANIKKARA








PLATE 6-SAMPLING METHODS

(A) (B)

(C) (D)

A-B Hand picking C-D Sweep netting

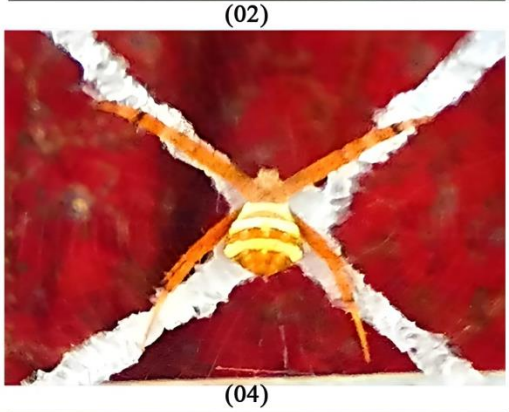
PHOTOGRAPHS OF SPIDERS COLLECTED

PLATE7

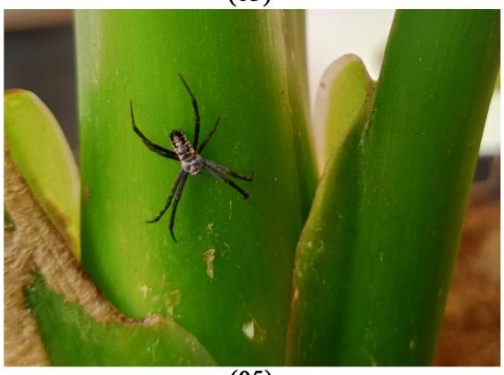
(01)

(02)

(03)



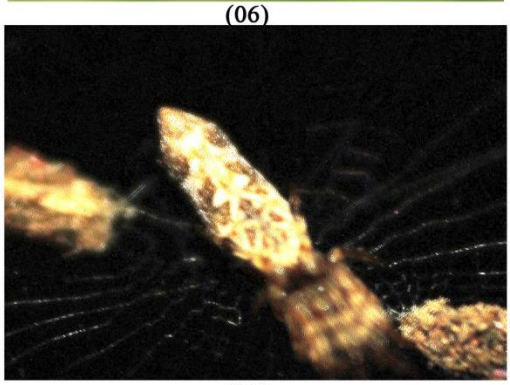
(04)



(05)

(06)

(07)



(08)

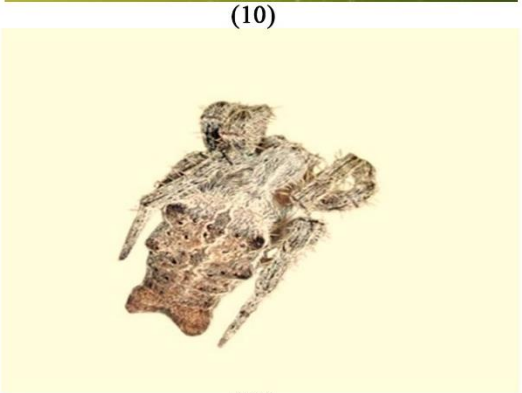
Family Araneidae (01) *Anepsion maritatum* (02) *Araneus sp.* (03) *Argiope aemula* (04) *Argiope anasuja* (05) *Argiope catenulata* (06) *Argiope pulchella* (07) *Bijoaraneus mitificus* (08) *Cyclosa confraga.*

PLATE 8

(09)

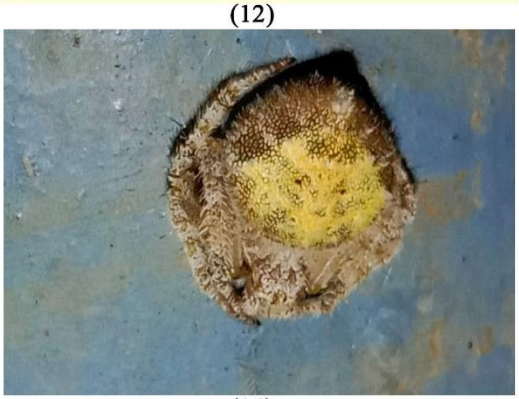
(10)

(11)

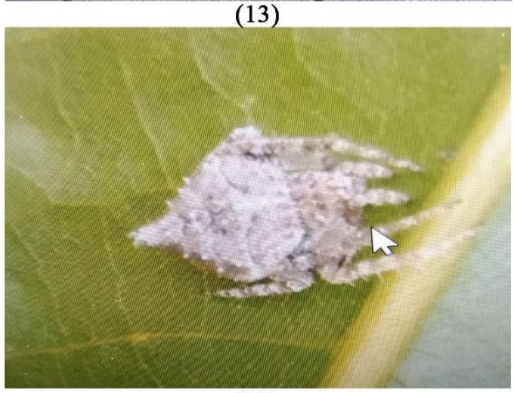


(12)

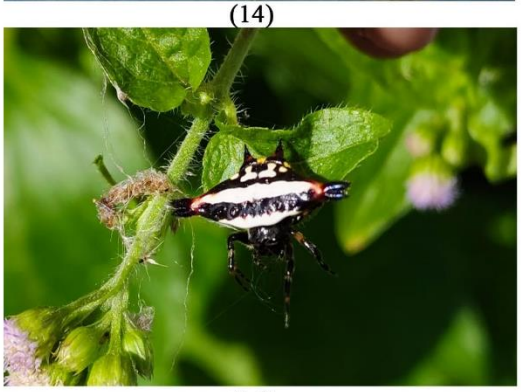
(13)



(14)



(15)



(16)

(09) *Cyclosa hexatuberculata* (10) *Cyclosa sp.* (11) *Cyrtophora cicatrosa* (12) *Cyrtophora citricola* (13) *Cyrtophora moluccensis* (14) *Eriovixia excelsa* (15) *Eriovixia laglaizei* (16) *Gasteracantha geminata.*

PLATE-9

(17) *Neoscona elliptica* (18) *Neoscona mukerji* (19) *Neoscona sp.* (20) *Neoscona vigilans* **Family: Cheiracanthiidae** (21) *Chieracanthium danielli* (22) *Chieracanthium melanostomum* **Family:Corinnidae** (23) *Castianeira zetes* (24) *Corinnomma sp*

PLATE-10

(25) (26)

(27) (28)

(29) (30)

(31) (32)

Family: Ctenidae (25) *Bowie cochinensis* **Family: Hersiliidae** (26) *Hersilia savignyi* (27) *Hersilia sumatrana* **Family: Lycosidae** (28) *Hippasa agelenoides* (29) *Pardosa pseudoannulata* (30) *Pardosa sumatrana* **Nephilidae** (31) *Nephila pilipes* **Family: Oxyopidae** (32) *Hamadruas sikkimensis.*

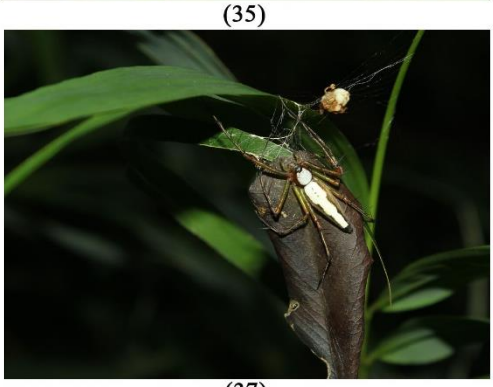
PLATE-11

(33)

(34)

(35)

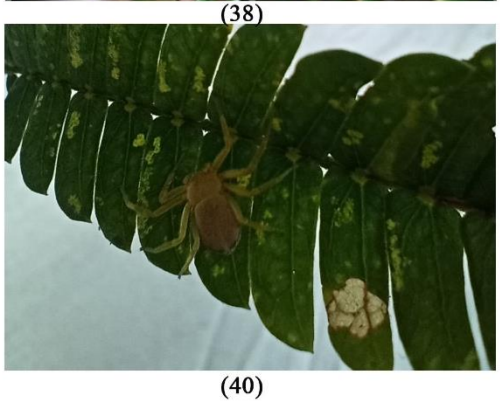
(36)



(37)

(38)

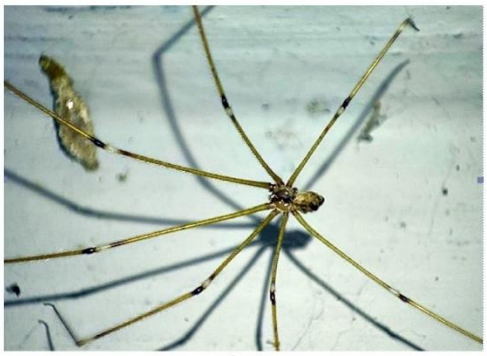
(39)



(40)

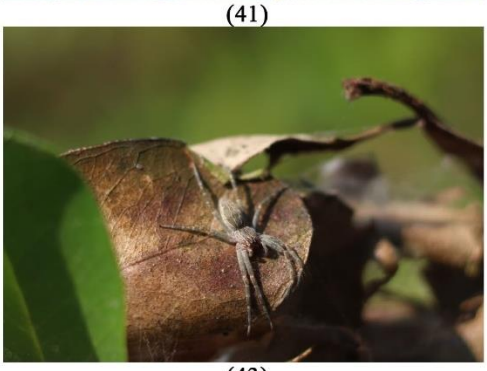
(33) *Oxyopes birmanicus* (34) *Oxyopes hindostanicus.* (35) *Oxyopes javanus* (36) *Oxyopes lineatipes* (37) *Oxyopes shweta* (38) *Oxyopes sunandae* (39) *Oxypes Sp.* **Family: Philodromidae** (40) *Psellonus sp.*

PLATE-12



(41)

(42)

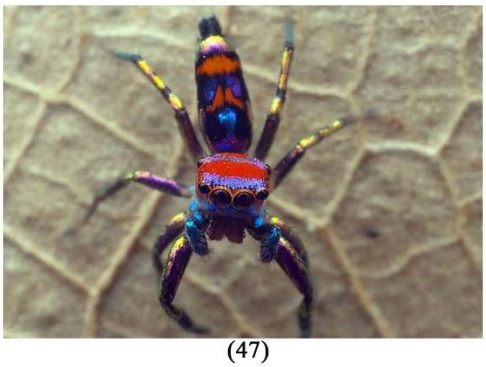


(43)

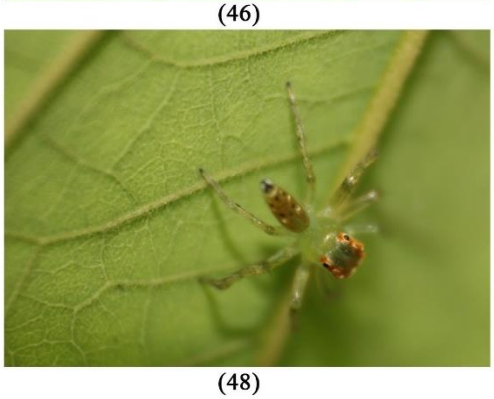
(44)

(45)

(46)



(47)



(48)

Family: Pholcidae (41) *Crossopriza lyoni* (42) *Pholcus phalangioides.* **Family: Pisauridae** (43) *Dendrolycosa gitae.* **Family: Salticidae** (44) *Asemonea tenuipes* (45) *Brettus cingulatus* (46) *Carrhotus viduus* (47) *Chrysilla volupe* (48) *Epeus indicus.*

PLATE-13

(49) (50) (51) (52) (53) (54) (55) (56)

(49) *Epeus tener* (50) *Evarcha sp.* (51) *Hasarius adansoni* (52) *Hyllus semicupreus* (53) *Indopadilla insularis* (54) *Menemerus bivitatus* (55) *Myrmaplata plataleoides.* (56) *Myrmarachne melanocephala.*

PLATE-14

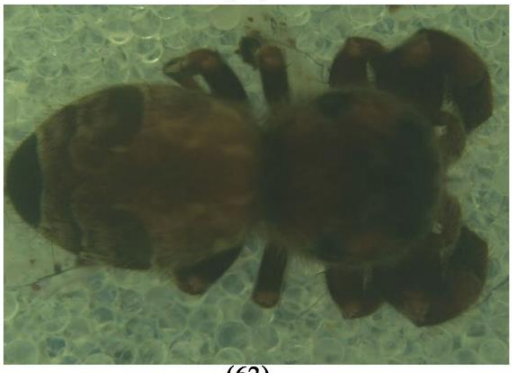
(57)

(58)

(59)

(60)

(61)



(62)

(63)

(64)

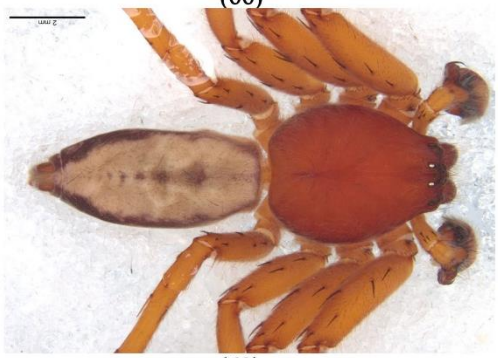
(57) *Phidippus yashodharae* (58) *Phintella vittata* (59) *Plexippus paykulli* (60) *Plexippus petersi* (61) *Portia fimbriata* (62) *Rhene flavigera* (63) *Siler semiglaucus* (64) *Telamonia dimidiata.*

PLATE-15

(65)

(66)

(67)



(68)

(69)

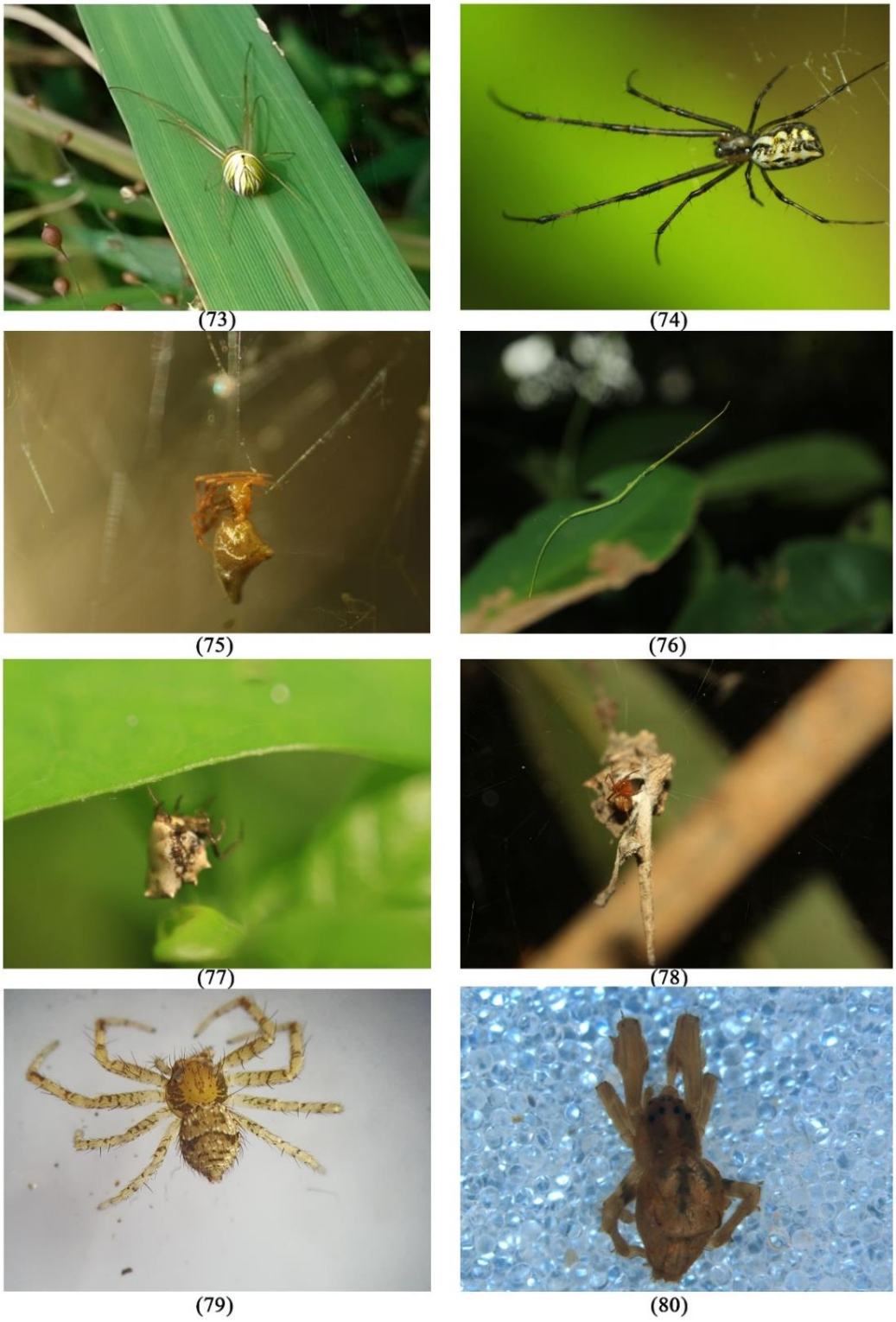
(70)

(71)

(72)

(65) *Thiania bhamoensis* **Family: Sparassidae** (66) *Heteropoda venatoria* (67) *Olios milleti (*68) *Thelcticopis moolampilliensis.* **Family: Tetragnathidae** (69) *Tetragnatha javana* (70) *Tetragnatha keyserlingi* (71) *Tetragnatha mandibulata* (72) *Tetragnatha viridorufa.*

PLATE-16



(73) *Tylorida striata* (74) *Tylorida ventralis* **Family:Theridiidae** (75) *Argyrodes sp. (*76) *Ariamnes flagellum* (77) *Phoroncidia septemaculeata* (78) *Theridion manjithar* **Family: Thomisidae** (79) *Indoxysticus minutus* **Family: Uloboridae** (80) *Uloborus krishnae.*