Herbarium insect pests of the Palermo botanical garden and focus on the use of semiochemicals for control *Lasioderma serricorne* F. (Coleoptera: Anobiidae)

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Abstract

The herbaria are not only a scientific tool of great importance by preserving extinct, rare, endemic, and common plant species but also have importance as Cultural Heritage for their historical and aesthetical value. Herbaria can be infested by several insect pests feeding on dried plants, and their management it is often complicate and difficult although with chemical insecticides which can have negative drawbacks. This suggests a strong need of new alternative control tools such as the use of semiochemicals to develop an Integrated Pest Management (IPM) of pests in the herbaria. A survey of the entomological infestation of the Herbarium and its *exsiccata* of the Palermo Botanical Garden's Herbarium, one of the largest in the world, was carried out in order to identify the main taxa that determine the major damages. Several insects caused the damages on the *exsiccata*, but *Lasioderma serricorne* was the key pest of the herbarium. Consequently, experiments were conducted to evaluate and optimize the use of semiochemicals for monitoring and mass trapping *L. serricorne*. Different sex pheromone releasers (polyethylene tubes and patch types) were evaluated for their efficacy in terms of emission and insect captures. A food attractant, the *Capsicum annum* dried fruits powder, was also evaluated as synergist of the pheromone in the traps to evaluate it as mass trapping tool. Results indicated that polyethylene tubes determined a pheromone emission more constant with time and in parallel a higher number of insect catches in comparison with patch type releasers. Moreover, the use of *C. annum* fruit powder in the pheromone traps determined a significant increase of catches compared with the traps loaded with pheromone alone, suggesting the possibility to use this tool for mass trapping *L. serricorne* in the herbaria.

1. Introduction

Herbarium collections represent an enormous sampling of world flora and are a tool for studying biodiversity, consulting and disseminating botanical, cultural, herbal and food uses and traditions (Bebber et al., 2010; Gillespie and Gillespie, 2016; McAllister et al., 2018). There are 3095 active herbaria in the world, containing 387,513,053 botanical specimens (Thiers, 2019). The word "herbarium" combines two different definitions, albeit conceptually and historically linked to each other: firstly, a compendium that describes the vegetable kingdom (herbarium or *hortus siccus*); secondly, a building that host one or more collections of dry plant samples called *exsiccata* (Moggi, 2012a). Herbarium collections preserve extinct, rare, endemic, and common plant species. The herbaria are scientific tool of great importance. When a new species is described, specimens of this plant, the *types*, are deposited in a herbarium and serve as reference for the identification of this species. Comparison with herbarium specimens or types allows confirming the species identification. Their proper conservation is important also in the perspective of further studies thanks to the new biomolecular techniques based on DNA investigations (Moggi, 2012c; Pezzella, 1993, Mossetti, 1990, Bini Maleci et al., 1993).

For all the above reasons the herbaria have not only a historical-scientific value but also importance as real Cultural Heritage (Amadei et al., 2007, Martellos et al., 2012; Harrison, 2015; McAllister et al 2018). In fact besides of their role as information botanical sources, the herbaria have been transformed into cultural heritage, testimony to the history of discovery and expansion of society in its territory, similarly to other natural heritages (Martellos et al., 2011; Isolani et al., 2012; Manachini et al., 2013; Piccinini et al., 2016; Walther 2018).

The Palermo Botanical Garden's Herbarium (hereafter named PAL as in the Index Herbariorum, Thiers, 2018), also known as *Herbarium Mediterraneum Panormitanum,* was founded at the beginning of the 18th century. PAL is part of the Botanical Garden (Fig. 1a) and attracts many visitors all year round. Its collections (vascular plants, ferns, mosses, liverworts, algae, fungi and lichens) come from Sicily (Italy) as well as many other parts of the world, including Australia, Africa, Central and South America, and Europe. PAL contains an interesting collection of dried fruits (Carpoteca), seeds (Spermoteca), wood samples (Xiloteca), and numerous fruits preserved in alcohol, dating back to the early 20th century**.** PAL contains over 600,000 *exsiccata* specimens. A large number of the *exsiccata* were donated in 2008 by the famous botanist Prof. W. Greuter, ex Director of Botanical Garden of Berlin (Germany) to the University of Palermo. Greuter's *herbarium* (Fig. 1b) collection consists of more than 180,000 *exsiccata* collected in several Mediterranean countries (e.g. France, Algeria, Greece, Italy, Crete). The collection, considering its historical and scientific importance, was collocated in the *Gymnasium*, a part of the historical building of the Botanical Garden of Palermo.

Recently, the scientific curator of PAL reported damages on several *exsiccata*, probably due to attack of insects or other arthropods. The level of damages recorded on *exsiccata* ranged from slight to severe (Fig. 2 a-c). However, a scientific survey on pests responsible of these damages was not carried out, till now.

Insect pest problems afflict the majority of herbaria (Drobnik, 2008; Roma-Marzio et al., 2017), and are considered the most common biotic factor of deterioration of museum objects made by wood, papers, tissues and other dry organic matters (Querner, 2015). In the herbaria, the *exsiccata* represent a potential food source for a variety of insect pests that can determine damages with their feeding, burrowing and defecating activities (Linnie, 1994). Scan literature is available on pest infesting herbaria (Hall, 1988; Retief and Nicholas, 1988; Drobnik, 2008; Roma-Marzio et al., 2017). The main insects reported affecting herbaria are: *Stegobium paniceum* L. and *Lasioderma serricorne* F. (Coleoptera: Anobidae), *Trogoderma granarium* (Coleoptera: Dermestidae), *Plodia interpunctella* (Lepidoptera: Pyralidae), *Liposcelis* spp. (Psocoptera: Liposcelididae), *Lepisma saccharina* L. (Zygentoma: Lepismatidae), *Blattella germanica* L. and *Periplaneta americana* L. (Dictyoptera: Blattidae) (Hall, 1988; Drobnik, 2008). Among them, anobids are particularly severe pests also in commercial stored products such as herbal tea, spices, tobacco (Ashworth 1993; Buchelos and Levinson 1993, Mahroof and Phillips 2008a, b, 2011). Their aggressiveness toward dried plants, such as herbs and dried fruit caused the most severe damage in the herbaria (Retief and Nicholas, 1988, Ashworth 1993). Thus, the control strategies of insects infesting the herbaria rely mainly on the protocols used against stored product pests infesting warehouses, similarly to what adopted in other cultural heritage contexts (Phillips and Throne, 2010; Pinniger, 2014, Querner, 2015). However, to date, the major methods adopted by herbarium curators to manage pests, are: 1) to freeze the bags were *exsiccata* are stored, 2) to use chemical products (like aspara-dichlorobenzene and camphor), 3) a combination of freezing and chemical products (Roma-Marzio et al., 2017).

The use of chemical insecticides has in several cases determined adverse drawbacks as environmental hazard and development of resistance in many insects, risks to the operators and incompatibility with the conservation and restoration of the herbarium collections (Linnie et al., 1990; Roma-Marzio et al., 2017). Moreover, *exsiccata* must be free from toxic compounds as they should be available for studying in anytime from all different researcher and users as adverse insecticide direct effects on the health on the curators was documented (Linnie et al., 1990).

There is an urgent need to assess new and alternative methods to the chemical pest control feasible for their use in herbaria. Integrated pest management (IPM) is receiving increasing interest in Cultural Heritage contexts (Trematerra and Pinninger, 2018). IPM is a term originally adopted to describe the development of pest control methods in agriculture, that do not rely merely on the regular and systematic use of pesticides. The main tactics of IPM are monitoring, discouraging pests, modifying the environment and targeting treatments.

The monitoring step is often neglected in herbaria but has a crucial importance. The right identification of the key pest/s is essential to target the control methods and gives information on where and when a particular pest is present. The insect monitoring can be conducted by visual inspection, chromotropic traps, sticky traps and pheromone traps.

The use of pheromones and other semiochemicals, such as food attractant, for monitoring and contrasting insect pests is highly recommendable for developing bio-rational control methods (Fields and White, 2002; Phillips and Throne, 2010; Trematerra 2012) following the IPM strategy (Welch et al., 2015). Pheromones baited traps are very sensitive tools and are highly specific to target species

(Savoldelli and Trematerra, 2011; Trematerra 2012). Pheromone traps could have tremendous potential as a tool for monitoring insect infestations in museum collections (Querner, 2015) and herbaria (Hall, 1988). However, to our best knowledge, very few investigations have been conducted on herbaria. The pheromones commercially available for the insect infesting the herbaria are restricted to few species. Specific studies on the use of pheromone in herbaria is crucial to evaluate their efficacy in controlling the pests. The capacity to attract insects into the trap is strictly related to the emission rate of semiochemicals during time, largely related to the dispenser types used (Kehat et al., 1994). These aspects need to be then carefully evaluated in order to optimize the pheromone use in herbaria.

In addition to increase the pheromone captures and explore the possibility to use a mass trapping technique, pheromone traps should be implemented with a food attractant (Spochacz et al, 2018). Therefore the objectives of this study are:

1. Survey of the main pests present in the *Herbarium* of Palermo and identification of the key pest.
2. Evaluation of the emission in the time of two pheromone releasers for the key pest.
3. Evaluation of the efficacy of two pheromone releasers in terms of number of specimens captured.
4. Evaluation of the efficacy of a combination of pheromone and food attractant calculated as number of individuals of key pest captured.

2. Material and methods

2.1. Survey of entomological infestation

The research was carried out in the herbarium of Historical Garden of Palermo (PAL) in particular in the collection of prof. Greuter (Fig. 1b). The collections of *exsiccata* are stored and protected in double transparent polyethylene bags, ideal for freezing, storing and shipping *exsiccata* (Fig. 1b). A survey on the pests causing the damages (Fig 2 a-c) to the collections of the PAL and the level of infestation was done through visual check. Inspection was done to the environment with particular focus on shelves and the bags where the *exsiccata* are stored. Samples were taken from the content of the bags (n=24) and directly from *exsiccata* (n=26). All arthropods were identified using a stereomicroscope (Zeiss SteREO Discovery. V12). Only the relevant pests were identified to the genus or species level.

2.2. Pheromone releasers evaluation

Based on the results of the survey of entomological infestation, the major pest infesting the PAL was *Lasioderma serricorne* (F.) (Coleoptera: Anobiidae). Therefore specific trap bioassays were conducted on this coleoptera.

Experiments were conducted in order to assess two different *L. serricorne* pheromone releaser in terms of adult insects captured and emission rate. The pheromone releaser tested were: 1) Polyethylene tube, 0.5-ml tubes loaded with a cyclohexane solution (100 µl) containing 4 mg of 4-6-dimethyl-7-hydroxy-nonan-3-one afterward named serricornin (purity grade 97.9%, Bedoukian, Dambury, USA) and 2) Patch type releaser, made by laminated tissue containing adhesive glue where the serricornin (4 mg) was mixed.

2.2.1 Pheromone trap experiments

Trapping experiments were conducted in PAL, placing the two releaser type in delta anobid traps (560 x 119mm; provided by GEA srl, Settimo Milanese, Italy). Nine traps were used in total, according the following treatments: three traps lured with polyethylene tube dispensers, three traps lured with patch type releaser and three traps left unloaded as control. Traps were positioned approximately 1.80 m from the floor and at least 5 m distant from other trap. The position of the traps was randomly assigned. Traps were inspected weekly from 3rd to 31st August 2018 in order to count the number of adult *L. serricorne* captured. The position of the traps was clock rotated after each inspection to avoid position bias.

2.2.2 Pheromone emission rate

In this experiment the pheromone emission from polyethylene dispenser and patch type was compared. The serricornin emission from the two releasers were collected by headspace, specifically by using the solid phase micro-extraction (SPME) method (Pawliszyn 1997). SPME is an equilibrium process involving headspace and the polymeric fiber stationary phase. The stationary phases used as coatings were poly(dimethylsiloxane) (PDMS, 100 μm). A manual SPME holder from the same manufacturer was used for injections. Fibers were conditioned in a gas chromatograph injector port as recommended by the manufacturer at 250 °C for 30 min.

For the headspace collections, the pheromone releaser were placed by forceps into 22 ml glass vials, which were sealed with a poly(tetrafluoroethylene) silicon septum-lined cap (Supelco, Bellefonte, PA, USA). As internal standard, 1 μl of a hexane solution of decane (200 ng μl^{-1}) was added. Subsequently an SPME needle was then inserted through the septum and volatiles were absorbed on the exposed fiber for 2 hours at room temperature (22 °C). Headspace collections were replicated three times for each releaser type. In order to assess the pheromone emission curve, collection were carried out respectively at day 0, 3, 10, 20, 30, 40, 50, 60, from the releasers opening. Experiments were replicated three times for each releaser type and time of sampling, for a total of 48 samples.

In order to perform the chemical analysis of the VOCs collected, the loaded fiber was, immediately after the end of the sampling time, desorbed in the gas chomatograph inlet port for 2 min. Coupled gas chromatography-mass spectrometry (GC-MS) analyses of the headspace collections from the two glue types were performed on an Agilent 6890 GC system interfaced with an MS5973 quadruple mass spectrometer was injected onto a DB5-MS column in splitless mode. Injector and detector temperatures were 260°C and 280°C respectively. Helium was used as the carrier gas. The GC oven temperature was set at 40°C for 5 min, and then increased by 10°C/min to 250°C. Electron impact ionization spectra were obtained at 70 eV, recording mass spectra from 40 to 550 amu. All the analysis were carried out in the laboratories of the Department of Agricultural, Food And Forest Sciences, University of Palermo (Italy).

2.3. Mass Trapping tests

In order to assess the efficacy of a food attractant to increase the number of insects captured in pheromone traps, was tested a chili (*Capsicum annuum* L. cv Pequin) powder as pheromone synergist. The chilli powder (2g) was weighted using a precision balance and placed inside the trap together with the pheromone releaser. For this test polyethylene vials dispensers were used as provided a higher number of insects captured (see result section). The trapping experiment was designed as follows: three traps loaded with chilli powder + pheromone, three traps loaded with pheromone alone and three traps left unloaded as control. The experiment was carried out from the 5th September to the 3rd October 2018. Similarly to pheromone trap experiments, the traps were inspected weekly and the number of captured insect was counted. The position of the traps was clock rotated after each inspection to avoid position bias.

2.4 Statistical analysis

The pheromone emission from the two releaser tested at each day from their opening was compared by t-test for independent samples. The number of catches of the pheromone trap experiment and of mass trapping test was root square transformed and analysed by using a one-way ANOVA, followed by Tukey test. All the statistical analyses were performed using Statistica 7.0 for Window (Statsoft 2001, Vigonza, PD, Italy).

3. Results

3.1 Survey of entomological infestation

Table 1 reports the number of entire specimens of insects collected in the bags according to the botanical family. Fifteen botanical families were sampled (Table 1). The anobiid beetles were the most abundant insects, recorded in all botanical families. The majority of anobiidae was represented by *Lasioderma serricorne* F. (Fig. 3a). That might be considered the key pest of this herbarium for number of individuals present and damages related. Among the other species recorded, the book lice, *Liposcelis* spp. (Fig. 3b) was also abundant particularly in the botanical families of Asteraceae, Brassicaceae, Cesalpinaceae, Lamiaceae (Table 1). The firebrat, *Thermobia domestica* Packard (Fig. 3c) and the silverfish, *Lepisma saccharina* L. were also recorded in Pinaceae, Scrophulariaceae, Solanaceae and Euphorbiaceae. Some Formicidae species were also infesting Rosaceae, Euphorbiaceae and Lamiaceae. Finally, hymenoptera parasitoids were recorded mainly in the bags containing the families Asparagaceae, Asteraceae, Brassicaceae, Cesalpinaceae, Lamiaceae (Table 1). Similar results were recorded on *exsiccata* where *L. serricorne* was sampled at adult and larvae stages (Fig. 4). In particular, the adults were more abundant in *Celtis australis* L. (Cannabaceae) and *Pinus nigra* Arnold (Pinaceae). In contrast, the largest number of larvae was found in *Asplessium* *trichamanes* L. (Aspleniaceae), *Taraxacum* sp. (Asteracea) and in the two Brassicaceae species (Fig. 4).

3.2 Pheromone releasers evaluation

3.2.1 Pheromone trap experiments

The results of the trap catches using different serricornin releasers are shown in Figure 5. The analysis of variance revealed differences in the number of adults captured between the blocks ($F_{2,33}$ = 16.09, P = 0.001, ANOVA followed by Tukey test). The traps loaded with polyethylene dispenser captured 15.33 ± 5.71 (mean ± SE) adults *L. serricorne* per trap per week, a number statistically greater than the traps loaded with patch dispenser and control traps, 1.33 ± 0.41 (mean ± SE) and 0.58 ± 0.28 (mean ± SE) (P < 0.01, ANOVA), respectively. Not statistically differences were recorded in the number of capture in the control traps and the traps loaded with the patch dispenser

3.2.2 Pheromone emission rate

The pheromone emission rate in terms of ng/hr from the releasers is reported in figure 6. Overall the highest amount of serricornin was emitted at the opening of the releaser for both of the releasers types. Moreover no statistical differences were recorded in the amount of pheromone emitted in the first 3 days . In Fact the release rate at day 0 was 5129.28 ± 174.26 (polyehtilen releaser) vs 6719.81 ± 1242.10 (pacth releaser) ng/hr (mean ± SE)] and day 3 [2680.87 ± 1242,100 vs 2423.76 ± 348.27 ng/hr (mean ± SE)] from the opening. The amount of pheromones decreased for both of the dispensed during the time but the amount of serricornin emitted from the polyethylene dispenser was higher than the one emitted from the patch respectively at day 10 [1538.21 ± 110.06 ng/hr vs 843.35 ± 219.45 ng/hr (mean ± SE), t = 2.83, df = 4, P < 0.05], day 20 [458.95 ± 10.46 ng/hr vs 133.43 ± 77.51 ng/hr (mean ± SE), t = 3.53, df = 4, P < 0.05], day 30 [380.13 ± 106.94 ng/hr vs 74.36 ± 37.40 ng/hr (mean ± SE), t = 3.53, df = 4, P < 0.05], day 40 [155.58 ± 12.18 ng/hr vs 40.90 ± 12.06 ng/hr (mean ± SE), t = 8.00, df = 4, P < 0.01] and day 50 [95.79 ± 5.95 ng/hr vs 35.76 ± 19.73 ng/hr (mean ± SE), t = 2.91, df = 4, P < 0.05]. However the serricornin emition rate decrease dramatically for both of the releaser types after two months (fig. 5).

3.3 Mass Trapping tests

The pheromone traps complemented with chilli powder significantly trapped a higher number of adult *L. serricorne* in comparison with traps loaded with pheromone alone (Fig. 7). These data are confirmed also by the analysis of variance that revealed differences in the number of adults captured between the blocks ($F_{2,33}$ = 12.40, P = 0.001, ANOVA followed by Tukey test). Traps complemented with chilli powder captured a mean of 9.50 ± 1.83 adults while the trap with pheromone alone trapped about half of the adults (4.48 ± 1.34; P < 0.05, ANOVA). Larvae of *L. serricorne* were also observed in the traps with chilli powder (data not shown).

4. Discussion

The control of herbarium pests is of primary concern to all herbarium curators, especially in tropical, sub tropical and hot regions of the world where ideal conditions for pest infestations occur.

The findings of this study highlight that in the PAL Herbarium there is a strong presence of insect pests, that are feeding and damaging the *exsiccata*. The majority of specimens collected during the survey were insects typically associated with indoor environments and especially with dry organic materials. The most abundant infesting insects found in PAL belonging to the Coleoptera Anobidae in particular *L. serricorne*, that can be considered the key pest of PAL herbarium, and to Psocoptera Liposcelidae mainly represented by the genus *Liposcelis*. This psocid is a primitive insect, commonly found in dry food such as: herbal tea, grains, flour, and meal; cereal-based products; and in residences, barns, and warehouses (Nayak et al., 1998). In the Cultural Heritage contest is primarily pest of paper materials (Pinniger and Meyer 2015; Querner, 2015). Thus in the herbarium the psocid can attack not only the dry plants, but also the paper sheets supporting the *exsiccata* that can be source of food. It is also reported to feed also on fungi, pollen, decaying organic materials, dead animals and plant remains (Nayak et al., 1998). In addition besides causing damage by feeding, they are a nuisance in large numbers and can contaminate, directly or indirectly, the *exsiccata*. There are few studies about the presence of psocid pests in herbaria (Broadhead, 1950; Retief, 1988; Forman, L., Bridson. D., 1989; Turner, 1999, Green 2014). For example *Liposcelis bostrychophilus* Badonnel was found to be the key pest in the Natal Herbarium (Retief et al., 1995) in Durban (South Africa) where the climate is warm and humid, similarly to Palermo environment. Hot, humid areas, such as those found along many tropical and semitropical coastlines, are ideal for the growth of the psocid *Liposcelis* spp.. Thus under ideal conditions in herbaria located in warm and humid area, populations of these wingless, parthenogenic insect pests can raise very rapidly and cause damage to books, specimens and herbarium packaging (Retief et al., 1995). The presence of this psocid should be seen as a warning that conditions are ripe for infestation by other, more destructive insect pests and then their presence should be viewed by curators with care. For example, the anobid *L. serricorne* was reported as a pest of Museum and Herbarium, together with the presence of the secondary pest *Liposcelis* spp., that can exploit warm and humid conditions, and take advantage of the global warming due to its tolerance to heat (Li et al., 2018).

So it is not surprising that in PAL the key pest was *L. serricorne*, also known as cigarette or tobacco beetle. Overall this anobid species, together with the related *Stegobium paniceum* L. is defined as the most common pest in museums that house dried food (Trematerra and Pinniger, 2018). This species is particularly polyphagous so it can be found in various types of storage and processing facilities such as mills, retail stores and tobacco warehouses (Buchelos 1981; Levinson and Buchelos 1988; Mahroof and Phillips 2011). *Lasioderma serricorne* showed, in our findings, all its highly polyphagia infesting all 15 botanical families. In addition the curator of PAL recorded many insect damages in almost all botanical families, probably, considering the high level of populations of *L. serricorne*. The high level of damage determined in herbaria from anobids species has been reported in other cases (Scoppola and Scarici, 1998; Drobnik, 2008). In particular, damages from *L. serricorne,* were also recorded in the National Herbarium of Pretoria (South Africa) (Retief and Nicholas, 1988). In our study, the related anobid *S. paniceum* was almost absent although was reported as key pest in several North Europe Herbaria (Gilberg and Brokerhof 1991; Rumball and Pinniger 2003; Drobnik, 2008).

The control of *L. serricorne* in herbaria is problematic for the restricted use of insecticides and the difficulties to apply other control methods such as using high or extremely low temperature, high concentration of CO_2,. Consequently the use of pheromones and food attractants for monitoring and mass trapping *L. serricorne* can be a recommendable alternative. Cigarette beetle females produce a sex pheromone made by serricornin (4,6-dimethyl-7-hydroxynonan-3-one) and/or anhydroserricornin (2,6-diethyl-3,5-dimethyl-3,4-dihydro-2H-pyran), attracting male beetles (Chuman et al., 1985). This pheromone is already commonly used for monitoring this pest in various types of storage and processing facilities (Buchelos 1981; Levinson and Buchelos 1988; Mahroof and Phillips 2011).

The data obtained in this study encourage the use of semiochemicals as useful tools for the management of *L. serricorne* in herbaria. The study conducted using two different pheromone releasers evidenced that the number of individuals captured is, as expected, strictly related to the pheromone emission. In the specific the polyethylene releaser emitted a higher amount of serricornin from 10^{th} to the 50^{th} day from the releaser opening in comparison with the patch releaser. These data can explain the higher number of captures observed overall in the traps loaded with the polyethylene dispensers rather than in the traps loaded with the patch dispenser, albeit the field test were conducted for circa 30 days. The higher emission rates observed in polyethylene dispenser determines a larger trap's active space, thereby increasing captures as suggested by Cardè et al. (2017). Athanassiou et al. in a recent study (2018), suggested a threshold release rate required for the attraction of *L. serricorne*. The rate was approximately 0.3 μg/h (Athanassiou et al., 2018) the same rate recorded after 30 days in our study. The relatively low numbers of captures recorded in the traps loaded with the patch releaser could be determined by a not-uniformity in the pheromone emission that quickly drops after the dispenser opening. These data suggested that the best releaser for pheromone traps in herbaria is the polyethylene dispenser and it should be substituted every 30 days.

Finally, in our experiment was evident that the chili powder enhances the number of insect captured in the traps acting as a co-attractant. The response to chili powder is determined by the volatiles emitted from this materials that elicit strong attraction to *L. serricorne* individuals by mimicking a suitable feeding and oviposition site, as suggested from Marhoof and Phillips (2007). In fact both of sexes were captured, and also larvae were recorded, demonstrating the enhancing of the efficacy of the trap.

Similarly, a past study conducted from Marhoof and Phillips (2008) evidenced that chili volatiles can increase the number of captured *L. serricorne* in pheromone traps. It is a known fact that the efficacy of pheromone lures may be enhanced by combination with host odours (Landolt and Phillips, 1997). The data obtained confirm the possibility to use a pheromone trap synergized by a food attractant such as the chili powder, for both have a more sensitive tool for detecting *L. serricorne* infestation, useful in case of detecting early insect infestation and moreover to have a more efficient tool in case of mass trapping. This latter case is particularly recommendable in the herbaria environment where other control techniques are strongly limited for their negative consequences and for practical and conservation reasons.

5. Conclusions

The herbarium of the Botanical Garden of Palermo contains a large number of plants of great scientific and cultural importance. The survey carried out in this study allowed to verify the presence of a variety of insect pests infesting the *exsiccata*, with the anobid *L. serricorne* being the key pest and psocid *Liposcelis* sp. the secondary opportunistic pest. This was a crucial first step for the development of Integrated Pest Management (IPM) in this herbarium. Furthermore, the experiments testing semiochemicals for monitoring and mass trapping *L. serricorne* allowed to improve our knowledge on this tools in herbaria. The results of the monitoring campaign and of the mass trapping were reported to the Director of the *Herbarium* to encourage the adoption of an IPM program as an invaluable preventive conservation tools.

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Figure captions

Fig. 1. a) *Gymnasium* of the Palermo Botanical Garden, b) Greuter's *herbarium* collection located in the Gymnasium.

Fig. 2. Different level of dammages on Greuter's herbarium exsiccata due to insect infestation from slight to severe (a-c): a) *Persoonia mollis*, b) *Bauhinia natalensis*, c) *Taraxacum* sp.

Fig. 3. a) *Lasioderma serricorne* b) *Liposcelis* spp., c) *Thermobia domestica*

Fig. 4. Larvae and adults of *Lasioderma serricorne* collected on the *exsiccata* of different botanical species listed in x-axis.

Fig. 5. Mean (+SE) release rates of serricornin from lures after one hour, measured by trapping volatiles at 22 °C. Asterisks indicate significant differences for $P < 0.05$ (t-test).

Fig. 6. Mean (+SE) number of *L. serricorne* captured weekly by each trap, lured with different pheromone dispensers. Different letters indicate significant differences between lures combination across the 4 weeks of the experiment (Tukey's test, $P < 0.05$).

Fig. 7. Mean (+SE) number of *L. serricorne* captured weekly by each trap, lured with different pheromone and pheromone + chilli powder. Different letters indicate significant differences between lures combination across the 4 weeks of the experiment (Tukey's test, $P < 0.05$).