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GALLING INSECT DISTRIBUTION ON *Psychotria barbiflora* (RUBIACEAE) IN A FRAGMENT OF ATLANTIC FOREST

DISTRIBUCIÓN DE AGALLAS DE INSECTOS SOBRE *Psychotria barbiflora* (RUBIACEAE) EN UN FRAGMENTO DE UN BOSQUE ATLÁNTICO EN BRASIL

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ABSTRACT

Distribution of a gall-forming Cecidomyiidae within leaves, individuals and populations was studied on *Psychotria barbiflora* (Rubiaceae) in an Atlantic forest remnant at Usina Serra Grande, Alagoas, Brazil. In this study, 345 galled leaves have been collected for gall characterization and analysis of gall patterns. The number of galls per galled leaf varied from 1 to 100. The galling herbivore oviposited on the leaf veins at the basal region of the abaxial epidermis. The Cecidomyiidae seemed to prefer young foliage located in the apex of shoots. Total number of leaves was positively correlated to plant height while individual leaf damage was negatively correlated with height showing that crown complexity and density does not affect the rate of attack by the gall inducing insect. From the 213 plants surveyed, 93 contained galls (43.7 %). Spatial density of host plant did not affect the individual leaf damage. The observed pattern of gall distribution may be due to strategies of the insect in a way to optimize gall nutrition.

Key words: Atlantic forest, Cecidomyiidae, herbivory, gall midges, gall makers, Neotropical, trophic interactions

RESUMEN

Se estudió la distribución de un Cecidomyiidae formador de agallas en las hojas, individuos y poblaciones de Psychotria barbiflora (Rubiaceae) en un fragmento de un bosque atlántico en Usina Serra Grande, Alagoas, Brasil. Se colectaron 345 hojas para caracterizar las agallas y analizar su patrón de distribución. El número de agallas por hoja infectada varió entre 1 y 100. La oviposición del insecto se produjo sobre las venas de la hoja en la región basal de la epidermis abaxial. El cecidomyiidae pareció preferir las hojas jóvenes ubicadas en el ápice de los brotes. El número total de hojas se correlacionó positivamente con la altura de las plantas, en tanto que el daño individual de las hojas se correlacionó negativamente, demostrando que la complejidad de los aglomerados y la densidad no afectan la tasa de ataque del insecto formador de agallas. De 213 plantas evaluadas, 93 tenían agallas (43.7%). La densidad espacial de la planta hospedera no afectó el daño individual de la hoja. El patrón observado de la distribución de agallas pudo ser debido a las estrategias del insecto para optimizar la nutrición de las agallas.

Palabras clave: Bosque Atlántico, Cecidomyiidae, herbívoria, mosquitos de agallas, formadores de agallas, interacciones tróficas.

INTRODUCTION

Studies on plant-herbivore interactions increased considerably in the last decades, especially those concerning insect-host plant systems (Faria and Fernandes 2001). A large number of hypotheses concerning the choice of the host plant and/or oviposition site by the insect herbivore have been generated (Leather 1985, Dodge *et al*. 1990, Ferguson *et al.* 1991). For insects which have a short mobile stage and do not change location after oviposition choice, such as galling insects, it appears that colonization of specific leaves or shoots within host is important, since not all plant parts can respond adequately to the insect attack (Whitham 1980, Burstein and Wool 1993). It has been assumed that natural selection would increase the preferential oviposition of insects during the co-evolution of plants and herbivore (Thompson 1988). Indeed, many studies suggest that the choice of oviposition sites by gall formers play a fundamental role for the development and survival of larvae within a population of host plants, or within an individual in that population (Whitham 1980, 1983, Denno and McClure 1983, Preszler and Price 1988, Craig *et al*. 1989, Fernandes and Price 1991) and even within a single leaf (Zucher 1982).

Burstein and Wool (1993) argued that an insect should be able to evaluate the quality of potential host or site. Host selection has been demonstrated experimentally in many studies (Leather 1985, Craig *et al.* 1989, Fritz and Nobel 1989, Roininen and Tahvanainen 1989). These choices can be made by the galling female so as to maximize the nutrition of the larvae during its development (Mani 1964, Rohfritsh 1992) or to minimize microclimatic conditions stress (Edward and Wratten 1980). Some other factors could also influence host selection, such as chemical defence (Bryant *et al*. 1983, Coley *et al*. 1985) or vigour of the plant module (Price 1991). A review of the hypotheses on the adaptive nature at galls is presented by Price *et al*. (1998). The degree of complexity in host architecture (plant height, number of shoots and leaves and crown volume) is also known to influence directly the diversity and density of phytophagous insects (Lawton 1983, Strong *et al.* 1984, Dansa and Rocha 1992, Collevatti and Sperber 1997, Vrcibradic *et al.* 2000), including galling insects (Espirito-Santo *et al*. 2007). Host plant spatial distribution could also influence the abundance of galls within a single individual (see Aber and Melillo 2001).

Psychotria barbiflora (Rubiaceae) is a shade-tolerant perennial shrub widely found in the Atlantic rain forests in northeast Brazil. Many insects are associated with *P. barbiflora*, including ants (Ribeiro *et al*. 1999) and gall inducing insects. In the present study, some morphological and ecological aspects of a gall inducing insects on *P. barbiflora* were described. Moreover, we studied the distribution of its galling insects by analyzing the patterns of gall distribution at the individual and leaf levels.

METHODS

Study Area

The study was conducted in a fragment of 3500 ha Atlantic forest in Alagoas State, north-eastern Brazil, from January to April 2005. The area contains variable levels of regeneration due to successive human disturbance and is located in a sugar-cane farm, “Usina Serra Grande” (08°30’S, 35°50’W). The annual rainfall is 1200 mm, with the wettest period between May and August, and the temperature is around 23 °C over the year (IBGE 1985).

We collected 345 galled leaves of *Psychotria barbiflora*. Samples were placed in numbered plastic bags and taken to the laboratory for counts of galls. Galls were after dissected to determine the status of the galling larvae (mortality factors and survive). Dissection and observations were done on a microscope (Leica Galen III).

The spatial distribution of galls at the leaf level was studied in three ways. First, we determined gall distribution at the leaf blade level, i.e., adaxial or abaxial epidermis. The differential distribution of galls between leaf lamina was tested by the G-test. Secondly, we counted the number of galls formed on the central vein, secondary vein and leaf lamina. Some leaves presented a high gall density that did not allow the determination the exact position where the galls were induced. Hence, only a sample of two hundred leaves was used in this analysis. Kruskal-Wallis test was used for statistical analysis of gall distribution between veins and leaf lamina. Thirdly, from another sub-sample of two hundred leaves, a count of whether the galls form on the apical, central or basal sections of the leaf was done. Each leaf was divided into three sections of equal length and a count of galls on each was made. Statistical analysis was realized by the Kruskal-Wallis test.

To evaluate host species distribution and galling

Figure 1. The leaf of *Psychotria barbiflora* (Rubiaceae) galled by midges (Diptera: Cecidomyiidae) in north-eastern Brazil. Bar = 1 cm.

insect distribution, ten transects of 50 m were conducted in the field. Along each transect, all individuals of the *P. barbiflora* species were examined for height (cm), total leaf bore and number of galled leaves. For each galled leaf, a position index was established to determine whether the galls were formed on apical leaves or on basal leaves. Differences in galled position on plant leaf were tested using Kruskal-Wallis test.

For each individual plant affected by the gall former insect an index of damage was estimated by dividing the number of galled leaves by total number of leaves. From these results, non-linear regressions were performed between height and total leaves and between height and index of individual damage. The regression between height and total leaves were performed using polynomial regression. For the regression between height and individual leaf damage, a log mathematical transformation of data was done to obtain linearity for statistical analysis. Only plants that containing galls were considered here for both regression analyses.

For all individuals, the distance from transect start point, has been made to determine an index of density of individuals. Each transect was divided in to five sections of 10 m x 10 m offering areas of 0.01 ha in which the number of individuals and the index of leaf damage per individual was recorded. The densities of individuals were classified into four density groups: 0 to 5, 5 to 10, 10 to 15 and more than 15 individuals per area. A Kruskal-Wallis test was performed to analyze the differences in each group in terms of leaf damage.

RESULTS

The galls of *Psychotria barbiflora* are conic, pale green, glabrous and occur on both leaf surfaces and petioles. Each gall possesses only one larval chamber perpendicularly localized on the leaf (Figure 1). The gall is induced by a still not described species of Cecidomyiidae (Diptera).

The number of galls on abaxial and adaxial faces of the leaf differed significantly ($p < 0.05$), more galls were found on the abaxial face (Table 1). Evidences of preferential gall development on leaf veins was also revealed (Table 1); most galls developed on the leaf veins, while fewer galls developed on the leaf lamina. Otherwise, no difference between the number of galls developed on central and secondary veins was detected ($p > 0.05$). Most galls were found on the basal region of the leaf, followed by the median region and finally the apical region ($p < 0.05$; Table 1).

At the plant level, most galls were found on the apical leaves (1.37 ± 0,13) compared to the more basal (0.46 ± 0,08) and middle (0.14 ± 0.04) ones (Table 2). On the other hand, no statistically significant difference was found in the number of galls between middle and basal leaves of a given individual. There was a significant positive regression between height of an individual and total leaf ($r^2 = 0.69$; $p < 0.05$) showing that the total leaf bearded follows a quadratic regression with the height of a plant (Figure 2a). From the 213 plants surveyed, 93 contained galls (43.7 %). The index of leaf damage on an individual decreased with the height of the host plant ($r^2 = 0.53$, $p < 0.001$;

Table 1. Distribution of galls on a) abaxial and adaxial epidermis (n= 345), b) central vein, secondary vein and leaf blade (n=200), and c) in the one leaf section (n=200) of *Psychotria barbiflora* (Rubiacea) in North-eastern Brazil. Mean values identified with the same letters are not significant different (G-test for epidermis, p< 0.05 ; Kruskal-Wallis for leaf veins and leaf section, p< 0.05).

Epidermis		**Leaf veins**			**Leaf section**		
abaxial	adaxial	central	secondary	leaf blade	apical	median	basal
13.1±1.1a	1.3±0.1b	2.8±0.3a	2.3±0.2a	1.4±0.2b	1.1±0.2c	4.2±0.2b	5.7±0.5a

Table 2. Preferential oviposition of the gall maker (Diptera: Cecidomyiidae) related of leaves position (apical, middle and basal leaves) on plant *Psychotria barbiflora* (Rubiacea) (n = 93) in Northeastern Brazil. Mean values identified with the same letters are not significant different (Kruskal-Wallis, p< 0.05).

Apical	**Middle**	**Basal**
1.37±0.13a	0.46±0.08b	0.14±0.04b

Figure 2b). There was no-significant difference (p = 0.75) between leaf damage and class densities of individuals (Table 3)

DISCUSSION

We found a preferential oviposition for leaf epidermis. Ten fold more galls were found on the abaxial epidermis of *P. barbiflora* leaves. The same results were obtained in a study on *Miconia prasina* (Melastomataceae), showing a preferential oviposition for the abaxial face (Silva 2002). Edward and Wratten (1980) explained the preference for inferior epidermis of *Guarea macrophylla subsp. tuberculata* by the less stressing microclimatic condition of inferior face than superior face that is subject to direct sun light.

The results showed that the occurrence of gall formation is highest on leaf veins than on leaf blade. A similar trend was obtained to *G. macrophylla* subsp. *tuberculata* with a marked preference of the galling insect for principal and secondary veins (Kraus *et al*. 1996). This preference from the inductor insect can be related to nutrition of galls, since the xylem and phloem elements are localized in leaf veins (Mani 1964, Rohfritsh 1992). Fernandes and Price (1991) showed that the choice of the ideal site for oviposition is important for gall growth and then reproductive success. Tavares (1921) in his study of gall morphology of plants from Neotropical regions indicates that the choice of leaf veins is ideal, since the eggs and larvae may be subject to desiccation and starvation in their development. The idea is then to choose the best site to exert oviposition that would increase the survivorship of the next generation.

The distribution of galls appeared to be higher in the basal region than in the two other regions and there are more galls in the median than in the apical region. This preferential oviposition for the basal part of the leaf can be associated with single-leaf variation in the concentration of herbivore inhibitors, since chemical defences against pests are known to influence host selection by the herbivores (Bryant *et al.* 1983; Coley *et al.* 1985). Indeed, Whitman (1983) found a positive relationship between the position on leaf and phenolic concentration, showing that the toxicity increase linearly from the basal to the apical section.

Our data are indicative that apical leaves of an individual are more prone to be attacked by galling

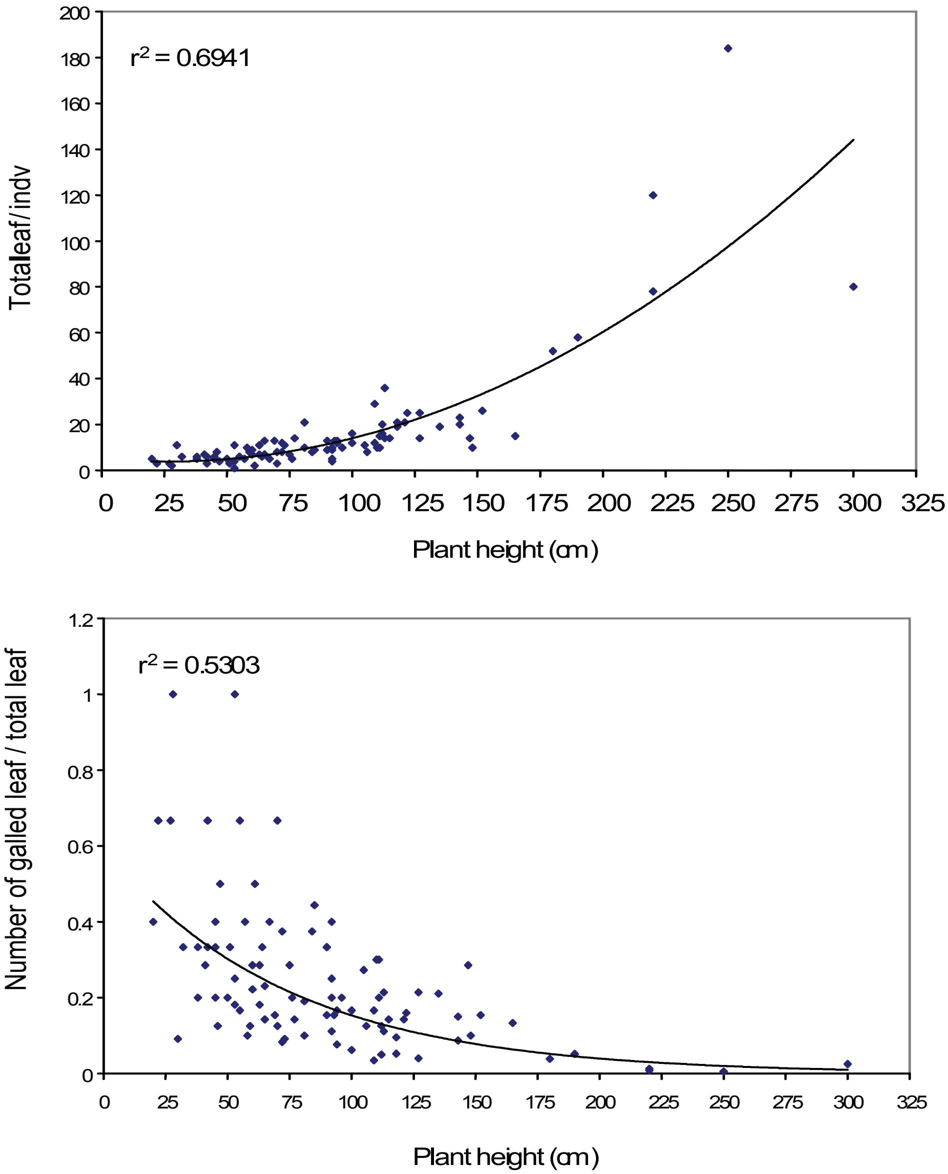

Figure 2. Non-linear regression between plant height (cm) and: a) total leaf / individual ($Y = ax^2 + bx + c$; $r^2 = 0.69$; $p < 0.001$). b) and index of leaf damage per individual (number of galled leaf / total leaf) ($Y= a^{-x} + b$: $r^2 = 0.53$; $p< 0.001$), *Psychotria barbiflora* (Rubiaceae) in Northeastern Brazil.

female insect than leaves located in most inferior levels on the shoot. This observation probably is due to the plant structure stimulate apical growth. Young foliage presents advantages for galling insects. First of all, the amount of qualitative and quantitative defences is low in young foliage (Coley *et al.* 1985). Indeed, the cuticle of young foliage is usually thinner and could permit an easier oviposition. Secondary compounds are also less present in young foliage (Hartley and Jones 1997). Young foliage contrary to old ones presents increasing rates of carbon gain and tends to be more vigorous (Larcher 1983). The choice of a leaf that confers a better nutrition state would then be an appropriated strategy for the insect female (Mani 1964).

Vrcibradic *et al.* (2000) found that relative intensity of galling on host plants and leaves

Table 3. Plant density classes and mean of individual leaf damage of *Psychotria barbiflora* (Rubiacea) in North-eastern Brazil. Mean values identified with the same letters are not significant different (Kruskal-Wallis, $p< 0.05$).

Density classes (n/0.01 ha)	Plant leaf damage (galled leaves/total leaves)	Plant (n)
≥5	0.071 ± 0.021 a	14
5≤10	0.093 ± 0.022 a	8
10≤15	0.099 ± 0.032 a	3
15<	0.079 ± 0.004 a	5

tended to decrease with plant height and structural complexity, indicating that smaller plants would be more intensely used by the gall maker. This result can be explained by the fact that older plants, taller individuals, bear more leaves that would suffer of abscission. In fact, Aber and Melillo (2001) indicate that short-lived shoots are less likely to be found and attacked by herbivores. Moreover, it is known that galling insects usually prefer undifferentiated meristematic tissues as oviposition sites than older sites (Mani 1964; Fritz *et al.* 1987; Price *et al.* 1987 a, b).

The results showed that there is no difference in terms of individual leaf damage between aggregated and isolated individuals. This observation supposes that the spatial density of host plant does not influence the intensity of the Cecidomyiidae insect. Vrcibradic *et al.* (2000) also found that the proportion of galled plants did not differ between isolated individuals and individuals in patches. This can be explained by usual galling insect behaviour that have a short mobile stage and do not change location once settled (Burstein and Wool 1993). The host plant population density would then be "invisible" for the gall maker. In this study, a few density classes presented a low effective, analysis of larger samples and more information on this peculiar Cecidomyiidae behavior could help to clarify this result.

In conclusion, preferential oviposition appeared to happen in this peculiar interaction between *P. barbiflora* and the gallmaker (Cecidomyiidae, Diptera). Preferential oviposition could be a strategy to avoid microclimatic stress and secondary compounds. In another point of view, the insect could choose to ovipositate on a site that would permit an easier oviposition or that would confer a better nutrition of the future gall. Finally, it seems that there is no "density-dependences effects" of the phytophagous insect in this study. Others investigations on surviving rates of larva contained in the galls and success of reproduction should be done to obtain more precise conclusions.

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