BIOLOGY AND ECOLOGY OF *LEPTODICTYA PLANA* Heidemann

(HEMIPTERA: TINGIDAE)

by

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(Under the Direction of S. Kristine Braman)

ABSTRACT

Leptodictya plana Heidemann is newly reported from Georgia, USA as a pest of ornamental grasses. Duration of development of *Leptodictya plana*, measured at six temperatures ranged from 23.3 days at 30°C to 40.5 days at 25°C. Development was not successful at 10, 15, 20, or 35°C, although eggs did hatch at 20°C. *L. plana* was present in the field from mid-March through late October. Highest population levels occurred in late August, which corresponded to the warmest temperatures of the season. Overwintering took place in the adult stage. Four generations occurred in central Georgia. Damage ratings on *Pennisetum* ornamental grasses averaged 20% for the 2008 and 2009 summer seasons. Thirty-two selections representing 24 species from varying genera of commercially available and five experimental *Pennisetum purpureum* ornamental grasses were evaluated for susceptibility to *L. plana* feeding and oviposition. While all sustained at least some feeding injury, only *Pennisetum* supported oviposition and development.

INDEX WORDS: *Leptodictya plana*, lace bug, ornamental grass, *Pennisetum*, landscape pest, seasonal phenology, development, host plant resistance

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CHAPTER 1

INTRODUCTION AND LITERATURE REVIEW

Lace bugs are small phytophagous pests that belong to the Hemipteran family, Tingidae. Adults and nymphs cause damage to plants when they feed on the chlorophyll from underneath the leaves by inserting their stylet mouthparts through the stomata which causes the surface of the leaves to have chlorotic spots (Malinoski 2002). In severe infestations, damage can cause reduced photosynthetic activity, early leaf drop or even death (Klingeman et al. 2000).

Lace bugs are widely distributed throughout the world; there are over 2,000 species of lace bugs in about 250 genera (Schuh and Slater 1995). The three most common lace bug species in the US are the azalea lace bug, *Stephanitis pyrioides* Scott, the Sycamore lace bug, *Corythuca ciliata* Say, and the rhododendron lace bug, *Stephanitis rhododendri* Horvath (Buss and Turner 1993). These lace bugs, as well as many others, are of major economic concern for growers and landscapers because their host plants are among some of the most widely planted perennials, shrubs and trees in the US (Balsdon et al. 1996). Other plants that are commonly infested with lace bugs include hawthorn, lantana, oak, pyracantha, and pieris (Buss and Turner 1993). The extent of damage caused by lace bugs has been strongly linked to varying growth and environmental conditions such as temperature, shade, irrigation, and surrounding landscape complexity (Bentz 2003; Braman et al. 2000; Kintz and Alverson 1999; Trumbule and Denno 1995). Control strategies for managing lace bugs typically involve the use of chemical insecticides; however, numerous natural enemies have demonstrated potential to suppress lace bugs (Baldson et al. 1993, Baldson et al. 1996, Braman et al. 1992b, Stewart et al. 2002).

Leptodictya plana was originally described in 1913, by Dr. Otto Heidemann, as having an elongate, oblong, extremely flat body, with a distinct narrowness across the elytra and opaque pronotal lateral margins; he also noted the distinct coloring of the insects yellow head, greenish-grey thorax and light brown abdomen (Heidemann 1913a).

According to all records, *Leptodictya plana* has only been found to feed and develop on panicoid grasses of tribe Paniceae, subtribe Setariineae, and specifically grasses belonging to the bristle clade – *Pennisetum, Setaria,* and *Zuloagaea* (Wheeler 2008). *Leptodictya plana* has primarily been collected from warm, dry habitats such as that found in the western states and Mexico. The recent severe drought conditions in the Southeast may explain the apparent increase in *L. plana* in this region. It is currently not known whether this insect was resident or migrated into the central Georgia area.

A population of *L. plana* was found in an experimental field plot in the Research & Education Garden at the University of Georgia Griffin Experiment Station located in Griffin, GA. The three-year-old ornamental grasses were composed of 23 different experimental accessions of *Pennisetum purpureum* Schumach and trispecific hybrids between *P. glaucum, P. purpureum,* and *P. squamulatum*. The accessions, developed by University of Georgia CAES grass breeder, Wayne Hanna, were originally evaluated for survival, performance, and potential pest infestation. Lace bugs were observed in the spring of 2008, after two previous years of having no pest activity on the grasses.

Previous host plants of *L. plana* are listed as *Pennisetum ciliare* L. (buffelgrass), *Setaria leucopila* Scribn. & Merr., and *Zuloagaea bulbosa* Kunth, with minor incidences occurring on *Eragrostis curvula* Schrad., and *Muhlenbergia rigens* Wasowski (Wheeler 2008). In the laboratory, *L. plana* was successfully reared on *Pennisetum glaucum* L. (pearl millet); however, it is unknown whether *L. plana* naturally can be found on this host plant.

Preliminary work is being done in the western US involving *L. plana* as a potential biological control agent against *Pennisetum ciliare*. *P. ciliare* is an invasive perennial warm-season grass native to Africa that was originally imported to increase rangeland performance due to its fire and drought tolerance. In the US, buffelgrass grows densely and crowds out native plants of similar size, often resulting in death to native species (Wheeler 2008). *L. plana* could help reduce populations of buffelgrass in large areas where it has become widespread. However, recent studies indicate that the spittlebug, *Aeneolamia albofasciata* Lallemand, is more effective in reducing overall plant health than *L. plana* (Wheeler 2008).

L. plana is most closely related to the sugar-cane lace bug, *Leptodictya tabida* Herrich-Schaeffer and originally they were classified as being the same insect until further investigations and observations revealed that they were two separate species (Heidemann 1913b). *L. tabida* occurs on sugar-cane and other species of Poaceae throughout the Caribbean and tropical regions within North and South America (Sétamou et al. 2005). Symptoms of *L. tabida* on sugar-cane include drying and senescence of lower and middle leaves during the late summer months. High infestations of *L. tabida* can lead to reduced sugar content within the plant (Sétamou et al. 2005). In Florida, *L. tabida* was present from late spring to winter with two annual peaks in density, one occurring during late spring and the other occurring during the fall; populations appeared to be negatively correlated with the amount of rainfall received (Hall and Sosa 1994). Another study conducted by Hall (1991) showed that there were significant varietal differences in lace bug resistance in sugarcane fields in Florida and Hawaii. Under laboratory conditions of 27˚C, *L. tabida* completes a generation from egg to adult in 20-30 days; the egg stage lasts 7 to 10 days and nymphs molt 5 times and mature in approximately 15 days (Nguyen and Hall 1998). The length of the life cycle is directly affected by temperature, amount of food available and the variety of food source (Chang 1985). Due to the severe economic impact of *L. tabida* in Florida, an attempt was made during May 1991 to introduce a mymarid parasitoid, *Erythmelus* sp., from Venezuela for control of eggs which did not prove successful (Hall and Sosa 1994).

Braman et al. (1992b) conducted field studies for seasonal occurrence of azalea lace bug, *S. pyrioides*. The study, conducted in Griffin, GA, showed that a total of four generations occurred and that populations were highly female biased, with the ratio of females to males collected as 2.7:1. By mid-March (Julian day 75), 50% of the overwintered eggs had hatched in both 1989 and 1990 and development of the first generation was largely completed by late April (Julian day 120). Adult lace bugs were present from that point, constantly contributing eggs to the population. Adults from the final generation matured by the end of September (Julian day 273) and were occasionally found in December. All eggs deposited during October or later overwintered (Braman et al. 1992b).

The biological requirements for reproduction and survival have been well studied in other species of lace bugs. Braman et al. (1992b) determined that the duration of development for the azalea lace bug, *Stephanitis pyrioides*, from oviposition to adult stage ranged from 21.7 days at 30˚C to 97.4 days at 15˚C; with successful development occurring at all temperatures studied except for 33˚C. Similarly, the Andromeda lace bug, *Stephanitis takeyai* Drake and Maa, was found to develop successfully at all temperatures studied except for 15˚C (Tsukada 1994). The hawthorn lace bug, *Corythuca cydoniae* Fitch, was found to have successful development at temperatures ranging from 24 to 33˚C, with unsuccessful development occurring at 18˚C (Braman and Pendley 1993). *Tingis ampliata* Herrich-Schaeffer, the thistle lace bug, has a reduction in development time with a rise in temperatures within the range of 15-30˚C; additionally, the percentage of hatching eggs tended to increase with humidity (Eguagie 1972). A separate study conducted by Stone and Watterson (1985) concluded that the morrill lace bug, *Corythuca morrilli* Osborn and Drake, development time from egg to adult ranged from 34.7 days at 20˚C to 17.3 days at 30˚C; with unsuccessful development occurring at 17.8 and 34.4˚C and above.

Host-plant resistance has been observed in many different species of lace bugs. The azalea lace bug, *S. pyrioides*, was shown to exhibit varying degrees of host preference to deciduous and evergreen azalea cultivars. Wang et al. (1998), determined susceptibility of cultivars using a rating system based on oviposition rate, percentage emergence from the egg, feeding damage and nymphal growth rate. In a similar study, Braman et al. (1992a) found that some species of deciduous azaleas were significantly less preferred by the azalea lace bug than the standard evergreen azalea, *Rhododendron mucronatum* ‘Delaware Valley White’.

Lantana lace bug, *Teleonemia scrupulosa* Stal, was studied for resistance among 28 different cultivars of lantana. *T. scrupulosa* was never detected on three of the cultivars throughout the season, while three cultivars exceeded an average of 40 nymphs and adults per three leaf sample (Reinert et al. 2006). Reinert et al. (2006) also found that cultivars with gold, red, purple, or white flowers have significantly fewer lace bugs than cultivars with orange, yellow or bicolors of yellow and another color.

Additionally, *L. tabida*, a close relative of *L. plana*, has shown varying levels of infestation in sugarcane. Significant cultivar preference was observed with ‘HoCP91-555’ having the lowest average of lace bugs and ‘NCo-310’ having the highest population of lace bugs over a two-year study. Data for infestation levels was calculated as the percentage of damaged leaves within each plant and the average density of lace bugs (nymphs and adults) per leaf (Setamou et al. 2005).

Traditionally lace bugs have been controlled using chemical insecticides. Balsdon et al. (1993) tested nine different insecticides with different formulations for their effectiveness at suppressing the azalea lace bug, *S. pyrioides*. All treatments examined reduced lace bug populations; however, six treatments required multiple applications to be effective. Acephate was shown to be the most cost effective method for control at that time.

Several natural enemies have also exhibited potential for controlling lace bugs in controlled environments. Two known natural enemies known to attack azalea lace bug include *Stethoconus japonicas* Schumacher, a mirid plant bug, and *Anagrus takeyanus*

Gordh, a parasitoid wasp (Braman et al. 1992a). Braman et al. (1992a) found that the greatest parasitoid induced mortality was observed in the over-wintering generation. In addition to specialist parasitoid, multiple generalist predators have been evaluated for their ability to reduce azalea lace bug populations. In addition to specialist parasitoids, multiple generalist predators have also been evaluated for their ability to reduce azalea lace bug populations. *Chrysoperla rufilabris* Burmeister, green lacewing, and *Rhinocapsus vanduzeei* Uhler, azalea plant bug, were tested for their ability to suppress azalea lace bug populations. Results from this study indicated that *C. rufilabris* was a more suitable candidate for augmentative release to reduce populations but that *R. vanduzeei* also could provide additional reduction in populations within a landscape when other natural predators were also present (Stewart et al. 2002).

In the literature there is very little information available on the biology and life history of *Leptodictya plana*. It is important to be able to predict the potential spread and phenological activity of *L. plana* in order to develop decision-making criteria for this pest. Therefore, research was initiated to better understand 1.) the phenology, abundance, and effect of temperature on the development and survival of *Leptodictya plana* on *Pennisetum* grasses and 2.) the host plant relationships of *Leptodictya plana*.

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CHAPTER 2

PHENOLOGY, ABUNDANCE, PLANT INJURY AND EFFECT OF TEMPERATURE ON THE DEVELOPMENT AND SURVIVAL OF *LEPTODICTYA PLANA* ON PENNISETUM GRASSES[1]

[1] Carr, E.R. and S.K. Braman. To be submitted to *Journal of Economic Entomology*

ABSTRACT Duration of development of *Leptodictya plana* Heidemann, measured at six temperatures, ranged from 23.3 days at 30°C to 40.5 days at 25°C. Complete development was not successful at 10, 15, 20, or 35°C. Base temperature for development of the egg stage was 17.4°C. *L. plana* was present in the field from mid-March through late October. Highest population levels occurred in late August, which corresponded to the warmest temperatures of the season. Overwintering took place in ground thatch as the adult stage. Four generations occurred in central Georgia. Damage ratings on *Pennisetum* ornamental grasses averaged about 20% for the entire 2008 and 2009 summer seasons. Damage inflicted to two ornamental grass standards, 'Prince' and 'Princess', was compared to new trial *Pennisetum* grasses. 'Princess' was preferred over 'Prince' in both sampling years. Differences between years could be based upon a large difference in the amount of precipitation at the site. The studies in this paper improve our understanding of this emerging pest lace bug.

KEYWORDS: lace bug, Tingidae, ornamental pest, damage rating

Lace bugs are a family of small insects that are found on many different types of herbaceous plants, shrubs and trees. Damage to foliage caused by lace bugs detracts from the plant's aesthetic beauty, reduces its vigor and makes the plant more susceptible to damage by other insects and disease (Buntin et al. 1996, Braman et al. 1992). In May, 2008 lace bugs were found inflicting significant injury to *Pennisetum* spp. ornamental grasses in Griffin, GA. Identification by the USDA Systematic Entomology Laboratory as *Leptodictya plana* Heidemann established this as the first record of this lace bug in Georgia.

Leptodictya plana was originally described from a single male specimen collected in Oklahoma. The adult has an elongate, oblong, extremely flat body, with a distinct narrowness across the elytra and opaque pronotal lateral margins, a yellow head, three characteristic low pronotal carinae, greenish-grey thorax and light brown abdomen (Heidemann 1913).

Leptodictya plana is a relatively rare lace bug that is most commonly found in warm, dry habitats in the western United States (Wheeler 2008). It has been reported from Oklahoma, Arizona, Alabama, Florida, Texas, Kansas, Mississippi, and New Mexico. The scarce literature indicates that this lace bug feeds and develops on panicoid grasses of the tribe Paniceae, subtribe Setariineae, and specifically grasses belonging to the bristle clade – *Pennisetum, Setaria,* and *Zuloagaea* (Wheeler 2008). Previous to this report, extensive damage to ornamental plants caused by large infestations of these lace bugs had not been documented.

Similarly to other species of lace bugs, *L. plana* nymphs and adults colonize the underside of the leaf blades and damage their host plants by piercing the leaf tissue and destroying the mesophyll which results in characteristic yellow chlorotic blotches that appear on the upper leaf surface (Braman et al.1992, Braman and Pendley 1993, Reinert et al. 2006, Schultz and Coffelt 1987). Severe infestation levels lead to leaf browning and wilting.

The state of *L. plana* as an emerging pest and lack of information on biology, ecology and host plant relationships prompted our study. Ornamental grasses are a staple in most landscapes and are used often due to their low maintenance and relatively pest free nature. If *L. plana* feeds on common landscape varieties of ornamental grass, it could pose a substantial economic issue. Control strategies for managing lace bugs typically involve the use of chemical insecticides; however numerous natural enemies have shown the potential to suppress various species (Baldson et al. 1993, Baldson et al. 1996, Braman et al. 1992, Stewart et al. 2002).

The objective of our research was to determine the seasonal activity of *L. plana* and define the relationship between temperature and development of *L. plana* to permit better prediction of damaging stages on ornamental grasses. Additionally, levels of damage on *Pennisetum* grasses were compared to two standard varieties, ‘Prince’ and ‘Princess’, to determine relative susceptibility of other grasses to this pest.

Materials and Methods

Controlled Temperature Studies. Specimens for experiments were obtained from a colony initiated with adults collected from ornamental grass plantings of *Pennisetum* spp. hybrids in Griffin, GA. The colony was periodically supplemented with additional field-collected individuals. *L. plana* were maintained in cages in the laboratory at approximately 25°C and a 12:12 (L:D) photoperiod on pearl millet (*Pennisetum glaucum*

L.) in three inch liners planted into Sun Gro Metro-Mix 300 (Sun Gro Horticulture, British Columbia, Canada). Plants were hand watered daily. Supplemental *P. glaucum* was grown from seed as needed.

Female lace bugs were caged on individual seedlings, placed in environmental chambers (Percival Manufacturing Company, Boone, Iowa) and allowed to oviposit for 24 hours at 25°C. Once oviposited, eggs were transferred to the experimental temperatures. At least 233 individual eggs were evaluated at each temperature (Table 2.1). Eggs and the emerging nymphs were monitored for development twice daily at each of six constant temperatures: 10, 15, 20, 25, 30, 35°C. First instars were transferred individually to fresh seedlings extending through a plastic lid into a 32 –ml plastic cup of water. A second cup was modified by replacing the bottom with mesh netting to allow for ventilation. That cup was inverted and placed over the seedling, and the union of the cups was secured with Parafilm M (American National Can, Greenwich, Connecticut). Date and time of ecdysis was recorded for each developmental stage.

The total hours required for oviposition and each subsequent developmental stage were recorded and compared among the experimental temperatures. Mean days to develop for each stage at each temperature were separated using a least significant difference (LSD) test at $\alpha = 0.05$. At least 233 replications were performed and are represented by each individual egg. Mean thermal units required to complete development were calculated by taking the mean (among all temperatures) of K_t, which was calculated by the following equation:

$$K_t = (T - T_0) * D_t$$

where *T* was 10, 15, 20, 25, 30, or 35°; T_0 was the base temperature threshold; D_t was the mean total developmental time (in days) for a particular *T*. Only the developmental times at temperatures where complete development occurred were analyzed.

Field Phenology Studies. Landscape plantings naturally invested with *L. plana* were sampled during 2008 and 2009. At the University of Georgia, Griffin Experiment Station (Griffin, Spalding County, GA), 21 different accessions with four replications of *Pennisetum* interspecific and trispecific ornamental grasses (3-years-old) in a contiguous planting were sampled approximately every 10 days from 2 May 2008 through 16 October 2008 and from 4 April 2009 through 28 September 2009.

Four infested leaf blades were randomly selected within each plant and placed in plastic bags corresponding to each plant. Leaf blades were then taken to the laboratory where the number of intact eggs, nymphs (first through fifth instars) and adult lace bugs per 4-leaf sample were counted underneath the microscope. Adults were also sampled by observing the number of visible adults per whole plant within a ten-second interval.

To further estimate the number of generations possible within a year, the Georgia Automated Environmental Monitoring Network website's degree day calculator was used. The University of Georgia Griffin Experiment Station located in Griffin, GA has a monitoring station located on site; therefore website data was taken within one mile of our experimental grass plots. Along with the data received from the controlled temperature studies, the number of total degree days per calendar year were calculated by entering the lowest and highest lethal temperatures for *L. plana*. The output, total number of days within the temperature parameters, was then divided by the mean thermal units required to reach development (*K*, found previously) to estimate the total number of generations possible within 2008 and 2009.

Field Damage Examination. *Pennisetum* grasses discussed in the preceding section were evaluated for percent foliar damage caused by *L. plana* three times during the 2008 sampling season and twice during the 2009 season. Estimates were made by two independent people and the values for each plant were averaged. Damage ratings for whole plants ranged from 0 to 100%, with zero indicating that no damage was observed and 100 meaning that complete damage was observed to the plant based on *L. plana* feeding. Two of the ornamental grasses in the field plot were commercially available landscape standards, *Pennisetum purpureum* cv. ‘Prince’ and ‘Princess’. The remaining 19 entries were trial varieties that are not yet publically available. The amounts of damage inflicted to the experimental trials were averaged and analyzed as one group and then compared to the percent damage caused to the standards, ‘Prince’ and ‘Princess’.

Statistical Analyses. Data were analyzed by analysis of variance (ANOVA) using the PROC GLM procedure in SAS (SAS Institute 2003, Cary, NC) to determine differences in susceptibility among the standard cultivars and the trial varieties. Means were separated using a least significant difference test at $\alpha = 0.05$. To determine the base temperature for development of the egg stage, the PROC REG procedure in SAS was utilized. Threshold temperatures for other developmental stages were not analyzed due to insufficient survival at temperatures other than 25 and 30°C. All percent damage data were transformed using an arcsine square root transformation to normalize data prior to analysis. The data presented in tables and figures are untransformed values.

Results

Controlled Temperature Studies. Successful development occurred at 25 and 30°C (Table 2.1). At 20°C, 62 nymphs emerged and underwent ecdysis but died shortly after reaching the second instar. Nymphs (103) attempted to emerge at 35°C; however, no further development occurred. Duration of development from oviposition to ecdysis to the adult stage ranged from 23.3 days at 30°C to 40.5 days at 25°C. About one third of the total developmental period was spent in the egg stage. Among nymphal stages, time required for development of the second instar was the least, whereas fifth instars required the longest time.

Mean days to develop were significantly different for total development at all temperatures for all stages and ages within a stage. Thermal units required for development, using a base temperature of 21°C, were 162 and 213.3 at 25 and 30°C, respectively; therefore mean K is 187.6. Since development was not successful between 15-20°C, regression analysis was used to calculate the base temperature for development of the egg stage at 17.4°C.

Field Phenology Studies. Throughout the entire sampling period in both years, adults were present continually contributing eggs to the population, resulting in overlapping generations; therefore distinct generations were difficult to observe (Figs. 2.1, 2.2). When represented graphically, population peaks indicate that three to four generations occurred in Griffin, GA.

Using the degree day calculator on the Georgia Automated Environmental Monitoring Network website (using data collected from the UGA Griffin Experiment Station), the number of degree days was estimated using a base temperature of 21°C and a high lethal temperature of 35°C (values obtained from controlled temperature study; Table 2.1). In 2008, there were 920 total degree days and in 2009, there were 909. As previously found, the average thermal units required for total development (*K*) is 187.6. Dividing total degree days by *K* indicates that in 2008, 4.9 generations could occur and in 2009, 4.8 generations could occur. If pre-ovipositional time is considered when making this calculation, the total number of generations are 4, which support our previous conclusion that 4 generations occur in Griffin, Georgia. Pre-ovipositional time is the period required for an adult to become sexually mature. The average pre-ovipositional time for tingids is between 4-9 days; therefore this must be considered when estimating the number of generations occurring (Rogers 1977, Pecora et al. 1992, Neal et al. 1992, Aysal and Kivan 2008).

Adults were observed in the field as early as mid March on freshly emerged grasses indicating that this lace bug species overwinters in ground thatch as the adult stage as opposed to the egg stage. In 2008 and 2009, highest population levels occurred in early August, which correlated with the highest temperatures. All plants had approximately the same life stages and relative number of individuals present; therefore, there were no differences observed between the plant accessions in terms of lace bug phenology. Additionally, no evidence of parasitism was observed in the collected samples from the field.

Approximately 30% fewer insects were collected in 2009 than in 2008. According to the Georgia Automated Environmental Monitoring Network Station located on the Griffin Experiment Station, there was 64% more rainfall received in 2009 than 2008 during our sampling period (May-October). This lace bug is more common in arid regions of the United States, suggesting that the increase in rainfall could have contributed to the population difference observed between the two years.

Field Damage Examination. The overall average percent damage observed in the field for both sampling seasons was approximately 20% among all cultivars. Percent damage to plants ranged from 5 to 90% during peak infestation levels. Damage inflicted to two ornamental grass standards, ‘Prince’ and ‘Princess’, were compared to new trial *Pennisetum* spp. grasses and were found to have significantly different levels of damage when compared to the singular grouping of the experimental ornamental grasses. For 2008, ‘Princess’ was more damaged than ‘Prince’ and all the other grasses in the field (Fig. 2.3). For 2009, ‘Princess’ and the other grasses were more damaged than ‘Prince’ (Fig. 2.4). Differences between years could be based upon a large difference in the amount of precipitation recorded at the site.

In addition to damage caused by lace bug feeding and defecation, we observed low to moderate damage caused by grasshoppers, mites, and two-lined spittlebugs, *Prosapia bicincta* Say, late in the season. Towards the end of the season, as lace bug numbers began to naturally decline, the ornamental grasses in the field plots were able to outgrow most of the damage inflicted by the lace bugs. New growth appeared in the center of the plant and spread outwards, with uninjured, healthy new foliage.

Discussion

The temperature range suitable for *L. plana* development was narrow when compared to other species of lace bugs, such as *Stephanitis pyrioides* Scott (Neal and Douglass 1988, Braman et al. 1992). However, there are some lace bugs that have similarly narrow ranges such as *Corythuca cydoniae* Fitch, which is also typically more severe in hot, dry weather (Braman and Pendley 1993). The data collected for the reproduction and development of *L. plana* suggest that this lace bug prefers hot, dry climates that are common during the summer months in central Georgia.

There are no previous reports of this lace bug occurring on ornamental grasses or of it occurring on *Pennisetum purpureum*. Additionally, it was successfully reared in the greenhouse on *Pennisetum glaucum*, pearl millet, and was found naturally infesting *Pennisetum* spp. interspecific and trispecific hybrid ornamental grasses in the field. This leads to the possibility that *L. plana* could pose a substantial economic impact if its distribution spreads further. Therefore, *L. plana* should be viewed as an emerging pest and considered as a potentially serious problem. The specific origins of this lace bug in Georgia are unknown, but it is likely that this pest has been sustained in a local population at low levels and was able to utilize a large planting of a suitable host material.

With the appearance of this lace bug in central Georgia, indicating a spread in habitat distribution, there is a greater importance to further study this insect to determine how its occurrence might affect the ecology of the region. From our studies, it is apparent that this insect causes significant damage and thrives in our hot, dry climate. It would be useful to understand how this insect originated in our area and what other potential host plants might exist. Ornamental grasses are a staple in many southern US landscapes and are used often due to their low maintenance and relative pest free nature. If *L. plana* feeds on other varieties of ornamental grass, it could pose a substantial economic issue. Therefore, it is critical to learn more about this pest in order to determine the most effective ways to manage and control its impact and potential further spread.

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Table 2.1. Mean ± SE duration of development in days, and number of corresponding individuals completing each stage, of *L. plana* on *Pennisetum glaucum* seedlings

Temp, °C	Egg	Instar					Total nymphal	Total
		1	2	3	4	5		
10	NE[a] (449)[c]	ND[b]	ND	ND	ND	ND	ND	ND
15	NE (381)	ND	ND	ND	ND	ND	ND	ND
20	39.4 ± 0.1A (359)	2.9 ± 0.3B (62)	ND	ND	ND	ND	ND	ND
25	15.1 ± 0.1B (416)	5.0 ± 0.1A (220)	3.4 ± 0.2A (82)	4.1 ± 0.3A (69)	4.8 ± 0.1A (54)	8.1 ± 0.3A (45)	25.4 ± 0.4A (32)	40.5 ± 0.2A (32)
30	8.5 ± 0.1C (584)	3.5 ± 0.2B (266)	2.8 ± 0.3B (112)	2.2 ± 0.1B (92)	2.9 ± 0.2B (63)	4.0 ± 0.3B (48)	15.2 ± 0.2B (27)	23.7 ± 0.3B (27)
35	8.6 ± 0.2C (233)	ND	ND	ND	ND	ND	ND	ND

[a] No live emergence from egg
[b] No development occurred
[C]Values in parentheses are numbers of individuals entering each stage

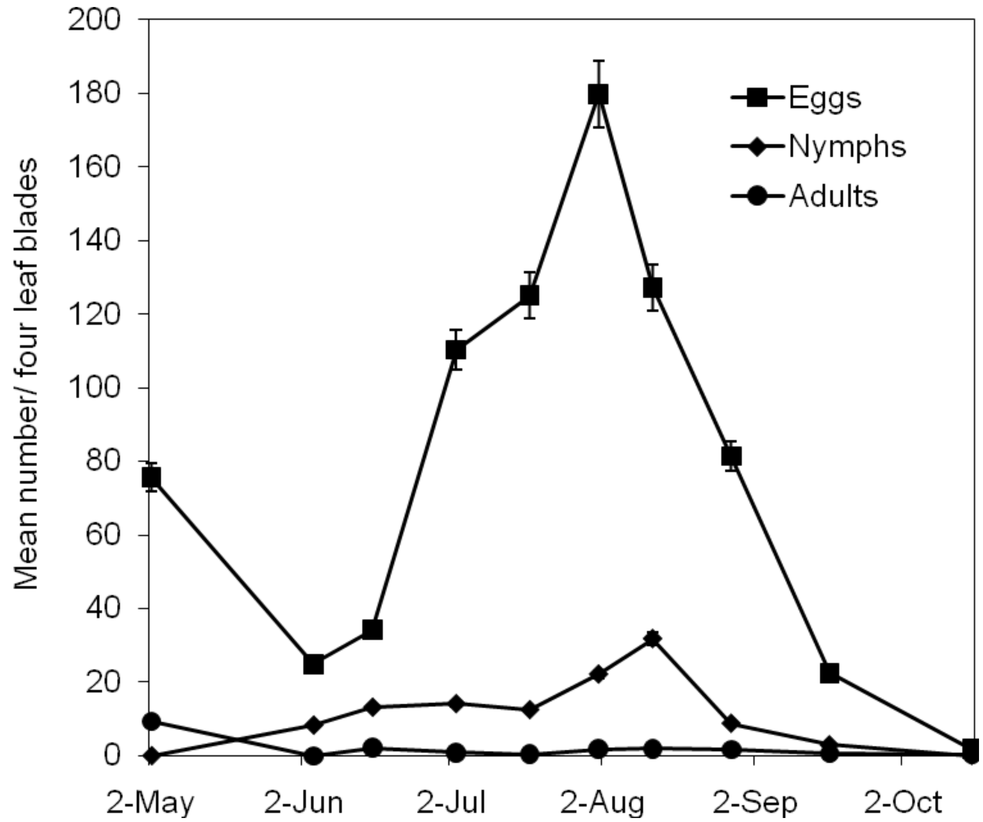

Figure 2.1. Seasonal occurrence of immature and adult *L. plana* lace bugs on *Pennisetum purpureum* ornamental grasses in Griffin, GA, 2008

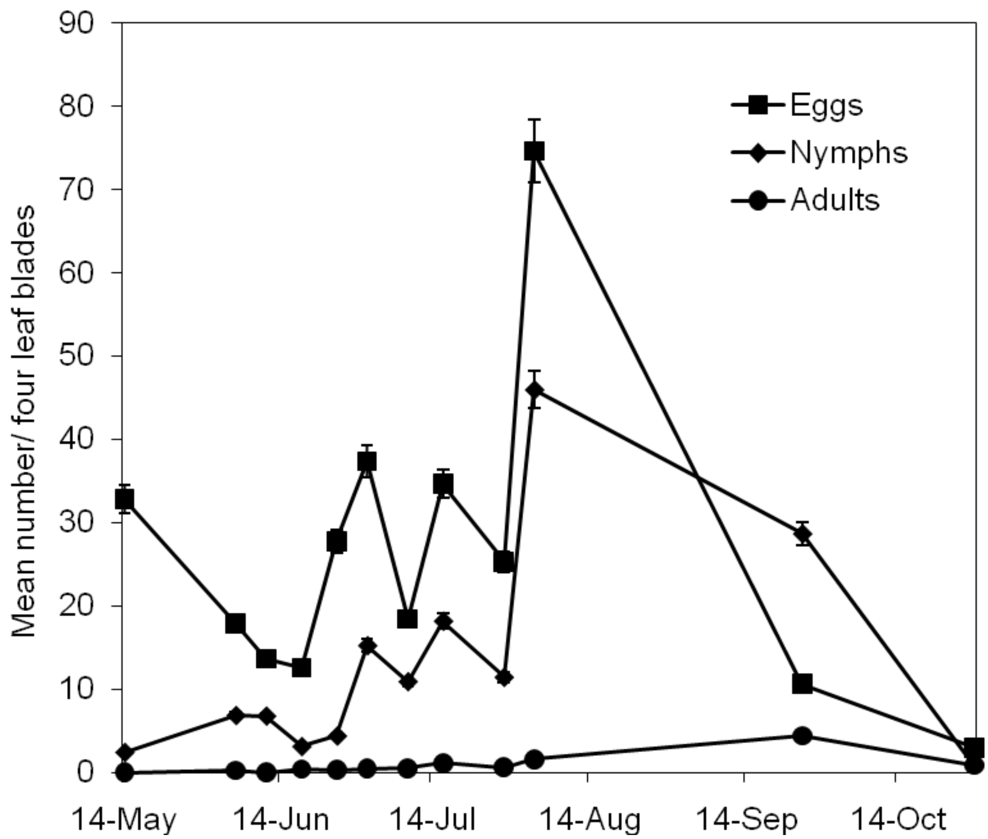

Figure 2.2. Seasonal occurrence of immature and adult *L. plana* lace bugs on *Pennisetum purpureum* ornamental grasses in Griffin, GA, 2009

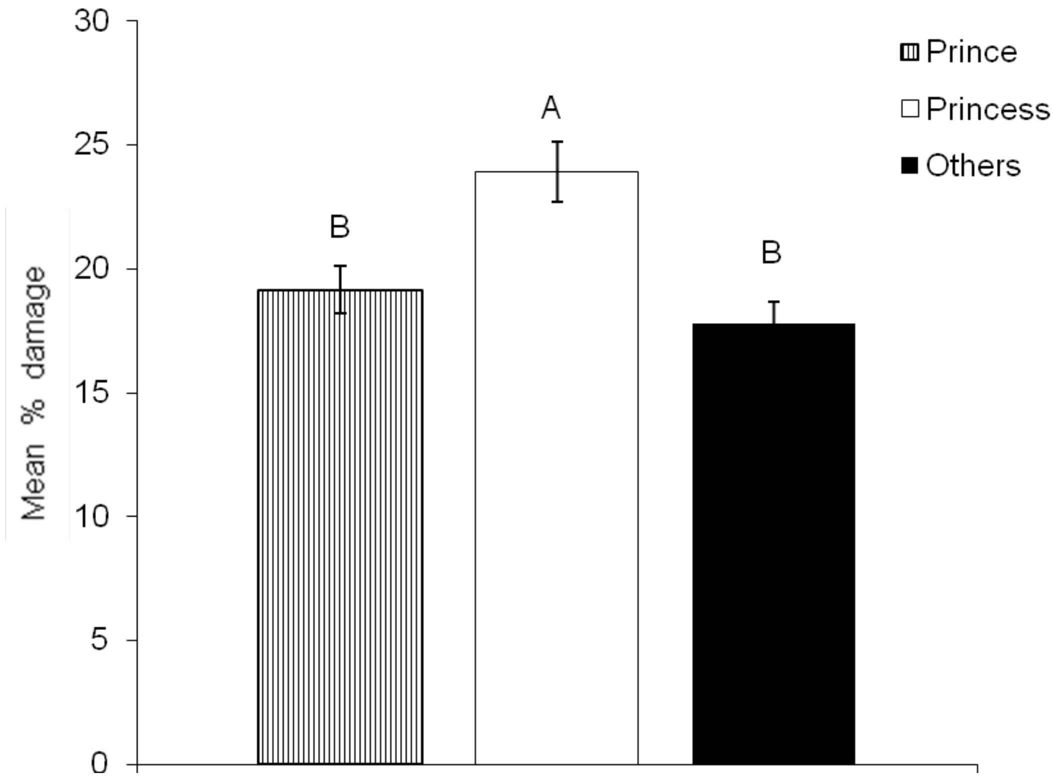

Figure 2.3. Mean percent damage of ‘Prince’ and ‘Princess’ ornamental grasses compared to all other grasses in field plot in Griffin, GA, 2008

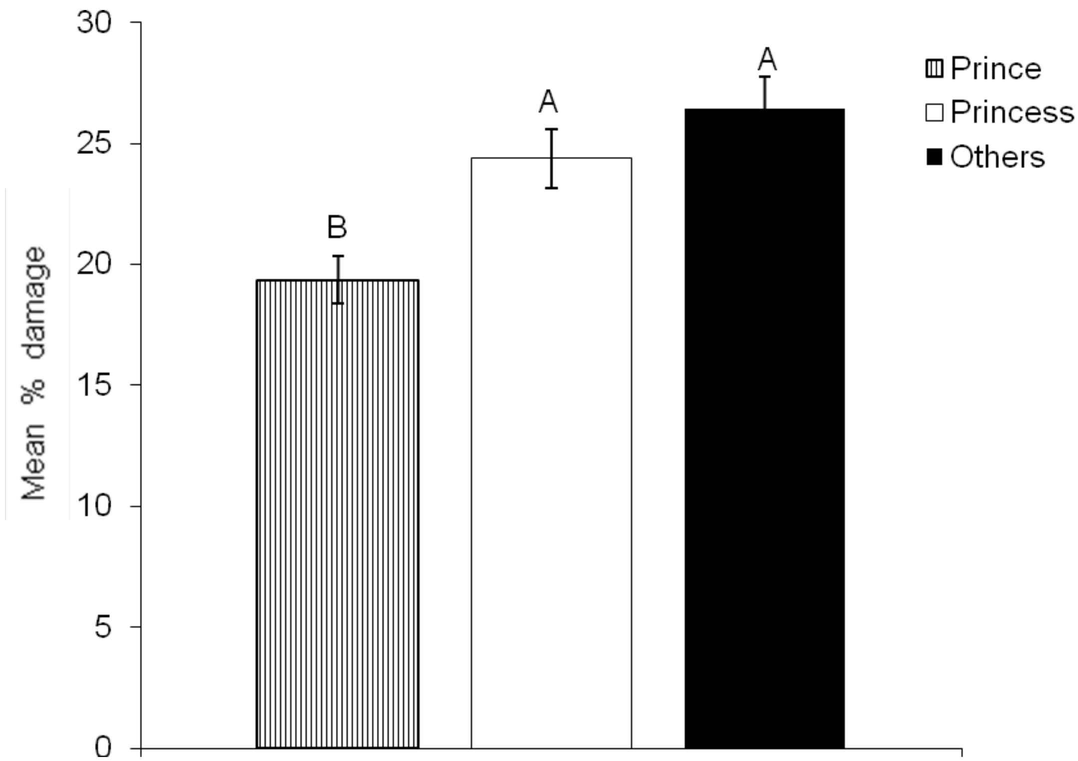

Figure 2.4. Mean percent damage of 'Prince' and 'Princess' ornamental grasses compared to all other grasses in field plot in Griffin, GA, 2009

CHAPTER 3

HOST PLANT RELATIONSHIPS OF *LEPTODICTYA PLANA* Heidemann[1]

[1] Carr, E.R. and S.K. Braman. To be submitted to *Environmental Entomology*

ABSTRACT *Leptodictya plana* Heidemann is an emerging pest on ornamental grasses in the southern United States. Thirty-two selections of commercially available ornamental grasses and sedges and five accessions of *Pennisetum purpureum* were evaluated for susceptibility to *L. plana* feeding and oviposition. No- choice studies were conducted in a greenhouse by securing four lace bugs to leaf blades of each plant using clip cages. Lace bugs stayed attached for five days. Damage and number eggs were recorded. Choice studies were conducted in the laboratory by placing leaf blades from each genus of plant species into a large petri dish in a spoke pattern. There were no plants tested that consistently received zero percent damage in both trials. Plants that sustained the least damage included *Acorus* spp., *Cordyline* spp., and *Panicum* spp. *Pennisetum* spp. entries exhibited the highest overall percent damage and was the only genera of plants that supported oviposition.

KEYWORDS: lace bug, Tingidae, ornamental grasses, *Pennisetum*, host plant resistance

Leptodictya plana Heidemann is a relatively uncommon lace bug that specializes on panicoid grasses and is mostly found in the southwest US (Wheeler 2008). *L. plana* is originally described as having an elongate, oblong, extremely flat body, with a distinct narrowness across the elytra and opaque pronotal lateral margins, a yellow head, greenish-grey thorax and light brown abdomen (Heidemann 1913).

Damage caused by *L. plana* is similar to other species of lace bugs. Adults and nymphs presumably feed like the azalea lace bug, *Stephanitis pyrioides* Scott, by removing leaf mesophyll from the underside of the leaf blades by piercing their mouthparts through the stomata, resulting in characteristic chlorotic damage that can be viewed from above (Baldson et al. 1993, Braman and Pendley 1992, Buntin et al. 1996). Severe infestations can lead to leaf wilting and eventual death if left untreated.

Recently, *L. plana* appeared in central Georgia in mass numbers feeding, reproducing, and causing significant damage on *Pennisetum* ornamental grasses. Ornamental grasses are common staples used in many landscape settings for their easy maintenance, pest-free nature, and drought tolerance. Numerous ornamental grass species are available on the market throughout the US.

Very little information is known about the life history of *L. plana.* No previous laboratory or field studies have been conducted on this lace bug. Therefore, the purpose of this study is to assess the ornamental grass plant species most suitable for the survival and development of *L. plana*.

Materials and Methods

No-choice Greenhouse Studies. Thirty seven ornamental grass or sedge selections representing 24 species (Table 3.2) were evaluated for feeding behavior and oviposition in a greenhouse study. Potted plants were purchased from Baker Environmental Nursery, Inc. located in Hoschton, GA. No pesticides were applied prior to or during the study. Plants were arranged in a randomized block design with four spatial replications and two temporal replications.

Two male and two female adult lace bugs were attached to the leaf blades of each plant using individualized clip containers. Clip containers were created by inserting the leaf blades through a hole in a plastic lid which was attached to a 32-ml plastic cup. The plastic cup was modified by replacing the bottom with mesh netting to allow for ventilation. Cups were secured to the plants by sealing the plastic opening holes with Parafilm M (American National Can, Greenwich, Connecticut) where the leaf blades were inserted.

After five days attached to the plant, cups were removed. The number of eggs, number of living adults, and leaf damage rating were recorded. Damage ratings were estimated by observing the amount of chlorotic injury per total leaf area on a scale from 0 to 10, with 0 being no damage observed and 10 being complete injury, or 100% chlorosis.

Choice Containerized Studies. One representative grass species from each of 14 genera (Table 3.3) was chosen to be placed into a large 30cm petri dish. The 14 leaf blades were arranged in a spoke pattern so that they were at equal distances from one another. In the center, a moistened piece of filter paper was placed over the cut ends of the blades to prevent desiccation. The blades were randomized within each of the six spatial repetitions, and there were two temporal repetitions performed.

In the first trial, five male and five female adult lace bugs were placed into the center of each petri dish. In the second trial, ten male and ten female adult lace bugs were placed into the petri dishes. The locations of the lace bugs were recorded 3, 27, and 51 hours after being placed into the dishes. At 51 hours, an overall damage rating was also recorded for each leaf blade and the insects were removed. Damage ratings were estimated as previously described.

A second choice study was performed using 10 different species of *Pennisetum* grasses to further determine performance within the genus because prior experiments had shown them to be the ovipositional host for *L. plana*. The ten leaf blades were arranged and the data was collected in the same manner as the other choice test conducted.

Statistical Analyses. Data were analyzed by analysis of variance (ANOVA) using the PROC GLM procedure in SAS (SAS Institute 2003, Cary, NC) to determine differences in susceptibility among the plant selections. Means in choice containerized study were separated using a least significant difference (LSD) test at $\alpha = 0.05$. Means in no-choice greenhouse study were separated using Tukey's studentized range test (HSD) at $\alpha = 0.05$. All damage rating data were transformed using an arcsine square root transformation to normalize data prior to analysis. The data presented in tables and figures are untransformed means.

Results

No-choice Greenhouse Studies. All plants in the study had at least a few spots of feeding damage observed (Table 3.3). There were no plants tested that consistently received zero percent damage in both trials. Plants that sustained the least damage included *Acorus* spp., *Cordyline* spp., and *Panicum* spp. All non-grass selections, including sedges, were consistently among the lowest damaged plants in all trials performed. It is evident that *L. plana* prefers grasses within the family Poaceae based on feeding damage incurred in our studies.

Pennisetum spp. plants incurred the highest overall percent damage. Other genera with substantial feeding damage observed (greater than 25%) were *Andropogon*, *Schizachryrium*, *Festuca*, *Spartina* and *Sorghastrum*. Plants that were not acceptable feeding host plants typically resulted in death of the insects after one day, which included *Scirpus cernuus*, *Cordyline* spp., *Acorus gramineus*, and *Carex comans*.

Pennisetum plants were the only genera that supported oviposition (Fig. 3.5). The overall average number of eggs laid per leaf blade was 7.1. All *Pennisetum* cultivars had eggs laid inside the leaf blades except for *P. alopecuroides*. The cultivars that had the most number of eggs were experimental hybrid variety #17, *P. alopecuroides* “Moudry’, and *P. alopecuroides* ‘Hamelin’.

Choice Containerized Studies. In both of the choice studies conducted, *Pennisetum* grasses sustained the highest overall damage ratings (Table 3.3). In the first trials conducted, damage ratings were low across all grass leaf blades; therefore, in the second trials the number of lace bugs was increased to 20 per petri dish. Some grass genera which had previously been fed on heavily under the no-choice experiment were hardly fed on at all in the choice experiment, such as *Miscanthus*, *Cortaderia*, *Muhlenbergia*, and *Spartina*.

At the 3 hour check time, lace bugs were more uniformly distributed among the leaf blade samples than they were at the 27 and 51 hour check times (Table 3.4). At the two later check times, there was a higher concentration of lace bugs on *Pennisetum*, *Phalaris*, and *Calagmograstis* leaf blades. This indicates that at first, lace bugs did not show a host preference, apparently probing and attempting to feed on the plants to determine the suitability of the host plant. The preferred host in the choice study was *Pennisetum alopecuroides* ‘Hamelin’. The least preferred ornamental grass in the choice studies was *Cortaderia selloana* “Pumila’.

The experimental hybrids were heavily preferred host plants for both feeding and oviposition. This correlates with previous data since all were *Pennisetum* spp. hybrids. The least preferred of the trial varieties was #12, whereas the most preferred was #17.

Discussion

The greenhouse and laboratory assays showed that the preferred host plants of *L. plana* belong to the genus *Pennisetum*. Among *Pennisetum* spp., the commercial cultivars most preferred were *P. alopecuroides* ‘Hamelin’ and ‘Moudry’. If planted among other ornamental grasses, these cultivars could serve as indicator species due to their high susceptibility. Plants not belonging to the panicoid subfamily had the overall lowest levels of damage incurred. These results correspond to Wheeler’s (2008) previous findings in the field, that *Pennisetum* spp. grasses are suitable host plants for feeding and development of *L. plana.*

The reason that some plant species were not preferred is unknown, however, heavily fed upon species had some morphological similarities. Plants possessing broad leaf blades with stiff, pronounced midribs as well as reduced pubescence on the undersides of the leaves seemed to be favored over species without these characteristics. Previous studies have examined color, pubescence, leaf wax composition, leaf water content, stomata and origin of plants to be correlated with possible resistance mechanisms against lace bugs (Braman and Pendley 1992, Reinert et al. 2006, Wang et al. 1998, Kirker et al. 2008). The experimental setup used in our studies resembled previous studies testing host preference of lace bugs (Schultz 1985, Bernardinelli 2006, Wang et al. 1998).

There are no previous reports of this lace bug occurring on ornamental grasses or of it occurring on the species of *Pennisetum* that we observed it on. Hence, it is important to start monitoring the movement and host preferences of *L. plana* throughout the southeast to ensure that it does not become a widespread pest problem.

L. plana is an emerging pest, with still very little information known about its origins and potential impact in the southeastern US. From our studies, it is apparent that this insect causes significant damage and thrives in a hot, dry climate. Additional host plant assays should be conducted to broaden our knowledge about its host range and damage capabilities. In-depth scouting and monitoring procedures should be implemented to track the spread of *L. plana*. Control strategies and techniques need to be investigated to halt the further movement of this destructive pest.

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Table 3.2. Ornamental grasses used in experimental studies with *L. plana*

Plant Number	Species	Cultivar	Common Name	Family	Subfamily
1	*Acorus gramineus*	'Ogon'	Golden Striped Sweet Flag	Araceae	Acoraceae
2	*Andropogon virginicus*		Broomsedge	Poaceae	Panicoideae
3	*Andropogon gerardii*		Big Bluestem	Poaceae	Panicoideae
4	*Andropogon glomeratus*		Bushy Bluestem	Poaceae	Panicoideae
5	*Calamagrostis acutiflora*	'Karl Foerster'	Feather Reed Grass	Poaceae	Pooideae
6	*Carex comans*	'Amazon Mist'	Sedge	Cyperaceae	Caricoideae
7	*Cordyline australis*	'Red Star'	Cabbage Tree	Laxmanniaceae	Rubioideae
8	*Cordyline indivisa*		Spike Dracaena	Laxmanniaceae	Rubioideae
9	*Cortaderia selloana*	'Pumila'	Dwarf Pampas Grass	Poaceae	Danthonioideae
10	*Eragrostis spectabilis*		Purple Love Grass	Poaceae	Chloridoideae
11	*Festuca glauca*	'Select'	Blue Fescue	Poaceae	Pooideae
12	*Festuca glauca*	'Elijah Blue'	Blue Fescue	Poaceae	Pooideae
13	*Miscanthus sinensis*	'Purpurascens'	Flame Grass	Poaceae	Panicoideae
14	*Miscanthus sinensis*	'Zebrinus'	Zebra Grass	Poaceae	Panicoideae
15	*Miscanthus sinensis*	'Morning Light'	Pink Muhly Grass	Poaceae	Chloridoideae
16	*Muhlenbergia capillaris*		Pink Muhly Grass	Poaceae	Chloridoideae
17	*Muhlenbergia capillaris*	'Pink Flamingo'	Pink Muhly Grass	Poaceae	Chloridoideae
18	*Nassella tenuissima*		Ponytail Grass	Poaceae	Pooideae
19	*Panicum virgatum*		Switchgrass	Poaceae	Panicoideae
20	*Panicum virgatum*	'Heavy Metal'	Blue Switchgrass	Poaceae	Panicoideae
21	*Panicum virgatum*	'Shenandoah'	Red Switchgrass	Poaceae	Panicoideae
22	*Pennisetum alopecuroides*		Fountain Grass	Poaceae	Panicoideae
23	*Pennisetum alopecuroides*	'Hamelin'	Dwarf Fountain Grass	Poaceae	Panicoideae
24	*Pennisetum alopecuroides*	'Moudry'	Black Fountain Grass	Poaceae	Panicoideae
25	*Pennisetum glaucum*	'Jester'	Ornamental Millet	Poaceae	Panicoideae
26	*Pennisetum orientale*	'Tall Tails'	Oriental Fountain Grass	Poaceae	Panicoideae
27	*Pennisetum setaceum*	'Rubrum'	Purple Fountain Grass	Poaceae	Panicoideae
28	*Phalaris arundacea*	'Picta'	Ribbon Grass	Poaceae	Panicoideae
29	*Schizachyrium scoparium*		Little Bluestem	Poaceae	Panicoideae
30	*Scirpus cernuus*		Fiber Optic grass	Cyperaceae	Cyperoideae
31	*Sorghastrum nutans*		Indian grass	Poaceae	Panicoideae
32	*Spartina bakerii*		Cord grass	Poaceae	Chloridoideae
33[a]	*Pennisetum* spp. hybrid			Poaceae	Panicoideae
34[a]	*Pennisetum purpureum* x *P. glaucum* x *P. squamulatum*			Poaceae	Panicoideae
35[a]	*Pennisetum* spp. hybrid			Poaceae	Panicoideae
36[a]	*Pennisetum* spp. hybrid			Poaceae	Panicoideae
37[a]	*Pennisetum* spp. hybrid			Poaceae	Panicoideae

[a]Experimental trial hybrid cultivar

Table 3.3. Average *L. plana* damage ratings for ornamental grass, choice and no-choice studies

Entry No	Plant name/ cultivar	Greenhouse No-choice Trial Damage Rating (1-10) 6/30-7/09	7/16-7/21	Pennisetum Choice Trial Damage Rating (1-10) 7/29-7/31	8/5-8/7	Genus Rep. Choice Trial Damage Rating (1-10) 7/29-7/31	8/5-8/7
1	*Acorus gramineus* 'Ogon'	0.0 f	1.25 gh	---	---	---	---
2	*Andropogon virginicus*	4.25 a-f	5.5 a-h	---	---	0.0 e	1.0 cd
3	*Andropogon gerardii*	2.25 c-f	4.5 a-h	---	---	---	---
4	*Andropogon glomeratus*	0.75 ef	0.75 h	---	---	---	---
5	*Calamagrostis acutiflora* 'Karl Foerster'	1.75 c-f	2.5 d-h	---	---	2.83 b	4.0 b
6	*Carex comans* 'Amazon Mist'	3.25 b-f	2.75 d-h	---	---	---	---
7	*Cordyline australis* 'Red Star'	0.0 f	0.0 h	---	---	---	---
8	*Cordyline indivisa*	0.25 f	1.75 e-h	---	---	---	---
9	*Cortaderia selloana* 'Pumila'	2.0 c-f	2.5 d-h	---	---	0.0 e	0.0 d
10	*Eragrostis spectabilis*	0.5 ef	3.5 b-h	---	---	0.0 e	1.33 cd
11	*Festuca glauca* 'Select"	4.75 a-f	7.25 a-g	---	---	0.17 e	2.17 c
12	*Festuca glauca* 'Elijah Blue'	3.25 b-f	3.5 b-h	---	---	---	---
13	*Miscanthus sinensis* 'Purpurascens'	1.75 c-f	3.0 c-h	---	---	0.5 c-e	0.0 d
14	*Miscanthus sinensis* 'Zebrinus'	0.25 f	1.5 f-h	---	---	---	---
15	*Miscanthus sinensis* 'Morning Light'	1.5 d-f	6.0 b-g	---	---	---	---
16	*Muhlenbergia capillaris*	2.0 c-f	2.5 d-h	---	---	---	---
17	*Muhlenbergia capillaris* 'Pink Flamingo'	2.25 c-f	2.75 d-h	---	---	0.0 e	0.17 d
18	*Nassella tenuissima*	0.25 f	1.75 e-h	---	---	0.33 de	0.0 d
19	*Panicum virgatum*	0.75 ef	0.5 h	---	---	---	---
20	*Panicum virgatum* 'Heavy Metal'	1.0 ef	1.25 gh	---	---	0.33 de	0.17 d
21	*Panicum virgatum* 'Shenandoah'	0.75 ef	0.75 h	---	---	---	---
22	*Pennisetum alopecuroides*	5.75 a-e	10.0 a	0.67 b	4.5 ab	---	---
23	*Pennisetum alopecuroides* 'Hamelin'	8.75 a	9.5 ab	3.17 a	1.5 b	7.33 a	7.67 a
24	*Pennisetum alopecuroides* 'Moudry'	7.75 ab	9.5 ab	3.5 a	2.17 b	---	---
25	*Pennisetum glaucum* 'Jester'	6.75 a-d	5.25 a-h	---	---	---	---
26	*Pennisetum orientale* 'Tall Tails'	8.25 ab	9.0 a-c	0.67 b	6.0 a	---	---
27	*Pennisetum setaceum* 'Rubrum'	7.0 a-c	7.75 a-e	0.83 b	4.83 ab	---	---
28	*Phalaris arundacea* 'Picta'	0.0 f	1.5 f-h	---	---	1.17 c	2.33 bc
29	*Schizachyrium scoparium*	5.25 a-f	4.75 a-h	---	---	0.33 de	0.17 d
30	*Scirpus cernuus*	0.5 ef	2.25 d-h	---	---	---	---
31	*Sorghastrum nutans*	2.0 c-f	6.0 a-h	---	---	1.0 cd	0.33 d
32	*Spartina bakerii*	3.25 b-f	5.0 a-h	---	---	0.0 e	0.17 d
33	# 12 Experimental Hybrid	4.25 a-f	7.25 a-g	0.83 b	3.33 ab	---	---
34	# 17 Experimental Hybrid	5.25 a-f	8.0 a-d	0.5 b	2.5 b	---	---
35	# 26 Experimental Hybrid	4.5 a-f	8.25 a-d	0.83 b	3.67 ab	---	---
36	# 10 Experimental Hybrid	4.25 a-f	7.5 a-f	0.16 b	3.83 ab	---	---
37	# 8 Experimental Hybrid	5.25 a-f	8.0 a-d	0.83 b	4.5 ab	---	---

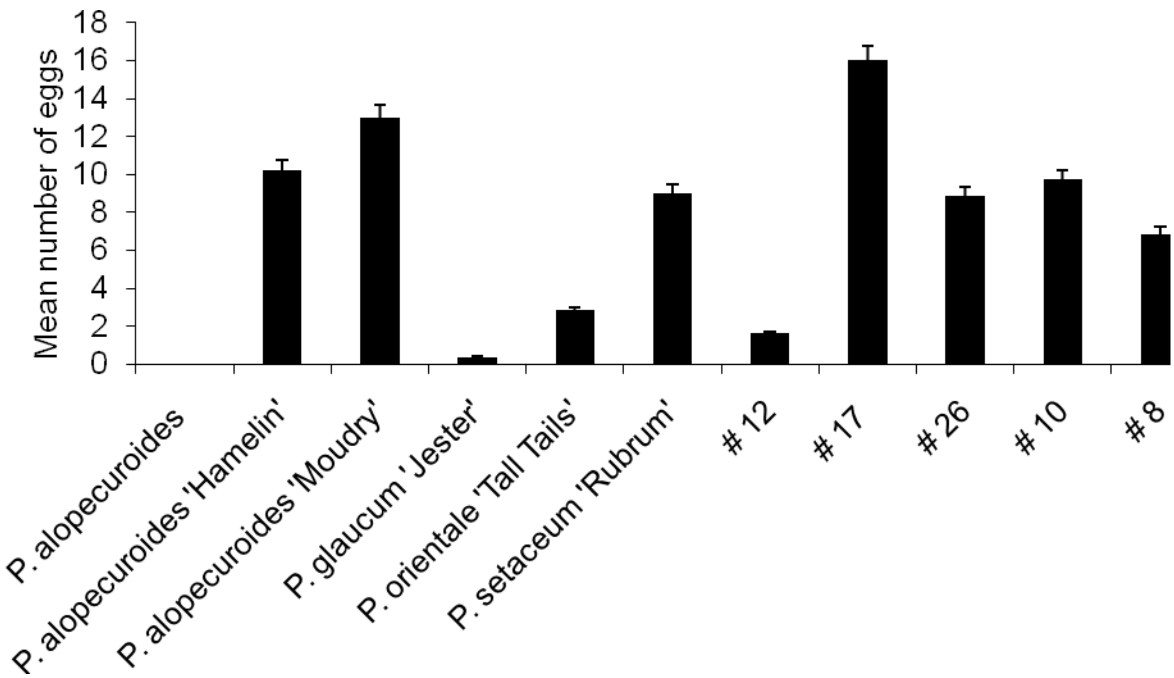

Figure 3.5. Mean number of *L. plana* eggs laid on *Pennisetum* spp. grasses in greenhouse no-choice study

Table 3.4. Mean number of *L. plana* adults present on leaf blades at each check in laboratory choice test

Plant species/ cultivar	Genus representatives			*Pennisetum* spp. only		
	3hrs	27hrs	51hrs	3hrs	27hrs	51hrs
Andropogon virginicus	1.17 bc	0.0 c	0.67 b-d	---	---	---
Calamagrostis acutiflora 'Karl Foerster'	2.83 a	2.5 a	1.17 bc	---	---	---
Cortaderia selloana 'Pumila'	0.33 bc	0.50 c	0.67 b-d	---	---	---
Eragrostis spectabilis	1.17 bc	0.83 bc	0.67 b-d	---	---	---
Festuca glauca 'Select"	0.33 bc	0.50 c	0.5 b-d	---	---	---
Miscanthus sinensis 'Purpurascens'	0.83 bc	0.17 c	0.33 cd	---	---	---
Muhlenbergia capillaris 'Pink Flamingo'	0.33 bc	0.33 c	0.33 cd	---	---	---
Nassella tenuissima	0.0 c	0.0 c	0.0 d	---	---	---
Panicum virgatum 'Heavy Metal'	0.83 bc	0.83 bc	0.67 b-d	---	---	---
Pennisetum alopecuroides	---	---	---	1.33 a-c	1.0 bc	0.17 c
Pennisetum alopecuroides 'Hamelin'	0.67 bc	2.67 a	3.83 a	0.33 c	0.33 c	0.50 bc
Pennisetum alopecuroides 'Moudry'	---	---	---	1.0 a-c	1.67 a-c	0.50 bc
Pennisetum orientale 'Tall Tails'	---	---	---	2.33 ab	1.67 a-c	1.67 bc
Pennisetum setaceum 'Rubrum'	---	---	---	0.83 a-c	1.33 bc	1.67 bc
Phalaris arundacea 'Picta'	1.5 b	1.83 ab	1.5 b	---	---	---
Schizachyrium scoparium	0.83 bc	0.17 c	0.17 cd	---	---	---
Sorghastrum nutans	0.50 bc	0.17 c	0.50 b-d	---	---	---
Spartina bakerii	0.0 c	0.0 c	0.33 cd	---	---	---
# 12 Experimental Hybrid	---	---	---	1.5 a-c	2.67 ab	2.0 a-c
# 17 Experimental Hybrid	---	---	---	0.67 bc	0.67 c	2.17 a-c
# 26 Experimental Hybrid	---	---	---	1.5 a-c	2.0 a-c	2.67 ab
# 10 Experimental Hybrid	---	---	---	2.5 a	1.33 bc	1.83 bc
# 8 Experimental Hybrid	---	---	---	1.5 a-c	3.33 a	4.17 a

CHAPTER 4

SUMMARY

The series of studies herein have further expanded our understanding of the biology and ecology of *Leptodictya plana* Heidemann. In environmental chamber studies, *L. plana* development was only successful at 25 and 30°C. Total developmental time ranged from 23.3 days at 30°C to 40.5 days at 25°C. Egg development was not successful at 10, 15 or 35°C. Base temperature for development of the egg stage was 17.4°C. At 20°C, few nymphs emerged and underwent ecdysis but died shortly after reaching the second instar. In this study, lace bugs were reared on *Pennisetum glaucum* (pearl millet) which is a newly discovered host plant.

We conducted field phenology studies and observed that adults overwintered in thatch on the ground and emerged in the spring when the first new growth of the ornamental grasses appeared. *L. plana* prefers warm, dry climates as is common during the summers in central Georgia. The grasses where *L. plana* was originally observed were experimental *Pennisetum* spp. hybrids. Infestations levels reached their peak in mid-August which correlated with the hottest temperatures in the region. Four generations were completed in Griffin, GA. Damage levels to field grasses averaged approximately 20% among all trials. Intense feeding and defecation from the lace bugs resulted in a significant aesthetic loss to the plants; however, towards the end of the summer as population levels began to decline, grasses were able to outgrow the damage and re-grow fresh, uninjured foliage. Two commercially available ornamental grass standards, 'Prince' and 'Princess', were included in the field trials and the level of

damage inflicted to them was compared to all other trial varieties. The two standards were found to have significantly different levels of damage when compared to the damage inflicted to the grouping of all other trial accessions. During the 2008 and 2009 sampling seasons, ‘Princess’ was more damaged than ‘Prince’. However, differences between years could be based upon a large difference in the amount of precipitation recorded at the site.

We performed no-choice greenhouse experiments investigating the feeding and developmental suitability of thirty-two selections of popular ornamental grasses and sedges. All plants studied received at least minimal feeding damage, however, plants not belonging to the family Poaceae were apparently not acceptable feeding hosts since they resulted in the death of the lace bugs after only one day. *Pennisetum* spp. plants had the highest overall percent damage, and were the only genera that supported oviposition. Additionally, laboratory choice assays were conducted by placing lace bugs in a petri dish with various selections of grasses to feed upon. Feeding activity was checked at 3, 27, and 51 hours after being placed in the dish. At the end of the assay, total damage caused to leaf blades was recorded. As previously observed, *Pennisetum* spp. grasses were highly preferred over all other genera of plants. *Pennisetum alopecuroides* ‘Hamelin’ was the most preferred host plant. The least preferred grass was *Cortaderia selloana* ‘Pumila’.

With such limited literature available on the life history and behavior of this lace bug, these studies greatly expand our knowledge of this emerging pest. These studies widely increase the list of known host plants. Previously, there are no reports of *L. plana* occurring on the species of *Pennisetum* that we found it on. In the greenhouse, it was successfully reared on pearl millet, *Pennisetum glaucum,* and was found naturally infesting *Pennisetum purpureum* hybrids in the field. Therefore, further research should be conducted to reveal even more popular host plants that are at risk of damage by this pest. *L. plana* could pose a substantial economic impact if its distribution spreads further. Thus, *L. plana* should be viewed as an emerging pest and considered as a potentially serious problem.

The specific origins of this lace bug in Georgia are unknown but it is likely that this pest has been sustained in a local population at low levels and took advantage of a large planting of a suitable host material. Now that we know the damaging capabilities of this pest combined with the fact that its habitat is spreading rapidly, there is a greater importance to learn more about this insect. We need to determine how its occurrence might affect the ecology of the region and to determine the most effective ways to manage and control its impact and potential further spread.