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Diversity of Spiders (Arachnida: Araneae) Recorded in Khasi Mandarin Ecosystem of Northeastern India

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ABSTRACT

Background: Spiders are one of the most abundant predatory groups found in the Citrus orchards. They feed on insects as well as other arthropod pests. Keeping in view of their important role in the natural biological control, the current study was carried out to study the spider fauna of the Khasi Mandarin (*Citrus reticulata*) ecosystem present in the Northeastern parts of India.

Methods: The field surveys were carried out during 2016-21 in the seven Northeastern states, namely, Assam, Arunachal Pradesh, Nagaland, Manipur, Mizoram and Tripura. The different localities were selected based on the pre dominance of Khasi Mandarin cultivation and the different geographical and climatic conditions.

Result: During the course of the survey, spiders belonging to 19 species, 16 genus and 8 different families were recorded from the study areas. The predominant families were Salticidae (36.84%) and Araneidae (26.31%) along with the reported presence of Oxyopidae (10.52%), Hersiliidae (5.2%), Heteropodidae (5.2%), Pisauridae (5.2%), Tetragnathidae (5.2%) and Thomisidae (5.2%). The highest and least population of spiders belonged to the species, *Oxyopes birmanicus* Thorell (Family: Oxyopidae) and *Neoscona* spp. (Family: Araneidae) respectively. The rich faunal diversity of spiders found during the present investigation indicate that spiders could be utilized as potential biocontol agents in the management of Khasi Mandarin pest complex.

Key words: Biocontrol agents, Citrus ecosystem, Spider fauna.

INTRODUCTION

Citrus is the third most important fruit crop of India, grown over an area of about 10.39 lakh ha with an annual production of 13.18 million tonnes (National Horticultral Board, 2019). Among the various species of Citrus, Khasi Mandarin (*Citrus reticulata* Blanco) is the most popular and economically important cultivar of North East India which is historically believed to be the centre for the dissemination of Citrus to other parts of the world (Srivastava and Singh, 2006). In India, Khasi Mandarin constitutes about 43.6% of the total Citrus fruits production, covering nearly 38.2% of the total Citrus cultivation area (Tariang *et al.*, 2018). Khasi Mandarin occupies the major area in the northeastern India due to its high commercial importance in with respect to its production and export value (Deshmukh *et al.*, 2016). In the North East Region (NER), Assam is the leading producer of Khasi Mandarin with a production of 598.96 thousand tones, covering an area of 105.49 thousand hectares of total 0.31 million hectares (Sangma *et al.,* 2018). Khasi Mandarin is known for its flavour, juice content and superior soluble sugar and acidity ratio (Deka *et al.,* 2018). Given its position as one of the major commercial crops of Northeastern region, an increase in the infestation of Citrus orchards by insect and arthropod pests has led to the incurrence of huge annual losses and yield reduction (Kakoti *et al.*, 2019). Severe incidence of pests *viz.* Trunk borer (4.40 to 48.65%), Bark eating caterpillar (10.80-43.76%), citrus leaf miner (4.00 to 49.27%) and Citrus butterfly (3.32 to 27.89%) have been reported by Deka *et al.,* 2016. Extensive use of pesticides to manage pest complexes in orchards has resulted in secondary pest emergence, development of pesticide resistance and loss of biodiversity among others. The growing concern over the harmful residual effects of pesticides on the environment and human health demands for the urgent need to look for innovative biological pest management practices. One of the most efficient and self sustainable bio control agents are natural enemies of the pest species in the form of predators or parasitoids.

Spiders (Class Arachnida: Order Aranae) are generally recognized as one of the most varied and functionally important invertebrates (Basumatary and Brahma, 2017). There are approximately 49669 species of spiders belonging to 4228 genera and 129 families worldwide (World Spider Catalogue version 21). In India, a total of 1686 species belonging to 60 families and 438 genera have been reported till date (Keswani *et al.,* 2012). By virtue of their polyphagous nature, spiders play an important role in regulating the

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arthropod population in various agro-ecosystems (Sunderland, 1999). Spiders are recognized as dominant insectivores in many agro- ecosystems due to their predatory behaviour. Spiders have been used successfully against various Citrus pests under both laboratory and field conditions (Xiao *et al.,* 2007). Considering the rich faunal diversity of spiders in Northeastern India and their role as efficient natural predators, an attempt was made to document and study the diversity of different spider species in the Khasi Mandarin Ecosystem of the Northeastern parts of India.

MATERIALS AND METHODS

The Northeastern region of India lies at the conjugation of Indo-Himalayan mega biodiversity hotspot. The region lies at 21°50′ and 29°34′ N latitude and 85°34′ and 97°50′ E longitude. Field observations were carried out during a period of five years, from May 2016 to May 2021 in the North Eastern states of Assam (Kamrup, Jorhat, Goalpara, Karbi Anglong, Dibrugarh and Tinsukia districts), Arunachal Pradesh (Lohit, Lower Dibang Valley and East Siang districts), Nagaland (Dimapur district), Manipur (Tamenglong, Bishnupur and Noney districts), Meghalaya (Ri-Bhoi and West Garo Hills districts), Mizoram (Kolasib, Lunglei and Aizawl districts) and Tripura (Sipahijala and Gomati districts). The spiders were collected quarterly at an interval of 3 months from *Citrus reticulata* orchards using methods suggested by Tikader (1987). The sampling was conducted randomly from four different sides of the lower branches of the plant. The spiders resting on the orb webs or plant parts were collected by placing a jar containing spirit below the spider and slightly tapping the spider into it. The collections were either made in the early hours of the mornings or in the evenings as the spiders are less active during these times. The spiders collected during each sampling were brought to laboratory, washed with alcohol, stored in a mixture of 75% ethyl alcohol with proper labeling of locality, date of collection and name of the host plant along with other notes of importance. The preserved spiders were later examined under stereomicroscope Labomed CZM6 in the laboratory and identified with the help of taxonomic keys and available literature. On the basis of the rate of occurrence, the spiders were divided into four categories *viz.* very common (spiders found in >35 collections), common (15<35 collections), rare (5<15 collections) and very rare (<5 collections) (Bhat *et al.,* 2013).

RESULTS AND DISCUSSION

During the course of the study, individuals belonging to 19 species, 16 genus and 8 different families were recorded. The observed data (Table 1) indicates that the most abundant species belonged to the family salticidae (36.84%) followed by the family araneidae (26.31%). The family oxyopidae (10.52%) ranked third with respect to diversity of species. The five families hersiliidae, heteropodidae, pisauridae, tetragnathidae and thomisidae had the lowest amount of species diversity at 5.2% each. Based on the classification given by Uetz *et al.* (1999), the spider population belonged to four different foraging guilds as illustrated in Fig 1. Stalkers were the most abundant group at 47.37%, followed by orb-weaver population of 31.58% while foliage runners and ambushers were found in equal amounts at 10.53% each. The spider species observed in the Khasi Mandarin Ecosystem are given in Fig 2.

Although the maximum population of spiders was observed during the winter months, there were considerable exceptions with respect to the individual families as well as species. In general, the spiders were found throughout the year but the least amount of population was recorded during the peak summer months. Individuals belonging to the family Salticidae were recorded throughout the year with a negligible amount of fluctuation. Among the individuals of the family Salticidae, the highest recorded species was *Telamonia elegans* followed by *Carrhotus* spp. Individuals belonging to the *Carrhotus decorata*, *Telamonia dimidata* and *Hasarius* spp. were also recorded, though in smaller amounts, showing their considerable presence in the ecosystem. The members of the family Araneidae ranked second highest in species diversity. The highest population belonged to the *Araneus* spp. The second highest population was recorded for the *Neoscona* spp. which was usually found active after sunset. Also, the occurrence of *Neoscona* spp. coincided with the onset of rainy season. *Eriovixia* spp.,

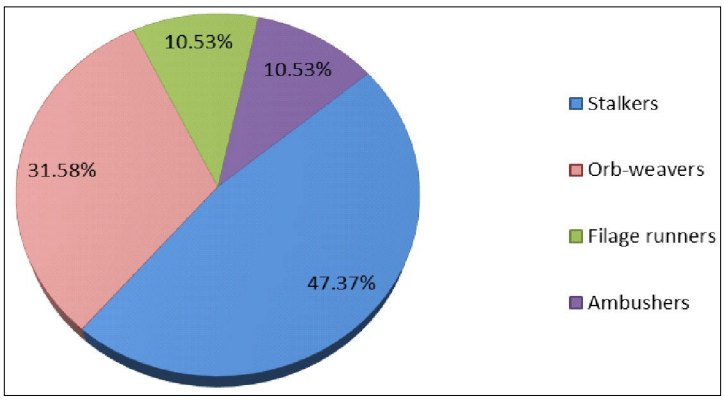

Fig 1: Guild wise distribution of spider species in khasi mandarin ecosystem of northeastern India.

Table 1: List of spiders collected from the khasi mandarin ecosystem of northeastern India.

Species	Distribution/Occurrence	Period of observation	Status
Family: Araneidae (Orb-weaving spiders)			
Araneus spp.	Assam, Arunachal Pradesh, Manipur, Mizoram, Tripura	April, May	Common
Eriovixia spp.	Assam, Arunachal Pradesh, Manipur, Tripura	February	Rare
Eriovixia laglaizei (Simon, 1877)	Assam, Arunachal Pradesh, Tripura	February	Rare
Neoscona spp.	Assam, Arunachal Pradesh	March-November	Very rare
Thelacanthabrevispina (Doleschall, 1857)	Assam, Arunachal Pradesh, Tripura, Manipur	October-November	Very rare
Family: Hersiliidae (Two-tailed spiders)			
Hersilia savignyii (Lucas, 1836)	Assam, Arunachal Pradesh, Manipur, Mizoram, Tripura	May-June	Common
Family: Heteropodidae (Huntsman spiders)			
Heteropoda spp.	Assam, Arunachal Pradesh, Tripura	April-May	Rare
Family: Oxyopidae (Lynx spiders)			
Oxyopes birmanicus (Thorell, 1887)	Assam, Arunachal Pradesh, Manipur, Mizoram, Tripura	April-November	Very common
Oxyopes shweta (Tikader, 1970)	Assam, Arunachal Pradesh, Manipur, Mizoram, Tripura	April-November	Common
Family: Pisauridae (Nursery web spiders)			
Nilus albocinctus (Doleschall, 1859)	Assam, Manipur, Tripura	March	Rare
Family: Salticidae (Jumping spiders)			
Brettus spp.	Assam, Manipur, Tripura	April-May	Very rare
Carrhotus spp.	Assam, Arunachal Pradesh, Manipur, Mizoram, Tripura	September-October	Very common
Carrhotus decorata (Tikader, 1974)	Assam, Arunachal Pradesh, Manipur, Mizoram, Tripura	September-October	Common
Hasarius spp.	Assam, Arunachal Pradesh, Manipur, Tripura	April-October	Rare
Phintella vittata (Koch, 1846)	Assam, Arunachal Pradesh, Manipur	August	Rare
Telamonia dimidiata (Simon, 1899)	Assam, Arunachal Pradesh, Manipur, Mizoram, Tripura	March-September	Common
Telamonia elegans (Thorell, 1887)	Assam, Arunachal Pradesh, Manipur, Mizoram, Tripura	August-September	Very common
Family: Tetragnathidae (Lonjawed orb-weaving spiders)			
Tylorida spp.	Assam, Arunachal Pradesh, Manipur, Mizoram, Tripura	April-May	Very common
Family: Thomisidae (Crab spiders)			
Thomisus spp.	Assam, Arunachal Pradesh, Tripura	September	Rare

Eriovixia laglaizei and *Thelacantha brevispina* were also recorded from the orchards. In case of the family Oxyopidae, the dominant species was *Oxyopes birmanicus* though a considerable population of *Oxyopes shweta* was also recorded. The members of the family Oxyopidae were observed in relatively large numbers during late August and early September. Although the two families Tetragnathidae and Hersiliidae lacked any species diversity, the populations of the individual species were in relatively large numbers. Overall, the highest population of individuals was recorded for *Oxyopes birmanicus* followed by *Telamonia elegans* with *Carrhotus* spp. and *Tylorida* spp. having the third and fourth highest populations, respectively. The lowest population belonged to *Neoscona* spp.

The Northeastern hilly region of India has a diverse population of spiders but much of it still remains unexplored. A few surveys have tried to document the spider diversity of North East India (Biswas and Majumder, 2006; Biswas and

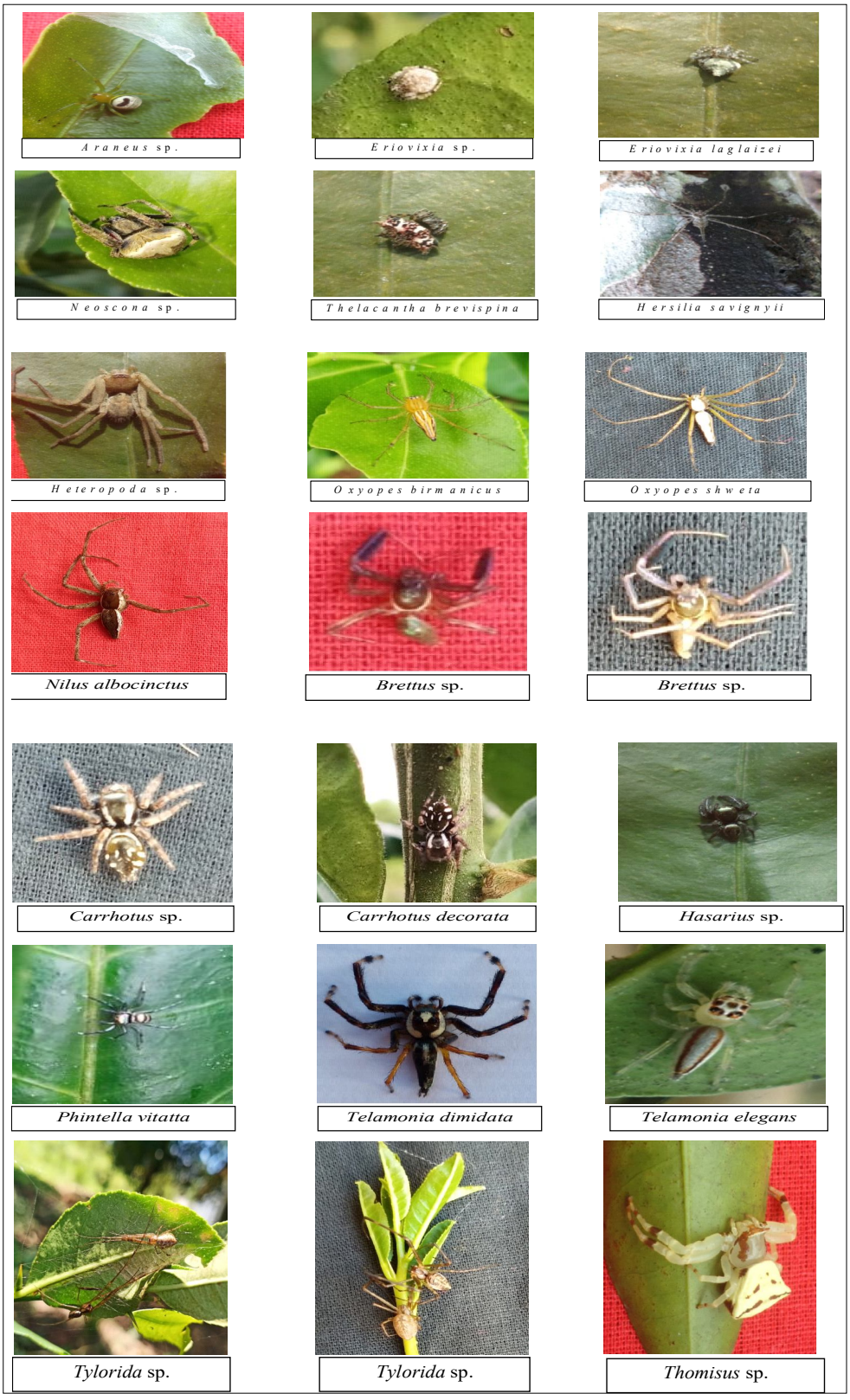

Fig 2: Important species of spiders observed in the khasi mandarin ecosystem of northeastern India.

Majumder, 2007; Anindita *et al.*, 2017) but it falls short considering the status of north-east India as a biodiversity hotspot. The results obtained during the present study confirm the presence of a complex and rich community of spiders in the Khasi Mandarin ecosystem of Northeastern India. The species diversity and distribution of spiders often vary from one geographical area to another due to slight changes in the habitat structure, complexity and microclimate (Downie *et al.*, 1999). High species diversity allows more healthier and complex interactions among the members of the community and is hence considered an indicator of good environmental conditions (Hill, 1973).

Citrus orchards have long since offered a semi permanent habitat harboring a rich and abundant arthropod fauna that enables more self-sustained spider populations to exist (Monzo *et al.*, 2011). Alvis (2003) reported the occurrence of 55 spider species in the Citrus canopy of a Citrus-growing area. Over the years, spiders have been used as biocontrol agents of many Citurs pests in different parts of the world. A population of spiders, dominated by *Chiracanthium mildei* played a prominent role in the management of scale *Ceroplastes floridensis* in the commercial Citrus groves of Northern Israel (Mansour and Whitecomb, 1986). In Florida, the three species of sac spiders, *Chiracanthium inclusum*, *Hibana velox* and *Trachelas volutus*, were reported as important predators of citrus leaf miner, *Phyllocnistis citrella* (Amalin *et al.*, 2001).

Apart from a few exceptions, the trend in species diversity was more or less the same all throughout the entire northeastern region. The most abundant species belonged to the families Salticidae and Araneidae in all the Khasi Mandarin cultivation areas. Salticidae and Araneidae have displayed high species richness and are more often than not found to be the predominant families in many ecosystems. Sudhikumar *et al.* (2005) recorded the highest number of species (17) of Salticidae belonging to 15 genera in the rice agroecosystem of Kerala. Among 21 families of spiders, captured from the Punjab province of Pakistan, Salticidae was the prominent family (31.09%) with 9 genera and 27 species (Parveen *et al.*, 2007). During the study of the occurrence of spiders in major fruit crops of Punjab, highest genetic diversity was observed in Salticidae, followed by Araneidae and Oxyopidae (Singh *et al.,* 2020). In the Wayanad plateau of Western Ghats, Araneidae was the dominant family constituting 24 species from 10 genera (Jose, 2010). Araneidae was also found significantly (28.14%) in Barpeta district of Assam, whereas the spider family Hersilidae had the least population (Singh *et al.*, 2012). Chetia and Kalita (2012) found the distribution of some families (Araenidae, Aalticidae, Tetragnathidae) to be continuous.

During the present study, most of the spider species found in the Citrus ecosystem were recorded all throughout the year. In general, a rise in the number of spiders was first observed during the early month of March, with the population attaining a peak during August-September. Most of the population tended to decline during late December-January. Similar to the results obtained during the current investigation, Tahir *et al.* (2011) reported abundance of adult spiders during the month of August in the citrus orchards of Lahore, Pakistan. Tahir *et al.* (2015) observed that there was a strong positive correlation between abundance of insect pests and spiders (predators) which suggested that spiders could effectively control insect pest populations in the field. This conclusion is concurrent with the findings of the present investigation as the peak rise in population of spider coincided with that of the peak period of infestation by citrus pests.

CONCLUSION

The observations made during the present investigation hopes to serve as a preliminary study on the spider diversity found in the Khasi Mandarin orchards of North-East India. Spiders play an important role in the ecosystem and exploiting their role as in pest management strategies cannot take place if the species involved are not known. Going forward, extensive studies should be carried out to record the species diversity to grasp a more in-depth knowledge of the predator-prey interactions between spiders and citrus pests. The various factors influencing the faunal diversity of the area need to be investigated as well.

Conflict of interest: None.

REFERENCES

Alvis, L. (2003). Identificación y abundancia de artrópodos depredadores en los cultivos de cítricos Valencianos. Ph.D. Dissertation (in Spanish). Universidad Politécnica de Valencia, Spain.

Amalin, D.M., Peña, J.E., Mcsorley, R., Browning, H.W., Crane, J.H. (2001). Comparison of different sampling methods and effect of pesticide application on spider populations in lime orchards in South Florida. Environmental Entomology. 30(6): 1021-1027.

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

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

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

Biswas, B., Majumder, S.C. (2006). Araneae: Spiders. Fauna of Arunachal Pradesh, State Fauna Series-13 (Part-2). Zoological Survey of India. pp. 491-518.

Biswas, B., Majumder, S.C. (2007). Araneae: Spiders. Fauna of Mizoram, State Fauna Series-14, Zoological Survey of India. pp. 455-475.

Chetia, P., Kalita, D.K. (2012). Diversity and distribution of spiders from Gibbon Wildlife Sanctuary, Assam, India. Asian Journal of Conservation Biology. 1: 5-15.

Deka, S., Kakoti, R.K., Sabir, N., Ahuja, D.B., Chattopadhyay, C., Barbora, C. (2016). Survey and surveillance of insect pests of citrus and their natural enemies in Assam. Journal of Insect Science. 29(1): 158-161.

Deka, S., Sehgal, M., Kakoti, R.K., Barbora, A.C. (2018). Module analysis for insect pest management of Khasi mandarin (*Citrus reticulata* Blanco) under climatic conditions of north-eastern India. Journal of Entomology and Zoology Studies. 6(4): 857-861.

Deshmukh, N.A., Patel, R.K., Rymbai, H., Jha, A.K., Deka, B.C. (2016). Fruit maturity and associated changes in Khasi mandarin (*Citrus reticulata*) at different altitudes in humid tropical climate. Indian Journal of Agricultural Sciences. 86(7): 854-859.

Doleschall, C.L. (1857). Bijdrage tot de Kennis der Arachniden van den indischen Archipel. Naturk. Tijdschr. Ned.-Ind. 13(3): 399- 434.

Doleschall, C.L. (1859). Tweede Bijdrage tot de Kenntis der Arachniden van den Indischen Archipel. Acta Soc. Sci. Ind.-Neerl. 5: 1-60.

Downie, I.S., Wilson, W.L., Abernethy, V.J., Mccracken, D.I., Foster, G.N., Ribers, I., Murphy, K.J., Waterhouse, A. (1999). The impact of different agricultural land use on epigeal spider diversity in Scotland. Journal of Insect Conservation. 3: 273-286.

Hill, M.O. (1973). Diversity and evenness: A unifying notation and its consequences. Ecology. 54: 427-432.

Jose, K.S. (2010). Diversity of spiders in the Wayanad plateau of Western Ghats, Kerala. Research Lines. 3(1): 43-8.

Kakoti, R.K, Saikia, J., Deka, S., Gogoi, A., Barbora, A.C. (2019). Present status of Khasi Mandarin in Tripura state of North East India. International Journal of Chemical Studies. 7(4): 2943-2948.

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

Koch, C.L. (1846). Die Arachniden. Nürnberg, Dreizehnter Band, pp. 1-234, Vierzehnter Band. pp. 1-88.

Lucas, H. (1836). Observations sur les Araneides du genre Hersilia et description de deux especes nouvelles appartenant a ce genre. Magasin de Zoologie. 6(8): 1-11.

Mansour, F., Whitecomb, W.H. (1986). The spiders of a citrus grove in Israel and their role as biocontrol agents of *Ceroplastes floridensis* (Homoptera: Coccidae). Entomophaga. 31(3): 269-276.

Monzó, C., Mollá, O., Vanaclocha, P., Montón, H., Melic, A., Castanera, P., Urbaneja, A. (2011). Citrus-orchard ground harbours a diverse, well-established and abundant ground-dwelling spider fauna. Spanish Journal of Agricultural Research. 9(2): 606-616.

National Horticultural Board. (2019). All-India area and production of vegetables. Indian Horticulture Database 2019, National Horticultural Board, Ministry of Agriculture, Government of India.

Parveen, R., Khan, A.A., Mushtaq, S., Rana, S.A. (2007). A checklist of the spiders of Punjab. Pakistan Journal of Agricultural Science. 44(4): 625-6.

Sangma, C., Anbazhagan, T., Rajkhowa, D.J. (2018). Influence of soil health and age of orchard on fruit quality of Khasi mandarin in Nagaland. 27th National Conference of Soil Conservation Society of India on Sustainable management of soil and water resources for doubling farmers' income, AAU, Jorhat, Assam.

Simon, E. (1877). Etudes arachnologiques. 5e Mémoire. IX. Arachnides recueillis aux îles Phillipines par MM. G.A. Baer et Laglaise. Annales de la Société Entomologique de France. 5(7): 53-96.

Simon, E. (1899). Contribution à la faune de Sumatra. Arachnides recueillis par M. J. L. Weyers, à Sumatra. Deuxiéme mémoire. Annales de la Société Entomologique de Belgique 43: 78-125.

Singh, S., Borkotoki, A., Sarmah, C.K. (2012). Species distribution of spiders in Barpeta district of Assam: A diversity measure. E-International Scientific Research Journal. 4(1): 47-57.

Singh, S., Sekhar, R., Jose, S.K. (2020). Predatory spider fauna in fruit crops of Punjab, India along with new records. Indian Journal of Agricultural Sciences. 90(9): 1695-1701.

Srivastava, A.K., Singh, S. (2006). Diagnosis of Nutrient Constraints in Citrus Orchards of Humid Tropical India. Journal of Plant Nutrition. 29(6): 1061-1076.

Sudhikumar, A.V., Mathew, M.J., Sunish, E., Sebastian, P.A. (2005). Seasonal variation in spider abundance in Kuttanad rice agroecosystem, Kerala, India (Araneae). European Arachnolog. 1: 181-190.

Sunderland, K. (1999). Mechanisms underlying the effects of spiders on pest populations. Journal of Arachnology. pp. 308-316.

Tahir, H.M., Butt, A., Naheed, R., Bilal, M., Alam, I. (2011). Activity density of spiders inhabiting the Citrus field in Lahore, Pakistan. Pakistan Journal of Zoology. 43(4): 683-688.

Tahir, H.M., Nazarat, I., Naseem, S., Butt, A., Yaqoob, R., Mukhtar, M.K., Samiullah, K. (2015). Seasonal dynamics of spiders and insect pests in citrus orchards of district Sargodha, Pakistan. Pakistan Journal of Zoology. 47(6): 1673-1681.

Tariang, J., Majumder, D., Papang, H. (2018). Efficacy of native *Bacillus subtilis* against postharvest *Penicillium* rot pathogen *Penicillium* sp. of Khasi Mandarin oranges in Meghalaya, India. International Journal of Current Microbiology and Applied Sciences. 7(12): 447-460.

Thorell, T. (1887). *Via*ggio di L. Fea in Birmania e regioni vicine. II. Primo saggio sui ragni birmani. Annali del Museo Civico di Storia Naturale di Genova. 25: 5-417.

Tikader, B.K. (1970). The spider fauna of Sikkim, Himalaya, India. Records of the Zoological Survey of India. 64(1-4): 1-84.

Tikader, B.K. (1974). Studies on some jumping spiders of the genus *Marpissa* from India (family-Salticidae). Proceedings of Indian Academic Sciences. 79(B): 204-215.

Tikader, B.K. (1987). Handbook of Indian Spiders. Zoological Survey of India. pp. 240.

Uetz, G.W., Halaj, J., Cady, A.B. (1999). Guild Structure of Spiders in Major Crops. Journal of Arachnology. 27: 270-280.

World Spider Catalog. 2021. World Spider Catalog. Version 22.5. Natural History Museum Bern, Switzerland, online at http://wsc.nmbe.ch, accessed on September 13, 2021.

Xiao, Y., Qureshi, J.A., Stansly P.A. (2007). Contribution of predation and parasitism to mortality of citrus leafminer *Phyllocnistis citrellla* Stainton (Lepidoptera: Gracillariidae) populations in Florida. Biological Control. 40(3): 396-404.