ARE ASSOCIATIONS OF ENDOPHAGOUS INSECTS AND *CAPITULA* OF ASTERACEAE SPECIES ENHANCED BY RESOURCE AVAILABILITY? A CASE STUDY OF COASTAL DUNES ENVIRONMENT

A.L. Lemes - Silva [1,2]

M.G. Bender[1,3]; G. A. Müller[6]; B. C. Lopes[1,4]; T.T. Castellani [1,5]

[1] Universidade Federal de Santa Catarina, Centro de Ciências Biológicas, Departamento de Ecologia e Zoologia, Campus Universitário Trindade, Florianópolis, 88040 - 900, Santa Catarina, Brasil. [2] Laboratório de Ecologia de Águas Continentais - Universidade Federal de Santa Catarina

Contato: luizalemes@yahoo.com.br

[3] Laboratório de Ecologia Humana e Etnobotânica - Universidade Federal de Santa Catarina

[4]Laboratório de Ecologia Vegetal - Universidade Federal de Santa Catarina

[5]Laboratório de Biologia de Formigas - Universidade Federal de Santa Catarina

[6]Universidade Federal do Paraná, Departamento de Zoologia, Programa de Pós - Graduação de Entomologia

INTRODUCTION

The Asteraceae family is one of the greatest groups of flowering plants which occur in temperate, subtropical and tropical regions, predominantly in grasslands and mountains when compared to forested areas (7; 13). The inflorescence of Asteraceae species-the *capitulum*-is composed of numerous florets sharing a single receptacle, which is surrounded by bracts. *Capitula* are an evident attribute of Asteraceae species, and its unique morphology act as food resource and microhabitat, attracting a diverse and rich fauna of endophagous insects (1; 24). Endophagous insects feed on internal parts of its host plants and can be gall makers, borers or miners, and are especially diverse and frequent in Asteracean flower heads (1). Endophagous insects associated to Asteraceae *capitula* in Brazil account at least 120 species and belong mainly to three distinct Diptera families (Agromyzidae, Cecidomyiidae and Tephritidae) and four Lepidoptera families (Gelechiidae, Pterophoridae, Pyralidae and Tortricidae) (15).

Endophagous insects show high host fidelity (10) and consequently are likely to be strongly influenced by changes in host - plant abundance (29). Resource abundance, measured as the abundance of individual plants or as plant biomass, for instance, represents an important feature affecting herbivores insect community structure (11). Therefore, host plants with greater biomass can attract and support more species and greater abundances of individuals. Plant species that occur in higher densities-resource concentration hypothesis-are more likely to be found by insect herbivores (24). Nonetheless, species richness is not always correlated to plant density (18).

Attributes such as plant size and architecture also influence the number of associated herbivores (26), such as endophagous insects. The plant species of more complex architecture and larger sizes might support more species of insects than do smaller, architecturally simple ones (8). However, the possible effects of size upon diversity are hard to evaluate once other factors such as life stage, phenology, architecture and density correlate with size (17).

Moreover, records of endophagous insects associated to their host plants are important once they represent community biodiversity (16; 17) as well as trophic structure (1). Thus, investigations of herbivores, such as endophagous insect species, are a key to our understanding of trophic relations of insects and plant communities.

The Asteraceae species *Noticastrum malmei* Zardini and *Senecio crassiflorus* (Poir.) occur in the investigated restinga vegetation and previous field surveys indicated the potential use of these species by endophagous insects. *S. Crassiflorus* is an herbaceous perennial, prostrate species restricted to coastal sand dunes and beaches of the Southwerstern Atlantic coastline, from Santa Catarina, Brazil to Argentina (3). It is distributed along the sea - continent gradient (5), especially concentrated the foredune (11).The species *N. Malmei* also presents herbaceous prostrate species, with higher abundance on interior dunes and dry slacks (11).

OBJECTIVES

Our intentions were: (1) to assess the existence of endophagous insects associated to these co - occurring Asteraceae species from Joaquina beach restinga; (2) identify the emergent insect families from rearing; (3) investigate if endophagous fauna abundance and richness are correlated to resource availability (measured as biomass and *capitulum* size of *N. Malmei* and *S. Crassiflorus*) and (4) discuss the possible differences of endophagous insect abundance in relation to plant species distribution pattern at the investigated site.

MATERIAL AND METHODS

Field sampling and insect rearing. In the Southwestern part of Santa Catarina Island lies Joaquina beach (27º36'40"S, 48º27'10"W) where our surveys for *Noticastrum malmei* e *Senecio crassiflorus capitula* were conducted. The coastline of Joaquina beach is 3km long and comprises sand hills covered by herbaceous and arborescent vegetation-trees, shrubs-as well as permanent lakes surrounded by small dunes (4). Climate in the area is categorized as humid mesotermic, with no drier season and mean annual precipitation of 1521mm (23). Monthly mean temperature in the summer is 24^0C and in the winter 17^0C. Winds blow predominantly from the south and north quadrants.
Field trips for *N. Malmei* and *S. crassiflorus* heads sampling were conducted from September to November (2008), the main flowering period of Asteraceae in Santa Catarina region. Moreover, the species *S. crassiflorus* presents a very short flowering period (6) that requested concentrated field work. Sampling of *S. crassiflorus* covered mainly the foredune of the shore (15-20m), where this species is more frequent (11). However, *N. malmei* individuals seem to be spatially separated from *S. crassiflorus*, and were sampled in a distance from the seashore (20-40m), mainly on interior dunes where the species is apparently numerous protected from the ocean wind and water dynamics.
For the present purpose, we define a sample as a group of flowerheads sampled from a population-*N. Malmei* and *S. Crassiflorus*-in each sampling period. *Capitulum* were sampled in two different periods (September 22nd and November 6th), adding up 80 capitula of each species (30 from our first sample, 50 from the second). Flower heads were allocated into plastic bags and transferred to our laboratory facilities. In the laboratory, inflorescences were separately kept in plastic containers of 25 ml, covered by a mesh lid in order to allow the air flow and to prevent endophagous fauna from escaping. Samples were checked every two days for the presence of adult emerging insects. Emerged adults were sedated with ether to facilitate manipulation and kept individually in ethanol (70%) for further identification.
Species identification. Emerged adults were identified using descriptions of (2) and (19). Specimens were deposited in Laboratório de Ecologia de Águas Continentais, Departamento de Ecologia e Zoologia, Universidade Federal de Santa Catarina. All specimens could not readily be identified to more than family level.
Resource measurement. Once inflorescences were accounted as a resource available to endophagous insects, flowerheads diameter was used as a measurement of resource offered. A digital paquimeter (Digimess, 150mm) was applied to measure *capitulum* size briefly following field sampling. After insect emerging, *N. Malmei* e *S. Crassiflorus* flowers-except the bracts enclosing the inflorescence and the receptacle disc-were dehydrated in a greenhouse (60^0C) for 48hrs. Afterwards, flowers dry weight values were determined through an electronic balance (AL500 MARTE). These values were utilized as a biomass measurement of each sampled inflorescence.
Data analyses. Shapiro - Wilk test was conducted to test for data normality. We applied the Student's T - test ($p < 0,05$), for parametric distributed data, in comparisons of resource availability-biomass and inflorescence diameter-and abundance of emerged adults between both Asteraceae species. Comparisons were also performed for different samples of the same species. In order to test our hypothesis of the possible association between endophagous insect number/richness and resource availability, we performed a Pearson correlation test. Data utilized to correlation testing were flowerheads diameter and number of emerged adults. Data statistical analyses were conducted with Statistica (versão 7.0) software.

RESULTS AND DISCUSSION

A total of 322 individuals were reared from 160 flowerheads of *N. malmei* (80 *capitula*) e *S. crassiflorus* (80 *capitula*). Among insects reared, those from the family Ulidiidae (Diptera) were the most abundant (63.4%), followed by Cecidomyiidae (Diptera) (36.6%). The picture - winged flies (Ulidiidae) are a diverse and large cosmopolitan family, which larvae are typically scavengers. Though, a few are phytophagous larvae and some (Otitinae) have been found associated to inflorescences (25).
This new record of Ulidiidae endophages associated to Asteraceae flowerheads represents the addition of data to this field of research, once Diptera species associated to Brazilian Asteraceae inflorescences are mainly those from Agromyzidae, Cecidomyiidae and Tephritidae families (16). The family Cecidomyiidae is one of the largest of the Diptera. Many larvae are gall makers, inducing galls on various plants, whilst some live free in flower heads or in the stems of plants without forming galls (27). The greatest mean of insects emerged from *S. crassiflorus* flowerheads reared (mean ± standard deviation) (x=3,45 ±3,05 individuals) while *N. malmei*endophage per *capitulum* average was 0,35 (x=0,35 ±0,76) individuals. This difference of endophagous insects/flowerhead between species is significant (t=7,1; p=0,0001). The higher occurrence of endophages associated to *S. crassiflorus* inflorescences could be explained by greater resource availability-biomass and *capitulum* diameter-of this Asteraceae species. Biomass (g) and diameter (mm) of *S. crassiflorus* flower heads were higher when compared to *N. Malmei* inflorescences. Mean biomass for *S. crassiflorus* was 0,153g (±0,051) against 0,047g (±0,018) for *N. malmei* flower heads (t=15,3; p=0,0003). *Capitulum* mean diameter was also greater in *S. crassiflorus* (x=10,93 ±1,68mm) than for *N. malmei* inflorescences (x=7,21 ±0,76mm), and this difference is also significant (t=12,9; p=0,0001).

Endophage abundance relationship with Asteraceae species studied are moderately correlated to flowerheads size (mm) (n=100, r=0,42; p=0.0001), and biomass (g) (n= 160, r=0,45; p=0.0001), i. e., larger, of greater biomass *capitula* may have the potential to support greater insect abundance. The obtained r (Pearson correlation) value could be a result of undersized field sampling. Herbivore insect's abundance and richness in their host plants vary frequently (13) and this variability is usually assigned to host plant phenotypical distinctions (28). The factors influencing on the abundance of herbivore insects have been the core of herbivore - plant theories (21). A frequent pattern correlates higher herbivory to larger and denser host plant populations (22). The plant architecture Hypothesis (14; 15) suggests that larger and more complex plants sustain greater herbivore populations, especially due to its structural complexity. Moreover, *capitula* have been regarded as an advance and key ecological feature behind the diversification success of the Asteraceae family (7). A tri - trophic approach to plant and herbivorous interactions (flowerheads-endophages-parasitoids) revealed that defense against parasitoids might be another pressure of endophagous insects upon larger *capitula* (9).

The Asteraceae species studied, *N. malmei* and *S. crassiflorus*, have distinct distribution pattern at the investigated coastal dune site. *S. crassiflorus* population is mostly concentrated in the frontal dunes whilst *N. malmei* presents higher abundance on interior dunes (11). In addition to inflorescence size and biomass, host plant distribution pattern (isolated or aggregated) could be affecting endophagous abundance on this Asteraceae species, leading to greater oviposition in *S. crassiflorus* instead of *N. malmei*. Patch size and its influence upon the colonization of *Praxelis clematidea* Asteracea) by flies has also been investigated (20) and the abundance of Tephritidae, for instance, increased with experimental patch size.

CONCLUSION

A number of theories have been developed on attempt to explain the possible laws that guide herbivore and its host plants associations such as resource availability, plant architecture, host plant distribution pattern Hypothesis. We found differences on the associations of endophagous insects (Cecidomyiidae and Ulidiidae families) to the Asteraceae species *N. Malmei* and *S. Crassiflorus* of the investigated site, and these distinctions could be related to *S. Crassiflorus capitulum* size and aggregated plant distribution. However, a longer and intensive field sampling period is required in order to confirm our hypothesis, especially because *S. Crassiflorus* short and intense 16 week flowering period (6) could influence upon endophage attraction. Moreover, studies focusing on attributes of flower architecture and complexity, as well as resource quality should be conducted to allow our understanding of this plant-herbivore interaction.

REFERENCES

1 - Almeida, A.M., Fonseca, C.R., Prado, P.I., Almeida - Neto, M., Diniz, S., Kubota, U., Braun, M.R., Raimundo, R.L.G., Anjos, L.A., Mendonça, T.G., Futada, S.M., Lewinsohn, T.M. Assemblages of endophagous insects on Asteraceae in São Paulo Cerrados. *Neotrop. Entomol.,* 35: 458 - 468, 2006.

2 - Borror, D.J. & Delong, D.M. *Introdução ao estudo dos insetos.* Edgard Blücher, São Paulo, 1988, 653p.

3 - Cabrera, A.L., Klein, R.M. "Compostas - Tribo: Senecioneae". In: Reitz, P.R. *Flora Ilustrada Catarinense.* Herbário Barbosa Rodrigues, Itajaí, 1975, p.126–222.

4 - Castellani, T.T., Vieira, S., Scherer, K.Z. Contribuição ao conhecimento da distribuição espacial de *Paepalanthus polyanthus* (Bong.) Kunth (Eriocaulaceae) em áreas de baixada úmida de dunas. *Acta Bot. Bras.,* 1: 25 - 36, 1996.

5 - Cordazzo, C.V., Seeliger, U. Zoned habitats of Southern Brazilian coastal foredunes. *J. Coastal Res.*, 9: 317 - 323, 1993.

6 - Cordazzo, C.V. Biologia de *Senecio crassiflorus* (Poir.) DC. nas dunas costeiras no sul do Brasil. I. Características reprodutivas. *Anais do IV Simpósio de Ecossistemas Brasileiros*, Águas de Lindóia, SP. 1998, p.92 - 96.

7 - Cronquist, A. *An integrated system of classification of flowering plants.* Columbia University Press, New York, 1981, 1262p.

8 - Cytrynowicz, M. Resource size and predictability, and local herbivore richness in a subtropical Brazilian Cerrado community. In: Price, P.W., Lewinsohn, T.M., Fernandes, G.W., Benson, W.W. (eds.). *Plant–Animal Interaction: Evolutionary Ecology in Subtropical and Temperate Regions.* John Wiley and Sons, New York, 1991, p.561 - 589.

9 - Dias, A.T.C. Efeito da disponibilidade de recurso em um sistema com três níveis tróficos. Instituto de Biologia, SP, UNICAMP. 2003, 63p.

10 - Gaston, K. J., Reavey, D., Valladares, G.R. Intimacy and fidelity: internal and external feeding by the British Microlepidoptera. *Ecol. Entomol.* 17: 86 - 88, 1992.

11 - Guimarães, T. B. Florística e fenologia reprodutiva de plantas vasculares na restinga do Parque Municipal das Dunas da Lagoa da Conceição, Florianópolis, SC. Departamento de Botânica, SC, UFSC. 2006, 102p.

12 - Hunter, M.D., Ohgushi, T., Price, P.W. *Effects of resource distribution on animal - plant interactions.* Academic Press, San Diego, California, 1992, 505p.

13 - Judd, W.S., Campbell, C.S., Kellogg, E.A., Stevens, P.F. *Plant systematics: A phylogenetics approach.* Sinauer Associates Inc. Publishers, Sunderland, 1999, 464p.

14 - Lawton, J. H. Plant architecture and the diversity of phytophagous insects. *Ann. Rev. Entomol.,* 28: 23 - 39, 1983.

15 - Lawton, J.H., Price, P.W. Species richness of parasites on hosts: agromyzid flies on the British Umbelliferae. *J. Anim. Ecol.,* 48: 619 - 637, 1979.

16 - Lewinsohn, T.M. Insects in flower heads of Asteraceae in Southeast Brazil: a tropical case study on species richness. In: Price, P.W., Lewinsohn, T.M., Fernandes, G.W.,

Benson, W.W.(eds.). Plant - animal interactions: Evolutionary ecology in tropical and temperate regions. Wiley/Interscience, New York, 1991, p.525 - 560.

17 - Lewinsohn, T.M., Novotny, V., Basset,Y. Insects on plants: Diversity of herbivore assemblages revisited. *Annu. Rev. Ecol. Syst.,* 36: 597 - 620, 2005.

18 - Marques, E.S.A.; Price, P.W., Cobb, N.S. Resource abundance and insect herbivore diversity on woody Fabaceous desert plants. *Environ. Entomol.,* 29: 696 - 703, 2000.

19 - McAlpine, J.F. Morphology and terminology-adults. In: McAlpine, J.F., Peterson, B.V., Shewell, G.E., Teskey, H.J., Vockeroth, J.R., Wood, D.M. (eds.). *Manual of Neactic Diptera.* Monograph of the Biosystematics Research Centre, Agriculture Canada, Ottawa, 1981, p.9 - 63.

20 - Ortiz, J.V.C. Respostas de dipteros endófagos de capitulos de *Praxelis clematidea* (Grisebach) King & Robinson (Eupatorieae - Asteraceae) a concentração de recurso e ao isolamento entre plantas. Instituto de Biologia, SP, UNICAMP. 1997, 57p.

21 - Price, P. W. The plant vigor hypothesis and herbivore attack. *Oikos,* 2: 244 - 251, 1991.

22 - Root, R.B. Organization of plant - arthropod association in simple and diverse habitat: the fauna of collards *(Brassica oleraceae) . Ecol. Monogr.,* 43: 95 - 124, 1973.

23 - Santos, C.R., Horn Filho, N.O., Castellani, T.T. Estudo geológico e ambiental da Praia da Joaquina, In: Absalão, R.S., Esteves, A.M. (eds.). *Oecol. Bras.,* Ecologia de praias arenosas do litoral brasileiro. Editora da UFRJ, Rio de Janeiro, 1997, p.259 - 270.

24 - Southwood, T.R.E. The insect/plant relationship-an evolutionary perspective. In: H.F.Van Emden (eds.). *Insect/Plant relationships.*Blackwell Publishers, Oxford, 1973, 215p.

25 - Steyskal, G.C. The genera of Platystomatidae and Otitidae known to occur in America North of Mexico (Diptera, Acalyptratae). *Ann. Entomol. Soc.* 54: 401 - 410, 1961

26 - Strong, D.R.Jr., Lawton, J.H., Southwood, T.R.E. *Insects on Plants: Community Patterns and Mechanisms.* Blackwell Publishers, Oxford, 1984, 313p.

27 - Weems, H.V.Jr. *Division of Plant Industry.* Florida Department of Agriculture and Consumer. Services, Gainesville, Florida,USA, 2006.

28 - Woods, J. O., Carr, T.G., Price, P.W., Stevens, L.E., Cobb, N.S. Growth of coyote willow and the attack and survival of a mid - rib galling sawfly, *Euura* sp. *Oecologia,* 6: 714 - 722, 1996.

29 - Wright, M.G., Samways, M.J. Plant characteristics determine insect borer assemblages on Protea species in the Cape Fynbos, and importance for conservation management. *Biodivers. Conserv.,* 8: 1089–1100, 1999.