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Research Article

Effects of street lights on the web site selection of two species of spiders *Neoscona theisi* (Walckenaer, 1841) and *Leucauge decorata* (Blackwall, 1864)

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Abstract: *Neoscona theisi* and *Leucauge decorata* are two orb-web weaving spiders that are generally found between the branches of the bushes, the shrubs and the trees. Ever since the artificial lightening of the streets became the norm in modern cities, it became a major component of urbanization which influences the overall biodiversity all around the world. This study concentrates mainly on the web-site selection based on the presence and the absence of the street light which may influence the prey abundance at that particular area. The spider species studied are found in higher abundance on the trees that are in the close proximity to the streetlights. The majority of the arthropod prey species are dipterans. Other arthropods prey belonging to Orthoptera, Coleoptera, Hymenoptera, Lepidoptera and Odonata are also found on the webs of these two spider species on the selected plant species in which they were studied.

Keywords: Orb-web spider, Streetlights, Prey diversity

I. Introduction

Spiders constitute the largest order of class Arachnida of phylum Arthropoda (Moore *et al.*, 2004). They possess jointed appendages and a chitinous exoskeleton. The members of the class Arachnida are generally characterized by two body regions, the cephalothorax having 4 pairs of segmented legs attached to it and the abdomen. Spiders are also unique as they possess spinnerets situated near the hind end of abdomen which produce silk (Bristowe, 1979). Spiders can be easily differentiated from other arachnids by the presence of the pedicle, a narrow stalk that joints the cephalothorax and the abdomen (Brusca *et al.*, 2003).

Spiders are abundant and widespread in almost all ecosystems and constitute one of the most important components of global biodiversity (Wise, 1993). They play a very significant role in ecosystem since they are exclusively predatory and therefore help in maintaining ecological equilibrium (Wise, 1993). Recently there is an increase in anthropogenic activities throughout the world which is causing significant changes to environment and it is creating similar patterns of patchworks of modified land covers types throughout the world (Gilbert, 1989). This is happening mainly because of the process of urbanization since half of the human population around the world is living in urban areas (Seto *et al*., 2012; Liu *et al*., 2014). Global urbanization has caused the loss of natural habitats (Miyashita *et al*., 1998; Gibbs and Stanton, 2001) for many species as well as alteration and modifications of the environmental components (Rebele, 1994). But there are some species of flora and fauna that are generalist and benefiting from changes caused by urbanization and these species are colonizing and invading urban habitats (McIntyre *et al.,* 2001). Thus, urbanization is a complex process from the point of view of the species of flora and fauna, and it requires a detailed, comparative study all over the world to explore the ecological consequences caused by urban development (Magure *et al*., 2010). Urbanized area has large number of characteristics such as; (i) high human population densities, (ii) highly developed business, industrial and residential sectors, (iii) degradation, alteration, modification and fragmentation of natural habitats, (iv) warmer temperature by 2-3˚C and (v) higher numbers of exotic, invasive and generalist flora and fauna (Thiele, 1977; McDonnell and Pickett, 1990; Morris, 1992; Guntenspergen and Levenson, 1997). These can cause many types of changes in the environment which impose multiple selection pressures on the behaviour of organisms. In animals, behaviour is often considered as the first route of adaptation to rapid environmental changes (Wong and Candolin, 2015). Numerous examples of both adaptive and maladaptive behavioural changes in response to human-induced environmental changes have now been recorded (Lowry *et al*., 2013). However, the potential costs and constraints associated with these behavioural changes are poorly understood (Dahirel *et al*., 2018).

Orb-weaving spiders are highly diverse, abundant in the fields and important regulators of pest populations in agro-ecosystems (Levi, 1981; Nyffeler and Benz, 1989; Aiken and Coyle, 2000). To optimize behavioural efficiency and to reduce energetic cost and time, a predator has to make several choices in the fields (Alcock, 1993). These choices are where to construct a web, where to eat, how much time to dedicate for eating and what types of prey to select for capture and consumption (Henaut *et al*., 2006). Other variables such as density of prey at site and quality of prey at site may also influence choosing of the hunting site (Pyke *et al*., 1977)

Orb web: The principal characteristic feature of an orb web is that the central portion known as the hub, lying within the supporting framework, consists of a series of radiation lines of dry and inelastic silk that support a thread of viscid and elastic silk. Orb webs vary in structure, shape and size according to the families and genera of the spiders.

Orb-web spiders usually do not compete for food or space (Wise, 1993), as various species use different predatory strategies (Henaut *et al*., 2006). Webs of spider's act as a filter and trap a large diversity of insects

(Henaut *et al*., 2006). The orb web with its elegant spirals is a familiar object created by orb-web weaving spider (Sebastian, 2009). As a trap for flying insects, the orb web is rather efficient, sieving the air continuously as long as it remains undamaged. A Spider is usually positioned at the hub of their web during day time with its head pointing downwards (Rod, 1984). The present study concentrates mainly on the web-site selection based on the presence and the absence of the artificial light which may influence the prey abundance at that particular area.

II. Materials and methods

Study site

A study site was selected within Banaras Hindu University campus (25°15’50.8”N and 82°59’18.0”E), Varanasi, Uttar Pradesh, India **(Fig.1)**. This included the Horticulture field mango plantation area (with 3 street lights) and guava plantation area (with one street light). The study period was from December 2018 to March 2019.

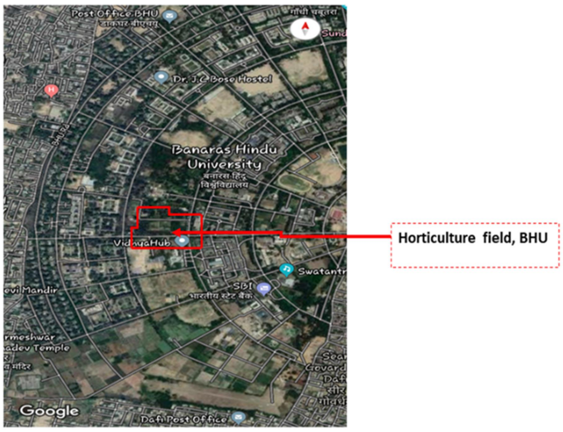

Fig.1 Map showing the location of the study site (Horticulture field) in Banaras Hindu University campus, Varanasi, U.P., India.

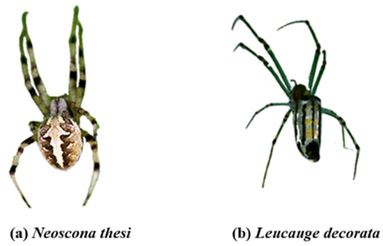

Fig.2 Perennial agroecosystem-inhabiting, (a-b) orb web-making spider species recorded in mango and guava agroecosystems, located in the Horticulture field of Banaras Hindu University, Varanasi, India (December, 2018 to March, 2019).

Selected spiders and plants species

Two species of arboreal orb web weaving spiders were selected: *Neoscona theisi* (Walckenaer, 1841) **(Fig.2a)** and *Leucauge decorata* (Blackwall, 1864) **(Fig.2b)**. Two weeks of preliminary studies revealed that two tree species: mango (*Mangifera indica*) and guava (*Psidium guajava*) were exclusively being utilized by these two orb-web making spider species *Neoscona thesi* and *Leucauge decorata* respectively in the selected study area. Therefore, all observations were conducted on these mango and guava trees located in the horticulture field.

Observation methods:

Fifteen fruit trees of each type (located in the darkened area) approximately 50 meters away from the street lights were selected as the control trees and fifteen each (located in the lighted area) approximately 50 meters within the lighted area were selected as the experimental trees. The numbers of webs of each species of spiders on the respective trees was counted at monthly intervals. Number of webs present on 2 control branches (i.e., present on the dark facing side) and 2 experimental branches (i.e., present on the light facing side) of each control and experimental tree of both categories of fruit trees were also counted. The number of different types of insect prey caught in the webs of each species of spider on the dark and light facing branches of control and experimental trees were recorded each month.

Statistical Analysis:

SPSS 16.0 and Microsoft Office Excel 2007 were used for the statistical analysis of data and the graphical representation. The unpaired *t*-test was applied for web abundance; Kruskal-Wallis's and Turkey's *post hoc* tests were applied to check the significant difference in insect prey abundance.

III. Results

Abundance of webs of *Neoscona theisi* and *Leucauge decorata*

Abundance of the webs of *N. theisi* at the light facing side of the mango trees located in the lighted area were found to be 4.8±0.46, 5±0.66 and 5.7±4.63; and that of the dark facing side were found to be 3.67±0.32, 3.07±0.95 and 4.63±0.4 during the months of January, February and March, respectively**(Fig.3)**. At the mango trees located at the darkened area, the light facing side had web abundance of 0.27±0.15, 0.55±0.21 and 0.53±0.24, and the dark facing side had 0.18±0.13, 0.13±0.09 and 0.2±0.14, during the months of January, February and March, respectively **(Fig.4)**. An overall abundance of the webs on the mango trees located in the lighted area (experimental) were 4.73±0.3, 4.87±0.58 and 3.93±0.34 and the webs present in the darkened area (control) were 0.2±0.1, 0.27±0.11 and 0.37±0.13 during the months of January, February and March, respectively **(Fig.7)**.

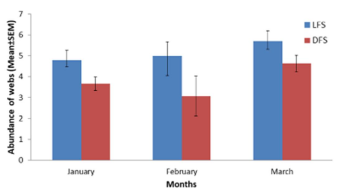

Fig.3 Abundance of the webs of *N. theisi* on the light facing branches/trunks and the dark facing branches/trunks of the mango trees located in the lighted area. (LFS-Light facing side, DFS-Dark facing side)

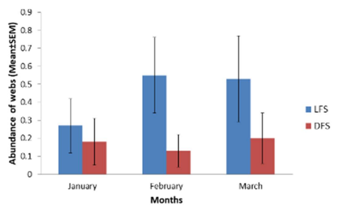

Fig.4 Abundance of the webs of *N. theisi* on the light facing branches/trunks and the dark facing branches/trunks of the mango trees located in the darkened area. (LFS-Light facing side, DFS-Dark facing side)

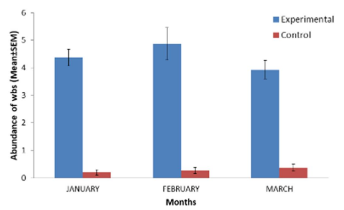

Fig.7 Abundance of the webs of *N. theisi* recorded on the control and the experimental mango trees, from January to March, 2019.

Abundance of the webs of *L. decorata* at the light facing side of the guava trees located in the lighted area were found to be 0.87±0.19, 1.13±0.29 and 1.47±0.29; and that of the dark facing side were found to be 0.8±0.17, 1.07±0.19 and 0.86±0.19 during the months of January, February and March, respectively **(Fig.5)**. At the guava trees located at the darkened area, the light facing side had web abundance of 0.13±0.09, 0.13±0.09 and 0.2±0.11; and the dark facing side had 0.06±0.07, 0.13±0.09 and 0.13±0.09 during the months of January, February and March, respectively **(Fig.6)**. An overall abundance of the webs on the guava trees located in the lighted area (experimental) were 0.83±0.12, 0.97±0.16 and 1.27±0.2, and the webs present in the darkened area (control) were 0.17±0.06, 0.13±0.06 and 0.1±0.05 during the months of January, February and March, respectively **(Fig.8)**.

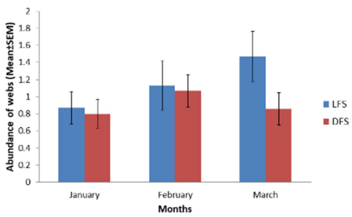

Fig.5 Abundance of the webs of *L. decorata* on the light facing branches/trunks and the dark facing branches/trunks of the guava trees located in the lighted area. (LFS-Light facing side, DFS-Dark facing side)

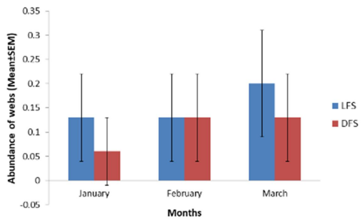

Fig.6 Abundance of the webs of *L. decorata* on the light facing branches/trunks and the dark facing branches/trunks of the guava trees located in the darkened area. (LFS-Light facing side, DFS-Dark facing side)

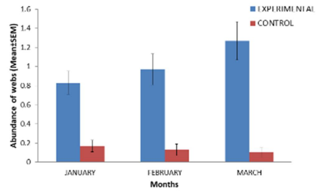

Fig. 8 Abundance of the webs of *L. decorata* recorded on the control and the experimental guava trees from January to March, 2019.

Statistical analysis of web abundance

The unpaired *t*-test analysis showed significant difference in the mean abundance of webs of both the spider species present in the lighted and the darkened area (df= 89, $p<0.001$). Web abundance of both the spider species present in the lighted areas were higher than the darkened areas ($p<0.001$).

Abundance of insect prey

Web numbers of both the spider species were found to be significantly higher in the lighted areas than in the darkened areas. The highest number of captured specimens was from the insect order Diptera **(Table 1 &2)**.

Insect prey abundance in the webs of *Neoscona theisi* present on the mango trees located in the lighted and the darkened areas differed significantly (Kruskal-Wallis's test, $H=173.11$, df=5, $p<0.001$). The insect prey abundance was higher in the lighted areas than the darkened areas (Turkey's *post hoc* test: $p<0.001$). Similarly, insect prey abundance in the webs of *Leucauge decorata* present on the guava trees located in the lighted and the darkened areas differed significantly (Kruskal-Wallis, $H=67.24$, df=5, $p<0.001$). The insect prey abundance was higher in the lighted areas than the darkened areas (Turkey's *post hoc* test: $p<0.001$).

Table 1: Prey abundance on webs of *Neoscona theisi* on the mango trees

Months	No of insect prey per web	
	Experimental (Mean±SEM)	**Control (Mean±SEM)**
January	1.64±0.15	0.42±0.19
February	1.63±0.19	0.29±0.10

March	1.57± 0.18	0.49±0.14

Table 2: Prey abundance on webs of *Leucauge decorata* on the guava trees

Months	No of insect prey per web	
	Experimental (Mean±SEM)	**Control (Mean±SEM)**
January	0.45±0.08	0.03±0.02
February	0.59±0.09	0.01±0.01
March	0.70±0.11	0.03±0.01

IV. Discussion and conclusion

The present study showed that the abundance of the webs of both *Neoscona theisi* and *Leucauge decorata* were much higher on the trees that were present within the area lighted by the street lights than on the trees that were present out of the range of the street lights, thus indicating influence of the street lights on the web-site selection in spiders. Spiders are generalist species and many generalist species benefit from the changes caused by urbanization and are colonizing urban habitats (McIntyre *et al*., 2001; Shochat *et al*., 2004). In the study of ground dwelling spiders, (Magura *et al*., 2010) showed significantly more spiders species trapped in the urban area compared to suburban and rural area. Similarly increased proportion of insect diets of riparian spiders was reported in heavily urbanized area than non-urbanized areas (Kelly *et al*., 2019). While a study on crab spider species richness (Argañaraz and Gleiser, 2017) indicated that urbanization does not necessarily have a positive or negative effect. In our study, the web numbers were also found to be significantly higher on the branches that are present on the light facing side of the tree trunks than the dark facing side of the tree trunks as expected thus showing us the web site preference for the area lit up by the street lights. This may be due to possible higher abundance of insect prey species (especially nocturnal insects) in the lighted area. Many groups of insects such as moths, lacewings, beetles, bugs, caddis flies, crane flies, midges, hoverflies, wasps and bush crickets are attracted to lights (Eisenbeis and Hassel, 2000). Many spiders may use the structural features of the habitat like street light as cues for settling in a site and for foraging (Enders, 1977: Riecher and Gillespie, 1986). The insect prey belonging to order Orthoptera, Hymenoptera, Diptera, Lepidoptera, Coleoptera and Odonata was higher in the webs located on the trees present in the lighted area. Insects belonging to order Diptera demonstrated highest abundance followed by Orthoptera, Coleoptera, Lepidoptera, Hymenoptera and Odonata. The abundance of almost all the insect prey orders were found to be increasing significantly from the winter month of January to spring season at March. The result showing decrease in the abundance of insect prey during winter months is probably because insects remain inactive during winter months (Denlinger, 1980).

This study concluded that the selected spider species, *Neoscona theisi* and *Leucauge decorata* that were studied on the mango trees and the guava trees respectively prefer to choose web-sites on the branches which were in closer proximity to the street lights. The prey abundance was higher on the webs of both *N. theisi* and *L. decorata* that were present in the lighted area. Thus, the street lights had significant influence on web site selection of these two spider species since it attracts a greater number of insect prey. These spiders can be considered as possible candidates to be used as biological control agents for various insect pests in agriculture farms where streets lights are deployed. However, further research on this topic is needed. Beside the knowledge of ecological consequences of urbanization, this study also gives us ideas about the requirements of research about the generalist predatory spider species that are possible biological control agent to be used in near future in agro-ecosystems.

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