



© 2014

Boletín Latinoamericano y del Caribe de Plantas Medicinales y Aromáticas 13 (5): 498 - 505

ISSN 0717 7917

www.blacpma.usach.cl

Artículo Original | Original Article

Screening for extracts with insect antifeedant properties in native plants from central Argentina

[Evaluación de la actividad antialimentaria de insectos en extractos de plantas nativas del centro de Argentina]

Soledad DEL CORRAL¹, Georgina N. DIAZ-NAPAL¹, Mariano ZARAGOZA¹, María C. CARPINELLA¹,
Gustavo RUIZ² and Sara M. PALACIOS¹

¹*Fine Chemical and Natural Products Laboratory, School of Chemistry, Catholic University of Córdoba.*²*Herbarium Marcelino Sayago, School of Agricultural Science, Catholic University of Córdoba.**Av. Armada Argentina 3555, Córdoba, Argentina**Contactos / Contacts: Sara M. Palacios - E-mail address: sarapalacios@ucc.edu.ar*

Abstract: Ethanol extracts obtained from aerial parts of 64 native plants from Central Argentina were tested for their insect antifeedant activity against *Epilachna paenulata* (Coleoptera: Coccinellidae) by choice test. Extracts derived from *Achyrocline satureioides* (Asteraceae), *Baccharis coridifolia* (Asteraceae), *Baccharis flabellata* (Asteraceae), *Ruprechtia apetala* (Polygonaceae) and *Vernonanthura nudiflora* (Asteraceae), showed more than 97% inhibition of the feeding of *E. paenulata* at 100 µg/cm². These active extracts were further evaluated for their effectiveness against *Spodoptera frugiperda* (Lepidoptera: Noctuidae). All these extracts except for that derived from *A. satureioides*, negatively influenced the feeding behavior of *S. frugiperda* at 100 µg/cm².

Keywords: Native plants to Argentina; insect antifeedants; *Vernonanthura nudiflora*; *Baccharis flabellata*; *Baccharis coridifolia*; *Ruprechtia apetala*; *Achyrocline satureioides*.

Resumen: Se evaluaron los extractos etanólicos obtenidos de las partes aéreas de 64 plantas de la región Central de Argentina, como antialimentarios de insectos mediante ensayos de elección, contra *Epilachna paenulata* (Coleoptera: Coccinellidae). Los extractos derivados de *Achyrocline satureioides* (Asteraceae), *Baccharis coridifolia* (Asteraceae), *Baccharis flabellata* (Asteraceae), *Ruprechtia apetala* (Polygonaceae) y *Vernonanthura nudiflora* (Asteraceae) mostraron más de 97% de inhibición de la alimentación de *E. paenulata* a 100 µg/cm². Estos extractos fueron posteriormente evaluados en su efectividad contra *Spodoptera frugiperda* (Lepidoptera: Noctuidae). Todos ellos, con excepción del extracto de *A. satureioides*, afectaron negativamente el comportamiento alimentario de *S. frugiperda* a 100 µg/cm².

Palabras clave: Plantas nativas de Argentina; antialimentarios de insectos; *Vernonanthura nudiflora*, *Baccharis flabellata*; *Baccharis coridifolia*; *Ruprechtia apetala*; *Achyrocline satureioides*

Recibido | Received: June 12, 2013

Aceptado en versión corregida | Accepted in revised form: March 16, 2014

Publicado en línea | Published online: September 30, 2014

Declaración de intereses | Declaration of interests: This work was supported by the Catholic University of Córdoba, FONCYT, Grant Numbers: BID 1728 OC/AR. PICT 33593 and PICTO CRUP 6-31396. SDC and GDN gratefully acknowledge receipt of a fellowship from CONICET.

Este artículo puede ser citado como / This article must be cited as: S del Corral, GN Diaz-Napal, M Zaragoza, MC Carpinella, G Ruiz, SM Palacios. 2014. Screening for extracts with insect antifeedant properties in native plants from Central Argentina. *Bol Latinoam Caribe Plant Med Aromat* 13(5): 498 – 505.

INTRODUCTION

Chemical control of pest insects has given rise to several problems including the pollution of the environment by insecticide residues (de Vlaming *et al.*, 2004), the selection of resistant pest populations (Storer *et al.*, 2012), the negative side effects on beneficial parasites and predators (Cordero *et al.*, 2007) and the deleterious effects on human health (de Jong, 1991, Sulak *et al.*, 2005). It is therefore necessary to design efficient insect control agents presenting reduced environmental consequences (Diaz Napal *et al.*, 2009).

Plants synthesize a wide array of compounds that are involved in plant-insect interactions. Such compounds of secondary metabolism as alkaloids, terpenoids, phenols, flavonoids, steroids, etc. confer some resistance against phytophagous insects (Carpinella *et al.*, 2002; González-Coloma *et al.*, 2002; Urzúa *et al.*, 2010a; Urzúa *et al.*, 2010b; Urzúa *et al.*, 2011; Céspedes *et al.*, 2013). These compounds act as antifeedant and toxic substances as well as growth regulators affecting several physiological processes of insects (González-Coloma *et al.*, 2002).

In this context, we are studying the insecticidal potential of the flora of Central Argentina (Palacios *et al.*, 2007, Palacios *et al.*, 2009), searching for environmentally-friendly pesticides. As a result of this ongoing study, we have identified several plants as sources of efficient pest controllers (Defagó *et al.*, 2006, Diaz Napal *et al.*, 2009, Diaz Napal *et al.*, 2010, Palacios *et al.*, 2010, Defagó *et al.*, 2011). In this report, we examine the insect antifeedant properties of another group of 64 plants from Central Argentina against *Epilachna paenulata*, as part of this program for the selection of highly active plant species for natural insecticide development.

E. paenulata Germar (Coleoptera: Coccinellidae) is a phytophagous insect that affects species from the Cucurbitaceae family, which was extensively used in our laboratory as model insect for insecticide studies (Diaz Napal *et al.*, 2010). The results were then confirmed testing the most active extracts in another pest insect: the fall armyworm *Spodoptera frugiperda* (Lepidoptera: Noctuidae). This insect comprises a pest of economic importance for basic grain production and for many other crops in North, Central and South America (Wyckhuys and O'Neil, 2006). Being the main corn pest in Brazil and in Argentina (Tavares *et al.*, 2009), *S. frugiperda* has developed resistance against many synthetic

insecticides (Tomquelski and Martins, 2010) and against transgenic BT-maize (Storer *et al.*, 2012).

MATERIALS and METHODS

Plant material

Plants were collected in the hills of Córdoba, Argentina, from November 2010 to December 2011. Voucher specimens have been deposited in the "Marcelino Sayago" Herbarium of the School of Agricultural Science, Catholic University of Córdoba and were authenticated by the botanist, Gustavo Ruiz. Plants were selected according to their availability and accessibility and emphasizing those for which there was no information about their activity or chemical contents. The vegetative material was air-dried at room temperature, crushed and extracted by 48 h maceration with ethanol. Yields of each viscous extract, obtained after solvent removal, were expressed as percentage weight of air-dried plant material.

Insects

E. paenulata and *S. frugiperda* larvae were obtained from a laboratory colony, reared on a natural diet of *Cucurbita maxima* Duch. leaves and artificial diet (Céspedes *et al.*, 2000), respectively. The insects were maintained in a growth chamber at $24 \pm 1^\circ$ C and 70-75% relative humidity, with a photoperiod of 16/8 h light-dark cycle and periodically renewed with field specimens (Diaz Napal *et al.*, 2010).

Test solution preparation

Ten mg of each extract were dissolved in 1 mL of acetone immediately before the corresponding assay.

Feeding choice assay

Two cotyledon leaves from a *C. maxima* seedling were placed in a Petri dish; a glass disk with two 1 cm² diameter holes was placed on top. A third-instar *E. paenulata* larva was placed equidistant from both a treated and an untreated leaf disk, with 10 µl of test solution and 10 µl of acetone, solvent control, respectively. The insect was allowed to feed for 24 h. Ten replicates were run for each test. In the case of the assays against *S. frugiperda*, two circular sections of *Lactuca sativa* seedling were placed in a Petri dish. A third-instar *S. frugiperda* larva was placed equidistant from both a treated (with 10 µl of test solution) and an untreated (with 10 µl of acetone, solvent control) leaf disk, and allowed to feed until 50 percent of the food was eaten. The relative amounts (recorded in

percentages from 0 to 100) of the treated and untreated substrate areas eaten in each test were estimated visually by dividing the food area into imaginary quarters. An antifeedant index (AI) was calculated as $[1 - (T/C)] \times 100$ (Diaz Napal *et al.*, 2009), where T

and C represent consumption on treated and untreated food, respectively.

A rank for each of the most active plants was estimated considering an index (I_n) calculated for that plant extracts by the following equation:

$$I_n = y_n \cdot AI(E. paenulata) \cdot AI(S. frugiperda)$$

where I_n is the rank of the species n, y_n is the yield extract of plant n base on 100 g of plant material, and the AI is the antifeedant index of extract of plant n at 100 $\mu\text{g}/\text{cm}^2$ for each insect. The plant extract with the highest I_n is the most active one and consequently received the lowest rank number (Rank = 1), with lower I_n receiving consecutive rank numbers (Rank > 1).

Statistical analysis

Results from feeding choice assays were analyzed for

statistical significance using the Wilcoxon signed ranks test.

RESULTS and DISCUSSION

The feeding inhibition properties of each extract obtained from the 64 plant species were evaluated in a choice feeding assay against *E. paenulata*. Most of the species were native to our environment although some of them (*Cotoneaster glaucophylla*, *Dipsacus fullonum*, *Marrubium vulgare*, *Melissa officinalis* and *Podranea ricasoliana*) are in fact naturalized. The results of this screening are presented in Table 1.

Table 1

Insect antifeedant activity of extracts from native plants against *Epilachna paenulata*.

<u>Plant species</u>	<u>AI(%)^a</u>
<i>Achyrocline satureioides</i> (Lam.) DC.	97.14
<i>Achyrocline tomentosa</i> Rusby	27.00
<i>Aloysia citriodora</i> Palau	66.90
<i>Aloysia gratissima</i> (Gill.& Hook.) Tronc.	75.70
<i>Ambrosia elatior</i> L.	-7.20
<i>Amphilophium cynanchoides</i> (DC.) L.G. Lohmann	21.00
<i>Angelphytum aspilioides</i> (Griseb.) H. Rob.	92.26
<i>Argemone subfusiformis</i> G. B. Ownbey	91.80
<i>Baccharis artemisioides</i> Hook. & Arn.	76.60
<i>Baccharis coridifolia</i> DC.	98.20
<i>Baccharis flabellata</i> Hook. & Arn.	97.00
<i>Baccharis salicifolia</i> (Ruiz & Pav.) Pers.	27.00
<i>Bidens pilosa</i> L.	57.14
<i>Capparis atamisquea</i> Kuntze	26.00
<i>Condalia microphylla</i> Cav.	63.50
<i>Cortaderia rudiusscula</i> Stapf	-2.20
<i>Cotoneaster glaucophylla</i> Franch.	4.30
<i>Croton lachnostachyus</i> Baill.	5.00
<i>Dipsacus fullonum</i> L.	8.71
<i>Dolichandra unguis-cati</i> (L.) L.G. Lohmann	5.00
<i>Dysphania ambrosioides</i> (L.) Mosyakin & Clemants	2.00
<i>Eryngium horridum</i> Malme	46.40
<i>Eupatorium hookerianum</i> Griseb.	29.00

<i>Eupatorium viscidum</i> Hook. & Arn.	42.00
<i>Flourensia campestris</i> Griseb.	85.16
<i>Gomphrena pulchella</i> Mart.	77.50
<i>Grindelia pulchella</i> Dunal	96.12
<i>Jarava ichu</i> Ruiz & Pav.	1.50
<i>Jodina rhombifolia</i> (Hook. & Arn.) Reissek	0.00
<i>Ligaria cuneifolia</i> (Ruiz & Pav.) Tiegh.	54.90
<i>Lippia turbinata</i> Griseb.	37.25
<i>Lithrea molleoides</i> (Vell.) Engl.	11.00
<i>Mandevilla laxa</i> (Ruiz & Pav.) Woodson	-83.00
<i>Marrubium vulgare</i> L.	71.30
<i>Melinis repens</i> (Willd.) Zizka	52.50
<i>Melissa officinales</i> L.	42.00
<i>Microliabum candidum</i> (Griseb.) H. Rob.	29.00
<i>Minthostachys verticillata</i> (Griseb.) Epling	56.41
<i>Morrenia brachystephana</i> Griseb.	64.13
<i>Ophryosporus charrua</i> (Griseb.) Hieron.	51.23
<i>Pavonia aurigloba</i> Krapov. & Cristóbal	34.00
<i>Podranea ricasoliana</i> (Tanfani) Sprague	80.00
<i>Porlieria microphylla</i> (Baill.) Descole, O'Donell & Lourteig	75.00
<i>Pterocaulon alopecuroides</i> (Lam.) DC.	95.90
<i>Pyrostegia venusta</i> (Ker Gawl.) Miers	55.00
<i>Ruprechtia apétala</i> Wedd.	97.75
<i>Schizachyrium condensatum</i> (Kunth) Nees	-18.00
<i>Senecio madagascariensis</i> Poir.	67.36
<i>Senecio vira-vira</i> Hieron.	78.00
<i>Senna aphylla</i> (Cav.) H.S. Irwin & Barneby	39.00
<i>Sida rhombifolia</i> L.	87.80
<i>Solanum argentinum</i> Bitter & Lillo	26.00
<i>Solanum palinacanthum</i> Dunal	39.20
<i>Solanum sisymbriifolium</i> Lam.	80.30
<i>Sphaeralcea bonariensis</i> (Cav.) Griseb.	14.00
<i>Spharalcea cordobensis</i> Krapov. (mutant)	49.00
<i>Tagetes minuta</i> L.	85.00
<i>Tripodanthus flagellaris</i> (Cham. & Schltld.) Tiegh.	67.00
<i>Verbesina encelioides</i> (Cav.) Benth. & Hook. f. ex A. Gray	0.00
<i>Vernonanthura nudiflora</i> (Less.) H. Rob. f. nudiflora	99.00
<i>Vernonia mollissima</i> Hook. & Arn.	47.00
<i>Viguiera tucumanensis</i> (Hook. & Arn.) Griseb. var. tucumanensis	25.40
<i>Wedelia glauca</i> (Ortega) O. Hoffm. ex Hicken	93.80
<i>Zanthoxylum coco</i> Hook.f. & Arn.	83.00
Azadiractin ^b	100.00

a: data represent the mean of ten replicates. b: reference natural insecticide at 4 µg/cm²

Those extracts that possess an AI between 50-75% were previously classified as moderate antifeedants (Hassanali and Lwande, 1989). Only those with values greater than 75% were considered to have high values. According to this criteria, 20% of the plant extracts showed moderate antifeedant properties (13/64 =

20%) against *E. paenulata* at 100 µg/cm², whereas 13 extracts (13/64 = 20%) had activity between 75% and 95% and only 7 extracts (7/64 = 11%) exhibited an AI superior to 95%. This last group is composed of the extracts derived from *Achyrocline satureioides*, *Baccharis coridifolia*, *Baccharis flabellata*, *Grindelia*

pulchella, *Pterocaulon alopecuroides*, *Ruprechtia apetala*, and *Vernonanthura nudiflora*. The rest of the plant extracts were divided between the non-active (27/64 = 42%) and the phagostimulant extracts with negative AI (4/64 = 6%).

Within the group with the greatest antifeedant activity, the most active ones were also tested against *S. frugiperda*, a polyphagous pest that is possibly more tolerant to allelochemicals due to its ability to detoxify xenobiotics (Ali and Agrawal, 2012). Four extracts also showed high antifeedant activity against *S. frugiperda*, *B. coridifolia* and *V. nudiflora* were the most active (Table 2). The effectiveness of these extracts suggests that they can be used as sources of natural antifeedants to control harmful pests. These results also suggest that these extracts could contain

highly active secondary metabolites. If we assume that such activity is due to a single metabolite and taking into account that these compounds do not normally exceed 10% of the extract, the results suggest that active ingredients would exert the antifeedant effect at a concentration approximately of 10 $\mu\text{g}/\text{cm}^2$. This level of activity make these compounds especially promising antifeedants, as compared with the vast majority of the plant antifeedants which are effective only at doses greater than 20 $\mu\text{g}/\text{cm}^2$ (Koul, 2005). The well-known antifeedants azadirachtin or meliartenin (Carpinella et al., 2006) have equivalent activities against *E. paenulata* and *S. frugiperda* at 4 and 1 $\mu\text{g}/\text{cm}^2$, respectively.

Table 2
Most active plant extracts against *Epilachna paenulata* and *Spodoptera frugiperda*

Plant species	Yield (g%)	AI (%)		Rank ^a
		<i>E. paenulata</i>	<i>S. frugiperda</i>	
<i>Achyrocline satureioides</i>	4.5	97.14	33.60	5
<i>Baccharis coridifolia</i>	2.2	98.20	91.22	3
<i>Baccharis flabellata</i>	7.5	97.00	80.36	2
<i>Ruprechtia apetala</i>	1.9	97.75	81.30	4
<i>Vernonanthura nudiflora</i>	7.2	99.00	98.61	1

a: for rank calculation, see Materials and Methods section.

In anticipation of the application of these extracts to control insects in domestic or organic agriculture, we propose to categorize each extract as an insect control product taking into account the antifeedant activity as well as the extract yield of each species. With this aim in mind, we established a rank of the most active extracts, using their yields and their activity on both insects, which are listed in Table 2. *V. nudiflora*, *B. flabellata*, *B. coridifolia*, *R. apetala* and *A. satureioides* had ranks from 1 to 5, respectively.

Based on the aforementioned analysis, it is clear that extracts from *V. nudiflora*, *B. coridifolia* and *B. flabellata* constitute the most promising insect control products.

V. nudiflora (Asteraceae) is a herbaceous plant with blue-purple flowers that is considered a weed in many crops. Neither antifeedant reports nor bioguided studies have been found in the literature for its ethanolic extract. Aerial parts of *V. nudiflora* furnished glaucolides A and B, flavonoids, hirsutinolide and cadinanolides derivatives (Bardón et al., 1992). The antifeedant activity of *V. nudiflora* could be attributed to glaucolide A, which has previously been reported

as a feeding deterrent against lepidopteran larvae (Burnett Jr et al., 1974).

B. coridifolia (Asteraceae) is a low-growing woody shrub known as “mio-mio”. This plant has an extensive distribution that includes the north-east, center and north of Argentina. No reference about antifeedant activity was found for this species. As far as we know, this is the first report on this matter, although the plant is toxic to livestock (Rizzo et al., 1997). The toxins of *B. coridifolia* are macrocyclic trichothecenes, including roridin A, D, and E and verrucarín A and J (Rizzo et al., 1997). The trichothecins in this plant are generally considered to be produced by entophytic fungi that live within the plant, although some soil microbes, primarily *Myrothecium roridum* and *M. verrucaria*, may also make them, they are no longer considered to be absorbed by the plants (Busam and Habermehl, 1982) but rather produced within them.

From the aerial parts of *B. flabellata* (Asteraceae), neo-clerodane diterpenoids such as flabeloic acid, 5,10-seco-clerodane diterpenoid derivative (Saad et al., 1988), 2,19;15,16-diepoxy-

neo-clerodan-3,13,14-trien-18-oic acid, 15,16-epoxy-5,10-seco-clerodan-1(10),2,4,13(16),14-pentaen-18, 19-olide and 15,16-epoxy-neo-clerodan-1,3,13(16),14-tetraen-18,19-olide were isolated (Juan Hikawczuk *et al.*, 2002). Some related neo-clerodanes isolated from different species have been reported as effective antifeedant compounds (Muñoz *et al.*, 1997, Bremner *et al.*, 1998, Cifuentes *et al.*, 2002) although this plant was not previously reported as antifeedant against insects.

R. apetala (Polygonaceae), known as “manzanito del campo”, is a small tree with pale pink flowers. Not many activities have been reported for the ethanolic extract, however a potent anticholinesterase inhibitory effect has been found (Carpinella *et al.*, 2010). This property could be connected with the anti-insect activity observed in this screening.

A. satureiodes (Asteraceae) (common name “marcela”) is a low-growing shrub with a woody base or suffrutex with grayish leaves. Infusions from this plant are used today in southern Brazil, Paraguay and Argentina for the treatment of different illnesses. Bactericidal properties of this species have been demonstrated (Joray *et al.*, 2011a, Joray *et al.*, 2011b), however, no information about its antifeedant properties has been reported.

In conclusion, the plants with good ranking, especially *V. nudiflora*, *B. coridifolia* and *B. flabellata* may be considered as potential insect control materials for different agricultural practices, due to their potencies and yields. It could also be highly advisable to study both the responsible compounds for the antifeedant effect and their mechanisms of action.

ACKNOWLEDGEMENTS

This work was supported by the Catholic University of Córdoba, FONCYT, Grant Numbers: BID 1728 OC/AR. PICT 33593 and PICTO CRUP 6-31396. SDC and GDN gratefully acknowledge receipt of a fellowship from CONICET. We thank Julie Mariano for revising the English language and two anonymous reviewers for helpful suggestions.

REFERENCES

Ali JG, Agrawal AA. 2012. Specialist versus generalist insect herbivores and plant defense. **Trend Plant Sci** 17: 293 - 302.

Bardón A, Kamiya NI, De Ponce De León CA, Catalán CAN, Díaz JG, Herz W. 1992. Glaucolides and related sesquiterpene lactones

from *Vernonia nudiflora* and *Chrysolaena propinqua*. **Phytochemistry** 31: 609 - 613.

Bremner PD, Simmonds MSJ, Blaney WM, Veitch NC. 1998. Neo-clerodane diterpenoid insect antifeedants from *Ajuga reptans* cv catlins giant. **Phytochemistry** 47: 1227 - 1232.

Burnett Jr WC, Jones Jr SB, Mabry TJ, Padolina WG. 1974. Sesquiterpene lactones-insect feeding deterrents in *Vernonia*. **Biochem System Ecol** 2: 25 - 29.

Busam L, Habermehl G. 1982. Accumulation of mycotoxins by *Baccharis coridifolia*, a reason for livestock poisoning. **Naturwissenschaften** 69: 392 - 393.

Carpinella C, Ferrayoli C, Valladares G, Defago M, Palacios S. 2002. Potent limonoid insect antifeedant from *Melia azedarach*. **Biosc Biotech Biochem** 66: 1731 - 1736.

Carpinella MC, Defagó MT, Valladares G, Palacios SM 2006. **Role of *Melia azedarach* L. (Meliaceae) for the control of insects and acari: present status and future prospects**. In: M Rai and MC Carpinella (eds). *Advances in Phytomedicine*, Elsevier, Amsterdam, Netherlands.

Carpinella MC, Andrione DG, Ruiz G, Palacios SM. 2010. Screening for acetylcholinesterase inhibitory activity in plant extracts from Argentina. **Phytother Res** 24: 259 - 263.

Céspedes CL, Calderón JS, Lina L, Aranda E. 2000. Growth inhibitory effects on fall armyworm *Spodoptera frugiperda* of some limonoids isolated from *Cedrela* spp. (Meliaceae). **J Agric Food Chem** 48: 1903 - 1908.

Céspedes CL, Molina SC, Muñoz E, Lamilla C, Alarcon J, Palacios SM, Carpinella MC, Avila JG. 2013. The insecticidal, molting disruption and insect growth inhibitory activity of extracts from *Condalia microphylla* Cav. (Rhamnaceae). **Ind Crops Prod** 42: 78 - 86.

Cifuentes DA, Borkowski EJ, Sosa ME, Gianello JC, Giordano OS, Tonn CE. 2002. Clerodane diterpenes from *Baccharis sagittalis*: insect antifeedant activity. **Phytochemistry** 61: 899 - 905.

Cordero RJ, Bloomquist JR, Kuhar TP. 2007. Susceptibility of two diamondback moth parasitoids, *Diadegma insulare* (Cresson) (Hymenoptera; Ichneumonidae) and *Oomyzus sokolowskii* (Kurdjumov) (Hymenoptera;

- Eulophidae), to selected commercial insecticides. **Biol Control** 42: 48 - 54.
- de Jong G. 1991. A study of exposure, health effects and mortality of workers engaged in the manufacture and formulation of the insecticides aldrin and dieldrin. **Toxicol Lett** 56: 206.
- de Vlaming V, DiGiorgio C, Fong S, Deanovic LA, de la Paz Carpio-Obeso M, Miller JL, Miller MJ, Richard NJ. 2004. Irrigation runoff insecticide pollution of rivers in the Imperial Valley, California (USA). **Environ Pollut** 132: 213 - 229.
- Defagó M, Valladares G, Banchio E, Carpinella C, Palacios S. 2006. Insecticide and antifeedant activity of different plant parts of *Melia azedarach* on *Xanthogaleruca luteola*. **Fitoterapia** 77: 500 - 505.
- Defagó MT, Dumón A, Avalos DS, Palacios SM, Valladares G. 2011. Effects of *Melia azedarach* extract on *Cotesia ayerza*, parasitoid of the alfalfa defoliator *Colias lesbia*. **Biol Control** 57: 75 - 78.
- Diaz Napal GN, Carpinella MC, Palacios SM. 2009. Antifeedant activity of ethanolic extract from *Flourensia oolepis* and isolation of pinocembrin as its active principle compound. **Biores Technol** 100: 3669 - 3673.
- Diaz Napal GN, Defagó M, Valladares G, Palacios S. 2010. Response of *Epilachna paenulata* to two flavonoids, pinocembrin and quercetin, in a comparative study. **J Chem Ecol** 36: 898 - 904.
- González-Coloma A, Reina M, Gutiérrez C, Fraga BM. 2002. **Natural insecticides: Structure diversity, effects and structure-activity relationships. A case study.** In: Atta ur Rahman (eds). *Studies in Natural Products Chemistry*, Elsevier, Amsterdam, Netherlands.
- Hassanali A, Lwande W. 1989. **Antipest secondary metabolites from African plants.** In: Arnason JT, Philogene, B.J.R., Morand, P. (eds). *Insecticides of Plant Origin*. American Chemical Society, Oxford University Press. Washington DC, USA.
- Joray MB, del Rollán MR, Ruiz GM, Palacios SM, Carpinella MC. 2011a. Antibacterial activity of extracts from plants of central Argentina- Isolation of an active principle from *Achyrocline satureioides*. **Planta Medica** 77: 95 - 100.
- Joray MB, González ML, Palacios SM, Carpinella MC. 2011b. Antibacterial activity of the plant-derived compounds 23-methyl-6-*O*-desmethyllauricepyrone and (Z,Z)-5-(trideca-4,7-dienyl)resorcinol and their synergy with antibiotics against methicillin-susceptible and -resistant *Staphylococcus aureus*. **J Agric Food Chem** 59: 11534 - 11542.
- Juan Hikawczuk VE, Rossomando PC, Giordano OS, Saad JR. 2002. neo-Clerodane diterpenoids from *Baccharis flabellata*. **Phytochemistry** 61: 389 - 394.
- Koul O. 2005. **Insect antifeedants**. CRC Press LLC. New York, USA.
- Muñoz DM, de la Torre MC, Rodríguez B, Simmonds MSJ, Blaney WM. 1997. Neo-clerodane insect antifeedants from *Scutellaria alpina* subsp. *javallambrensis*. **Phytochemistry** 44: 593 - 597.
- Palacios SM, Maggi ME, Bazán CM, Carpinella MC, Turco M, Muñoz A, Alonso RA, Nuñez C, Cantero JJ, Defago MT, Ferrayoli CG, Valladares GR. 2007. Screening of Argentinian plants for pesticide activity. **Fitoterapia** 78: 580 - 584.
- Palacios SM, Bertoni A, Rossi Y, Santander R, Urzúa A. 2009. Insecticidal activity of essential oils from native medicinal plants of Central Argentina against the house fly *Musca domestica* (L.). **Parasitol Res** 106: 207 - 212.
- Palacios SM, del Corral S, Carpinella MC, Ruiz G. 2010. Screening for natural inhibitors of germination and seedling growth in native plants from Central Argentina. **Ind Crops Prod** 32: 674 - 677.
- Rizzo I, Varsavky E, Haidukowski M, Frade H. 1997. Macrocyclic trichothecenes in *Baccharis coridifolia* plants and endophytes and *Baccharis artemisioides* plants. **Toxicon** 35: 753 - 757.
- Saad JR, Davicino JG, Giordano OS. 1988. A diterpene and flavonoids of *Baccharis flabellata*. **Phytochemistry** 27: 1884 - 1887.
- Storer NP, Kubiszak ME, Ed King J, Thompson GD, Santos AC. 2012. Status of resistance to Bt maize in *Spodoptera frugiperda*: Lessons from Puerto Rico. **J Invert Pathol** 110: 294 - 300.
- Sulak O, Altuntas I, Karahan N, Yildirim B, Akturk O, Yilmaz HR, Delibas N. 2005. Nephrotoxicity in rats induced by organophosphate insecticide methidathion and ameliorating effects of

- vitamins E and C. **Pestic Biochem Physiol** 83: 21 - 28.
- Tavares WdS, Cruz I, Petacci F, de Assis Júnior SL, de Sousa Freitas S, Zanuncio JC, Serrão JE. 2009. Potential use of Asteraceae extracts to control *Spodoptera frugiperda* (Lepidoptera: Noctuidae) and selectivity to their parasitoids *Trichogramma pretiosum* (Hymenoptera: Trichogrammatidae) and *Telenomus remus* (Hymenoptera: Scelionidae). **Ind Crops Prod** 30: 384 - 388.
- Tomquelski GV, Martins GLM. 2007. Eficiência de insecticidas sobre *Spodoptera frugiperda* (J.E. SMITH, 1797) (Lepidoptera: Noctuidae) em milho na região dos Chapadões. **Rev Bras Milho Sorgo** 6: 26 - 39
- Urzúa A, Santander R, Echeverría J, Cabezas N, Palacios SM, Rossi Y. 2010a. Insecticide properties of the essential oils from *Haplopappus foliosus* and *Bahia ambrosoides* against the house fly, *Musca domestica* L. **J Chilean Chem Soc** 55: 392 - 395.
- Urzúa A, Santander R, Echeverria J, Villalobos C, Palacios SM, Rossi Y. 2010b. Insecticidal properties of *Peumus boldus* Mol. essential oil on the house fly, *Musca domestica* L. **Bol Latinoamer Caribe Plant Med Aromat** 9: 465 - 469.
- Urzúa A, Di Cosmo D, Echeverria J, Santander R, Palacios SM, Rossi Y. 2011. Insecticidal effect of *Schinus latifolius* essential oil on the housefly, *Musca domestica* L. **Bol Latinoamer Caribe Plant Med Aromat** 10: 470 - 475.
- Wyckhuys KAG, O'Neil RJ. 2006. Population dynamics of *Spodoptera frugiperda* Smith (Lepidoptera: Noctuidae) and associated arthropod natural enemies in Honduran subsistence maize. **Crop Protect** 25: 1180 - 1190