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Individual physical variables involved in the stabilimentum decoration in the wasp spider, *Argiope bruennichi*

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Abstract

The physical factors of *Argiope bruennichi* (Araneae, Araneidae) that influence the stabilimentum decoration on the web, a conspicuous white silk structure reflecting much more ultraviolet light than other spider silks in the web, have been poorly understood. In this study, individual variables involved in decorating the webs with stabilimenta by *A. bruennichi* were examined. The results revealed that the physical condition of the female *A. bruennichi* affected the behaviors of the stabilimentum decoration on the web. Among the 82 female spiders building their webs, the 49 female spiders adding upper and lower stabilimenta on their web weighed less, and had a narrower cephalothorax and shorter abdomen than the 33 female spiders that did not use stabilimentum. The heavier females decorated their webs with stabilimentum of greater widths. There were also significant positive relationships between the stabilimentum area and the female spider's cephalothorax width, and between the stabilimentum area and female spider's abdomen length. Taken together, this study suggests that spiders allocate their resources in stabilimentum decoration as a functional response to the spider's physical conditions, and also supports the "prey-attraction hypothesis," which states that the use of stabilimentum increases the foraging success by attracting more prey to the web.

Key words: *Argiope bruennichi*, individual variable, stabilimentum, wasp spider

INTRODUCTION

Variables influencing the web structures of the spider such as climate factors, prey abundance, competition with the same and other species, predation, individual variables, etc. have been studied (Eberhard 1990, Foelix 2010). However, the spider's physical factors that influence its decision about whether to add a silk decoration on a web or not have been poorly understood (Eberhard 1990, Schoener and Spiller 1992, Watanabe 1999, Théry and Casas 2009). Many orb-web weaving spiders (Araneae: Araneidae, Tetragnathidae, Uloboridae) decorate their webs with species-typical silk structures, so called stabilimentum (Simon 1895, Herberstein et al. 2000, Bruce 2006).

Stabilimentum is a conspicuous white silk structure that reflects much more ultraviolet light than areas without stabilimentum in the web (Craig and Bernard 1990, Bruce et al. 2005). This is surprising, given that "web-building" spiders' silk generally has low UV reflectance, presumably to reduce the visibility of the web to insect prey (Blackledge and Wenzel 2000).

Recently, the "prey-attraction hypothesis" has suggested that the stabilimentum functions to increase foraging success by attracting more prey to the web (Craig and Bernard 1990, Tso 1998, Watanabe 1999, Kim et al. 2012). The

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stabilimentum decoration on the web of the wasp spider, *Argiope bruennichi*, actually increased the foraging success, because the web decorations reflected UV light similar to that of UV-reflecting flowers and thus, attracted insect pollinators seeking flower nectar (Kim et al. 2012). The results of several studies done on the Araneid genus *Argiope* have offered the support for the prey-attraction hypothesis: *A. trifasciata* (Tso 1996), *A. aetherea* (Elgar et al. 1996), *A. appensa* (Hauber 1998), *A. aurantia* (Tso 1998), *A. keyserlingi* (Herberstein 2000, Bruce et al. 2001), *A. versicolor* (Li 2005), and *A. savignyi* (Gálvez 2009).

This study examined whether decorating webs with stabilimenta was affected by individual physical variables in *A. bruennichi* (Araneae, Araneidae), which is abundant in paddy fields, wetlands, and shrub areas in South Korea. Rearing individual spiders to build webs within custom-designed cages in laboratory conditions, the individual physical variables between individual spiders constructing webs with stabilimenta and those constructing webs without stabilimenta were compared.

MATERIALS AND METHODS

Study species

Argiope bruennichi (Araneidae), also known as the wasp spider, is a panpalearctic orb-web building spider. It reaches maturity and reproduces during August and September, when females (2.0-2.5 cm) are much bigger than males (0.8-1.2 cm), and have clear yellow and black bands on their abdomen, like many other members of the genus *Argiope* (Scopoli 1772). Also, Scopoli (1772) described that the female spider builds the spiral orb-webs at dawn or dusk, usually in long grass with small shrubs a little above ground level. After they finish building the orb spirals, *A. bruennichi* individuals decorate their webs with stabilimenta to be placed in a vertical linear pattern through the center of the web. A stabilimentum is made by using a densely-woven zig-zag stich and consists of two parts: an upper part and a lower part (Walter et al. 2008). In this report, it is described that because *A. bruennichi* do not always decorate their webs, and the number and size of silk bands placed on their webs vary depending on daily conditions, the spiders can be found on webs without stabilimenta, on webs with one-armed stabilimenta consisting of either a lower part or an upper part, or on webs with both upper and lower parts of the stabilimentum, depending on daily conditions. Stabilimenta are constructed from the same silk used by orb-web spiders to wrap prey, which are originated from the aciniform and piriform glands (Walter et al. 2008).

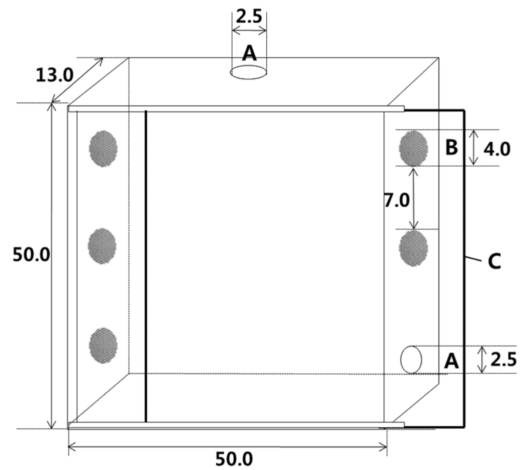

Fig. 1. Breeding box for *Argiope bruennichi* (50 × 50 × 13 cm^3) made from acryl material. A, hole for prey provision; B, wire meshed hole for ventilation; C, transparent sliding door for observation. Unit of the numbers presented in the figure is cm.

Collection and rearing

Adult female *A. bruennichi* were collected along a paddy field in Hwaseong-si, Gyeonggi-do, South Korea (126°50′N, 37°11′E; altitude: 30-70 m) during August and September, and immediately transported to the laboratory. For individual variables, the body mass was measured with a precision balance (CAUW-D 220; CAS, Seoul, Republic of Korea), cephalothorax width and abdomen length with a digital vernier caliper (500-196-20; Mitutoyo, Kawasaki, Japan), after putting the female spiders to sleep using CO_2 gas. Each individual female spider was placed in a square acrylic frame (50 × 50 × 13 cm^3) custom designed for orb-web spiders with removable and transparent front and back covers (Fig. 1). The spiders were kept in laboratory environments at 25 ± 1°C and 100 lux illumination with a 12:12 h light:dark cycle. The inner sides of the cage were humidified twice a day by spraying water. The spiders were not offered prey to minimize the possible influences of information emitted from the prey on the first web building behavior in the cage.

Web measurements

Measurements were conducted on the first web constructed by *A. bruennichi* after installation in the laboratory. The spiders built their webs overnight in the laboratory. After removing the front and back covers from the

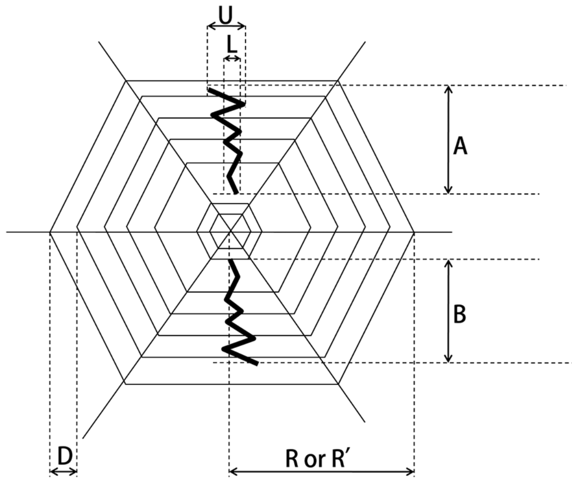

Fig. 2. Illustration of *Argiope bruennichi* web measurements. R or R′, longer and shorter radii; A and B, stabilimentum lengths; U and L, upper and lower width of stabilimentum; D, mesh size.

cage, the webs were photographed with a black velvet background to measure the following parameters: the shorter and longer radii of webs, the widths of upper and lower stabilimenta, stabilimentum lengths, the number of spirals, and mesh size (Fig. 2).

To observe the effects of individual variables on the stabilimentum decoration, webs with stabilimenta or without stabilimenta were selected for measurements. For webs with stabilimenta, only webs that had both upper and lower stabilimenta were included.

To estimate the web size, the outermost and innermost diameters of each web from the sticky spirals were measured (Fig. 2). The web area was then calculated as: web area= π x longer radius x shorter radius. As the stabilimentum of *A. bruennichi* is a ladder form, the stabilimentum area was calculated as length × (upper width of stabilimentum + lower width of stabilimentum)/2. The mean radius length was calculated from the shorter- and longer radii. The number of spirals was measured as the number of sticky silk circles from the center of the web to the outermost radius. The mesh size (average distance between spirals) was calculated as [longer radius/ (number of spirals at that area – 2) + shorter radius/ (number of spirals at that area – 2)/2].

Statistical analysis

Nonparametric statistics in SigmaPlot (version 12.3; Systat Software Inc., San Jose, CA, USA) were used, but the mean and standard deviation of the data were presented instead of medians and inter-quartile ranges on nonparametric statistics. The individual variables (body mass, cephalothorax width, and abdomen length) were compared using the Mann-Whitney rank sum test (Mann and Whitney 1947). Regression analysis with ANOVA was also used to examine the relationship of individual variables and parameters of webs with and without stabilimenta.

RESULTS

This study investigated the web structures of 82 webs made by female spiders: 49 webs with stabilimenta and 33 webs without. Overall, the body mass of the female spiders (N = 82) was 402.1 ± 174.1 mg (mean ± SD), the cephalothorax width was 4.8 ± 0.7 mm, and the abdomen length was 11.6 ± 1.5 mm. The total web area of the 82 webs was 667.2 ± 285.9 cm^2, the mean radius length was 14.5 ± 3.2 cm, the mesh height was 4.5 ± 1.0 mm, and the number of spirals was 32.5 ± 11.0. The stabilimentum area measured in the 49 webs was 1.76 ± 1.72 cm^2.

There was no significant difference in the web area between webs with or without stabilimenta (Table 1). The mean length of radii and mesh size also did not differ in webs with or without stabilimenta (Table 1). However, the webs with stabilimenta had more spirals on average than the webs without stabilimenta (Table 1). However, the number of spirals showed no positive- or negative relationship with the stabilimentum area (ANOVA test for regression analysis: $F_{1,47} = 2.445$, $R^2 = 0.029$, $P = 0.125$).

Actually, the stabilimentum decorations reflected the

Table 1. Comparison of web structures between webs with stabilimenta and webs without stabilimenta of *Argiope bruennichi* (mean ± SD)

Web structural variables	Webs with stabilimenta (N = 49)	Webs without stabilimenta (N = 33)	Mann-Whitney Rank Sum test
Web area (cm^2)	675.9 ± 312.7	654.2 ± 245.0	U = 787.0, *P* = 0.843
Mean length of radii (cm)	14.4 ± 3.5	14.7 ± 2.7	U = 781.0, *P* = 0.798
Number of spirals	35.7 ± 11.7	27.7 ± 8.0	U = 456.0, *P* < 0.001
Mesh size (cm)	0.44 ± 0.10	0.47 ± 0.10	U = 690.0, *P* = 0.265

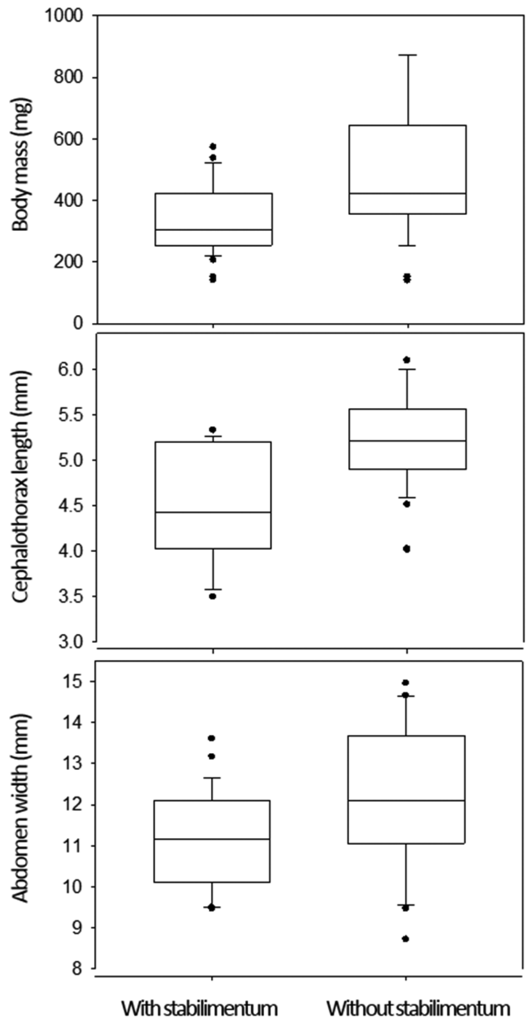

Fig. 3. Box plots to compare body mass, cephalothorax width, and abdomen length between females of *Argiope bruennichi* building webs with and without stabilimentum. In the box plots, the boundary of the box closest to zero indicates the 25th percentile, a line within the box marks the median, and the boundary of the box farthest from zero indicates the 75th percentile. Whiskers (error bars) above and below the box indicate the 90th and 10th percentiles. Values out of the 90th and 10th percentiles were presented as black dots.

individual variables (Fig. 3). The female spiders that made the webs with stabilimenta weighed lighter than the females that made the webs without stabilimenta (342.0 ± 114.8 mg compared with 491.5 ± 207.8 mg; Mann-Whitney rank sum test, U = 439.0, N_1 = 49, N_2 = 33, P < 0.001). The cephalothorax widths were significantly shorter in the female spiders using stabilimenta (4.5 ± 0.6 mm in individual spiders using stabilimentum vs. 5.2 ± 0.5 mm in individual spiders not using stabilimentum; Mann-Whitney rank sum test, U = 356.5, P < 0.001). The abdomen length was also shorter in the female spiders using stabilimenta (11.2 ± 1.2 mm compared with 12.2 ± 1.7 mm; Mann-Whitney rank sum test, U = 489.0, P = 0.003).

The heavier females decorated webs with wider stabilimentum (Fig. 4A; ANOVA for regression analysis: $F_{1,47}$ = 11.792, R^2 = 0.201, P = 0.001). There were also significantly positive relationships between the stabilimentum areas and the cephalothorax widths (Fig. 4B; ANOVA for regression analysis: $F_{1,47}$ = 11.634, R^2 = 0.181, P = 0.001), and the stabilimentum areas and abdomen lengths (Fig. 4C; ANOVA for regression analysis: $F_{1,47}$ = 10.953, R^2 = 0.172, P = 0.002).

DISCUSSION

The results revealed that the physical conditions of the female *A. bruennichi* affected stabilimentum decoration behaviors on webs. In this study, the female spiders adding upper and lower stabilimenta on the web weighed less, had narrower cephalothoraxes and shorter abdomens than the females that did not use stabilimentum.

A spider's decision making on an orb web structure should be associated with its allocation of energy for reproduction or capturing prey (Higgins and Buskirk 1992, Sherman 1994, Herberstein et al. 1998, Watanabe 1999,

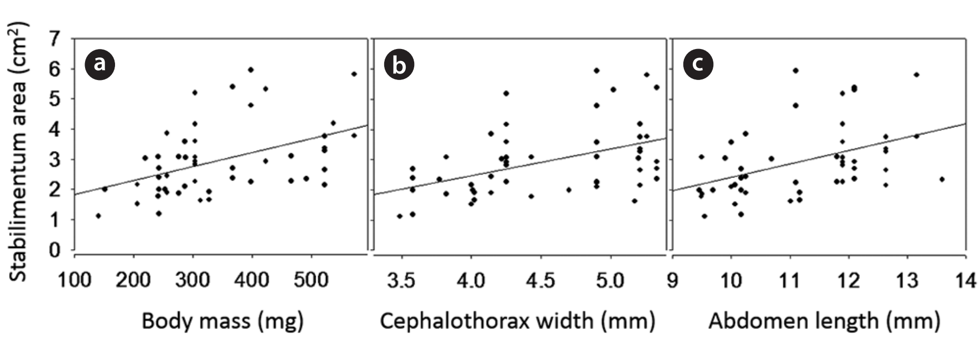

Fig. 4. Regression plots of the stabilimentum area according to the individual variables. (a) Body mass; (b) Cephalothorax width; (c) Abdomen length. Functions of the regression line are y = 0.0046·x + 1.362 (a), y = 0.882·x - 1.053 (b), and y = 0.438·x - 1.956 (c).

Théry and Casas 2009). Spiders in very poor physical condition cannot expend much energy for web building. They might not have enough protein for silk production, and thus, it could be difficult to cover the energy costs for web construction. On the other hand, female spiders of a good enough weight to reproduce might not need prey, and therefore may reduce investment of energy in web building to allocate protein and energy to reproduce. But females with average physical conditions could change their investment in web building as a functional response to the changes in the spider's physical state. Lighter reproductive females should expend more energy in web building to capture more prey, even if this entails the energetically expensive decorating of webs with stabilimentum.

In fact, a previous study on *A. bruennichi* demonstrated that more prey items were intercepted in webs with stabilimenta than in webs without stabilimenta (Kim et al. 2012). The stabilimentum increased spider foraging success by intercepting more UV-sensitive insect pollinators. The stabilimentum of *A. bruennichi* also had a strong effect on rates of capture for larger prey items: webs with stabilimenta captured more than twice as many large prey than webs without stabilimenta. The presence of stabilimenta did not seem to affect the capture rates of small prey.

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LITERATURE CITED

Blackledge TA, Wenzel JW. 2000. The evolution of cryptic spider silk: a behavioral test. Behav Ecol 11: 142-145.

Bruce MJ. 2006. Silk decorations: controversy and consensus. J Zool 269: 89-97.

Bruce MJ, Herberstein ME, Elgar MA. 2001. Signalling conflict between prey and predator attraction. J Evol Biol 14: 786-794.

Bruce MJ, Heiling AM, Herberstein ME. 2005. Spider signals: are web decorations visible to birds and bees? Biol Lett 1: 299-302.

Craig CL, Bernard GD. 1990. Insect attraction to ultraviolet-reflecting spider webs and web decorations. Ecology 71: 616-623.

Eberhard WG. 1990. Function and phylogeny of spider webs. Annu Rev Ecol Syst 21: 341-372.

Elgar MA, Allan RA, Evans TA. 1996. Foraging strategies in orb-spinning spiders: ambient light and silk decorations in *Argiope aetherea* Walckenaer (Araneae:Araneoidea). Aust J Ecol 21: 464-467.

Foelix R. 2010. Biology of Spiders. 3rd ed. Oxford University Press, New York, NY.

Gálvez D. 2009. Frame-web-choice experiments with stingless bees support the prey-attraction hypothesis for silk decorations in *Argiope savignyi*. J Arachnol 37: 249-253.

Hauber ME. 1998. Web decorations and alternative foraging tactics of the spider *Argiope appensa*. Ethol Ecol Evol 10: 47-57.

Herberstein ME. 2000. Foraging behaviour in orb-web spiders (Araneidae): do web decorations increase prey capture success in *Argiope keyserlingi* Karsch, 1878? Aust J Zool 48: 217-223.

Herberstein ME, Abernethy KE, Backhouse K, Bradford H, de Crespigny FE, Luckock PR, Elgar MA. 1998. The effect of feeding history on prey capture behaviour in the orbweb spider *Argiope keyserlingi* Karsch (Araneae: Araneidae). Ethology 104: 565-571.

Herberstein ME, Craig CL, Coddington JA, Elgar MA. 2000. The functional significance of silk decorations of orb-web spiders: a critical review of the empirical evidence. Biol Rev 75: 649-669.

Higgins LE, Buskirk RE. 1992. A trap-building predator exhibits different tactics for different aspects of foraging behaviour. Anim Behav 44: 485-499.

Kim KW, Kim K, Choe JC. 2012. Functional values of stabilimenta in a wasp spider, *Argiope bruennichi*: support for the prey-attraction hypothesis. Behav Ecol Sociobiol 66: 1569-1576.

Li D. 2005. Spiders that decorate their webs at higher frequency intercept more prey and grow faster. Proc Roy Soc B 272: 1753-1757.

Mann HB, Whitney DR. 1947. On a test of whether one of two random variables is stochastically larger than the other. Ann Mathemat Statist 18: 50–60.

Scopoli GA. 1772. Flora Carniolica: Exhibens Plantas Carnioliae Indigenas et Distributas in Classes, Genera, Species, Varietates, Ordine Linnaeano. 2nd ed. Vol. 1. Impensis Ioannis Pavli Kravss, Vienna.

Schoener TW, Spiller DA. 1992. Stabilimenta characteristics of the spider *Argiope argentata* on small islands: support of the predator-defense hypothesis. Behav Ecol Sociobiol 31: 309-318.

Sherman PM. 1994. The orb-web: an energetic and behavioural estimator of a spider's dynamic foraging and reproductive strategies. Anim Behav 48: 19-34.

Simon E. 1895. Histoire naturelle des Araignées. Vol. 1. Roret, Paris.

Théry M, Casas J. 2009. The multiple disguises of spiders: web colour and decorations, body colour and movement. Phil Trans R Soc B 364: 471-480.

Tso IM. 1996. Stabilimentum of the garden spider *Argiope trifasciata*: a possible prey attractant. Anim Behav 52: 183-191.

Tso IM. 1998. Isolated spider web stabilimentum attracts insects. Behaviour 135: 311-319.

Walter A, Elgar MA, Bliss P, Moritz RFA. 2008. Wrap attack activates web-decorating behavior in *Argiope* spiders. Behav Ecol 19: 799-804.

Watanabe T. 1999. The influence of energetic state on the form of stabilimentum built by *Octonoba sybotides* (Araneae: Uloboridae). Ethology 105: 719-725.