'RESEARCH JOURNEY' International E- Research Journal
Impact Factor - (SJIF) – 6.261, (CIF) - 3.452(2015), (GIF)–0.676 (2013)
Special Issue 110 (G)- Zoology
UGC Approved Journal

ISSN : 2348-7143
February-2019

Orb Web Features of Giant Wood Spider Nephila Pilipes

A. S. Sawarkar[1] and S. B. Sawarkar[2]
Department of Zoology,
Shri Radhakisan Laxminarayan Toshniwal
College of Science, Akola, 444001
Department of Physics, Shri Shivaji College of Arts,
Commerce & Science, Akola 444001
E-mail: assawarkar@yahoo.com

Abstract

Orb webs are composite structures built from multiple types of silks, each with its own unique molecular structure and mechanical function. Nephila spiders are the eminent silk craftsmen among arachnids and are best known for producing aerial orb webs. Female giant wood spider Nephila pilipes builds highly efficient and specialized aerial trap in the form of planar and vertical orb web. Orb web features and web architecture parameters like web asymmetry, hub displacement, ladder index, average mesh height and web area of female Nephila pilipes web were studied. The architecture of orb webs clearly influence the types of prey ultimately captured and consumed by spiders. Hence, we concluded that larger asymmetrical orb webs might be interpreted as increased foraging effort. A tight and nearly uniform mesh provides more silk per unit area for kinetic energy absorption as well as more stickiness per unit area and may well result in more effective snare for relatively larger prey.

Key words: Nephila pilipes, orb web, web architecture

Introduction

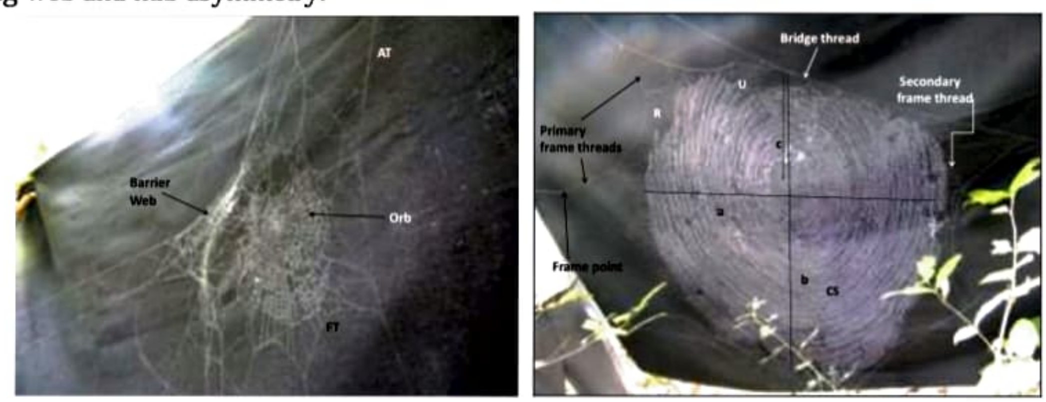
Spider webs are supreme examples of evolution in animal architecture. These are becoming a focus of biological and interdisciplinary research (Agnarsson et al., 2010) with web architecture. Spider webs have inspired numerous biomimetics material and structural designs in the fields of architecture (Burkhardt, 2016). The orb webs of spiders are perfect geometrical architectural models (Pasquet et al., 2013). Nephilid genera construct webs of exaggerated proportions, which can be aerial, arboricolous or intermediate (Kuntner et al., 2018). The orb webs like that of the golden orb weaver Nephila pilipes are examples of animal design that can be studied in great detail, both for web building behaviour and web architecture. The webs are especially well-made, as they are meant to last for long time. More importantly, since these spiders are found in sub tropical regions, their insect prey is naturally larger than insects in other regions. While webs are designed to catch large insects like grasshoppers, butterflies, moths etc. Orb webs are more appropriately distinguished from other types of spider webs in their suspension in the air column upon discrete networks of frame threads.

Material And Methods

Web architecture and features of orb web of Nephila pilipes were studied in natural habitat. Our study area was the woods of Melghat (21°26′45″N 77°11′50″E21.44583°N 77.19722°E). Web architectures of spiders were recorded in the field by using a FUJIFILM FINEPIX 52000HD 10.0 MEGA PIXELS 15x wide digital camera. In order to increase visual contrast, webs were dusted with cornstarch. We observed, studied and measured a randomly encountered sample of 30 webs of Nephila pilipes from forest area of Gullarghat in the months of July to November during daylight hours. Following parameters were measured on every web: 1. Web width (a) as the horizontal distance between the outermost sticky spirals; 2. Web height (b) as the vertical distance between the top and lowest sticky spirals; 3. Top sticky spirals to hub distance (c); Number of sticky spirals per 10 cms in the finished webs. All measurements were reported in centimeters. Web orientation and inclination was observed. Web architecture parameters like hub displacement (HD = (b-c)/b) and Ladder Index (LI = b/a) were calculated as used by Kuntner et al. (2008 b) and Gregoric et al. (2010); Web area ($WA=\left(\frac{a}{2}\right)\left(\frac{b}{2}\right)\pi$) as in Blackledge and Gillespie (2002) and Mesh width (Gregoric et al., 2010) was measured.

Observations And Results

Nephila pilipes are most easily recognized by their special web building habit. Their orb webs are placed in opening between trees and shrubs where insects are likely to fly. The main structural elements of an orb web of Nephila pilipes are the bridge thread, which anchors to the substrate; the frame threads, which may connect directly to the substrate or to other lines in the web; the radii which connect the frames with the central of web termed as hub, and the capture spiral which is a continuous thread that is attached to the radii as it spirals from the periphery to the hub and is constructed using viscid adhesive silks (Fig. 1 b). Orb web of juvenile Nephila pilipes include additional features such as 3D networks of threads to at least one side of the orb plane, termed barrier web (Fig. 1 a). The young ones first appear with their tiny webs during August. Their body measures about 1 cm in length and the legs have a span of about 4 to 5 cm. Their webs are less than one foot in diameter. Area of the web construction increases with age of spider. It was observed that larger and heavier spiders exhibited a higher hub displacement. Vertical orb webs of these spiders appear generally parallel to the water streams and randomly distributed in all direction, but maximum spiders avoid North- South direction. It is found that, web width, web height and ultimately web area increases significantly with spider size and age. We could measure maximum web width of 112 cm and web height of 124 cm. But still there were some larger webs at unreachable heights which we were unable to measure in the field, definitely having larger web area than calculated. In various developmental stages, mesh width ranges between 0.38 to 0.83 cm was measured. Both measures of web allometry, i.e. ladder index (LI) and hub displacement (HD) increases with spider size. In the web of Nephila pilipes, the sticky spiral usually contain several 'U' turn. Most of them are observed at the web periphery causing web and hub asymmetry.



a b

Fig. 1 - Web architecture of Nephila pilipes a. Barrier web of juvenile N. pilipes b. Asymmetrical orb web of subadult N. pilipes (In figure, web architecture abbreviations are: H-Hub; FT- Frame thread; AT-Anchor thread; R- Radius; U- U turn; CS- capture spiral; a- web width; b-web height; and c - upper web height)

Table 1- Measured & derived parameters of orb web of Nephila pilipes

Sr.No.	Web Width (a)cm	Web Height (b)	Top to Hub (c)	Web Asymmetry WA=(b-a)/b	Hub displacement HD= (b-c)/b	Ladder Index LI=b/a	Sticky Spiral/ 10 cms	Mesh height 10/SS-1	Web Area (a/2)(b/2)πcm²
1	13	15	5.2	0.133	0.653	1.153	27	0.386	153.07
2	14	16	5.5	0.125	0.687	1.142	24	0.434	175.84
3	19	17	6	-0.117	0.647	0.894	26	0.400	253.55
4	18	19	7.5	0.052	0.605	1.055	23	0.454	268.47
5	20	24	8.2	0.166	0.658	1.200	22	0.476	376.80
6	25	23	7	-0.086	0.695	0.920	24	0.434	451.37
7	25	27	8	0.074	0.703	1.080	21	0.500	529.87
8	26	28	10.5	0.071	0.625	1.076	22	0.476	571.48
9	27	24	6.5	-0.125	0.729	0.888	20	0.526	508.68
10	30	34	12	0.117	0.647	1.133	22	0.476	800.70
11	33	36	11	0.083	0.694	1.090	20	0.526	932.58
12	36	38	13	0.052	0.657	1.055	21	0.500	1073.88
13	37	52	20	0.288	0.615	1.405	22	0.476	1510.34
14	40	43	14	0.069	0.674	1.075	16	0.666	1350.20
15	42	53	21	0.207	0.603	1.261	19	0.555	1747.41
16	47	50	15.5	0.060	0.690	1.063	17	0.625	1844.75
17	49	60	15.8	0.183	0.736	1.224	15	0.714	2307.90
18	50	52	18	0.038	0.653	1.040	16	0.666	2041.00
19	56	70	30	0.200	0.571	1.250	18	0.588	3077.20
20	59	67	22	0.119	0.671	1.135	15	0.714	3103.10
21	60	89	34	0.325	0.617	1.483	14	0.769	4191.90
22	64	65	18	0.015	0.723	1.015	15	0.714	3265.60
23	67	86	18	0.220	0.790	1.283	13	0.833	4523.17
24	63	66	13	0.045	0.803	1.047	14	0.769	3264.03
25	62	67	18.5	0.074	0.723	1.288	15	0.714	3260.89

26	80	84	26	0.047	0.690	1.050	13	0.833	5275.20
27	71	74	17.8	0.040	0.759	1.042	14	0.769	4124.39
28	87	95	31.5	0.084	0.668	1.091	13	0.833	6488.02
29	94	101	36.3	0.069	0.640	1.074	14	0.769	7452.79
30	112	124	52	0.096	0.580	1.107	13	0.833	10902.08

Discussion

Nephila webs changes through ontogeny from small round orbs with extensive additional three dimensional features termed the barrier web to giant two dimensional orbs with dozens of radii and with an asymmetrically positioned hub towards the top of the frame (Kuntner et al., 2008a). Web orientation probably affects web microclimate. Prolonged direct sun exposure could harm the spider or its web, or may affect pray availability and/or predation pressure. That is why spiders may avoid East- West direction. Nephila pilipes prefers roadside area and trees nearby water streams. The webs are in general parallel to the water streams where majority of insects are likely to fly. Humid atmosphere also helps for thermoregulation and to maintain catching spiral threads moist for longer duration. Vertical web inclination may also play a significant role in spiders foraging success. Orb webs of Nephila pilipes lie in a perfect plane which provides largest projection area per web area. Another advantage of planer orb web is that the forces on the radii are more equally distributed when an insects hits to web (Lin et al., 1995). Female body size correlates positively with absolute web size. However, intermediate sized females build the largest webs (Kuntner et al. 2018). Heavier instars have significantly displaced hub towards the top web frame. The detected ontogenetic pattern of progressive vertical web asymmetry in Nephila may best be explained by optimal foraging due to gravity because spider downward running speed is greater compared with upward speed (Nakata and Zschokke, 2010). Thus by increasing the lower and decreasing the upper half of the web, spiders may increase the chance that prey will be intercepted and captured successfully. Spider maximize their foraging success if sitting head down in a vertical asymmetrical web (Maciejewski, 2010). Distance between sticky spirals i.e. Mesh width also goes on increasing with the age and developmental stages of spider (Table-1). Smaller mesh width in juvenile stages aimed to capture and retain smaller insects prey. Greater mesh width in adult spider must be better at resisting the impact of higher kinetic energy prey like moths, crickets, grasshoppers, dragonflies etc. Some Nephila pilipes webs showed conspicuous sign of damage and repair; others had some open holes, suggesting that the spider does not immediately replace a damaged web, but continues to use it through periodic renewal.

Conclusion

In Nephila pilipes, the name 'orb' is somewhat misleading in that the web is not symmetric circles but web asymmetry and hub asymmetry is observed. Nephila pilipes builds web with the aim to capture the largest and/or most profitable prey available in its immediate environment. In almost all observed cases, HD value is more than 0.5, implying than hub was placed above the geometric center of capture area. Thus, highly dense, planer vertical and asymmetric Nephila pilipes web is an optimal orb web that captures as many insects as possible for given construction efforts.

References

1. Agnarsson, I., Kuntner, M. and Blackledge, T.A. (2010). Bioprospecting finds the toughest biological material: extraordinary silk from a giant riverine orb spider. PLoS ONE **5(9)**:e11234. doi:10.1371/journal. pone.0011234
2. Blackledge, T. A. and Gillespie, R.G. (2002). Estimation of capture areas of spider webs in relation to web asymmetry. J. Arachnol. **30**, 70–77.
3. Burkhardt B. (2016). Natural structures—the research of Frei Otto in natural sciences. Int. J. Space Struct. **31**, 9–15. (doi:10.1177/0266351116642060)
4. Gregorič, M., Kostanjšek, R. and Kuntner, M. (2010). Orb web features as taxonomic characters in Zygiella s.l. (Araneae: Araneidae). J. Arachno.l **38**, 319–327.
5. Kuntner, M., Coddington, J. A. and Hormiga, G. (2008a). Phylogeny of extant nephilid orb-weaving spiders (Araneae, Nephilidae): testing morphological and ethological homologies. Cladistics **24**, 147–217.
6. Kuntner, M., Haddad C.R., Aljančič, G. and Blejec, A. (2008b). Ecology and web allometry of Clitaetra irenae, an arboricolous African orb-weaving spider (Araneae, Araneoidea, Nephilidae). J Arachnol **36**:583–594.
7. Kuntner, M., Hamilton, C.A., Cheng, R.C., Gregorič, M., Lupše, N., Lokovšek, T., Lemmon, E.M., Lemmon, A.R., Agnarsson, I., Coddington, J. A. and Bond, J.E. (2018). Golden Orbweavers Ignore Biological Rules: Phylogenomic and Comparative Analyses Unravel a Complex Evolution of Sexual Size Dimorphism. Syst. Biol. 0(0):1–18, DOI:10.1093/sysbio/syy082
8. Lin, L. H., Edmonds, D. T. and Vollrath, F. (1995). Structural engineering of an orb-spider's web . Nature, **373,** 146-148.
9. Maciejewski, W. (2010). An analysis of the orientation of an orb-web spider. J. Theo. Biol. **265**, 604–608. doi:10.1016/j.jtbi.2010.05. 025
10. Nakata, K. and Zschokke, S. (2010). Upside-down spiders build upside-down orb webs: web asymmetry, spider orientation and running speed in Cyclosa. Proc. R. Soc. B **277**, 3019– 3025. doi:10.1098/ rspb.2010.0729
11. Pasquet, A., Marchal, J., Anotaux, M. and Leborgne, R. (2013). Imperfections in perfect architecture: The orb web of spiders. Eur. J. Entomol., **110(3)**, 493–500,