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Insecticidal Effect of Botanical Extracts on Developmental Stages of *Bactericera cockerelli* (Sulc) (Hemiptera: Triozidae)

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Abstract. Insecticidal effect of aqueous and ethanol extracts of dried leaves of *Ambrosia artemisiifolia* L., *Piper auritum* Kunth, and *Taraxacum officinale* F. H. Wiggwere determined on developmental stages of potato/tomato psyllid, *Bactericera cockerelli* (Sulc). When aqueous extract at 0.2 g/ml was applied to psyllid nymphs, *A. artemisiifolia* extract was most toxic, *P. auritum* was moderately toxic, and *T. officinale* was slightly less toxic. Ethanol extract of *A. artemisiifolia* killed more than 50% of 2nd, 3rd, and 5th instar nymphs treated with 0.001, 0.01, and 0.1 g/ml, respectively. *P. auritum* was effective on 3rd and 4th instars and *T. officinale* on 5th and 3rd instars at 0.01 and 0.1 g/ml, respectively. Ethanol extracts of the three plant species killed 50 to 60% of adults with 0.1 g/ml and 30 to 45% with 0.01 g/ml. Extracts of *Argemone mexicana* L., *Azadirachta indica* A. Juss, *Petiveria alliacea* L., and *Tagetes filifolia* Lag. were evaluated on 4th and 5th instar nymphs. Ethanol extract of leaves of *A. mexicana* at 0.2 g/ml killed 100% of 5th instar nymphs at 24 hours and 93% of 4th instars at 72 hours. *A. indica, P. alliacea,* and *T. filifolia* at 0.2 g/ml killed 85, 88, and 87%, respectively, of 5th instar nymphs.

Resumen. Se desarrolló la investigación para determinar la efectividad biológica de extractos acuosos y etanólicos de especies vegetales sobre *Bactericera cockerelli* (Sulc). Se evaluaron extractos de hojas secas de *Ambrosia artemisiifolia*, *Piper auritum*, y *Taraxacum officinale* sobre los estados de desarrollo del insecto, cuando se aplicó el extracto acuoso a 0.2 g/ml el extracto de *A. artemisiifolia* alcanzó mayor efecto toxico sobre ninfas, *P. auritum* presentó susceptibilidad intermedia, y *T. officinale* fue ligeramente menos susceptible. El extracto etanólico de *A. artemisiifolia* presentó más del 50% de toxicidad en 2do, 3ro, y 5to instar al ser tratadas con 0.001, 0.01, y 0.1 g/ml, respectivamente; *P. auritum* presentó efectividad sobre 3ro y 4to instar, y *T. officinale* sobre 5to y 3ro estadio a 0.01 y 0.1 g/ml. Los extractos etanólicos de las tres especies vegetales mostraron efectividad sobre adultos, registrando datos entre 50 y 60% con 0.1 g/ml y entre 30, y 45% con 0.01 g/ml. Se evaluaron extractos de *Argemone mexicana, Azadirachta indica; Petiveria alliacea*, y *Tagetes filifolia* sobre 4to y 5to instar. La extracción etanólica

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de hojas de *A. mexicana* presento 100% de efectividad a las 24 horas sobre 5to instar y 93% sobre 4to instar a las 72 horas aplicando dosis a 0.2 g/ml. *A. indica*; *P. alliacea*, y *T. filifolia* a 0.2 g/ml presentaron 85, 88, y 87% de toxicidad sobre ninfas de 5to instar, respectivamente.

Introduction

The potato/tomato psyllid, *Bactericera (=Paratrioza) cockerelli* (Sulc) (Hemiptera: Triozidae), is a pest of solanaceous crops. The insect has high reproductive capacity during a lifetime of 24-33 days (Abdullah 2008, Xiang-Bing and Tong-Xian 2009), wide geographical distribution, a variety of cultivated and wild hosts, but perhaps also has developed resistance to insecticide (Vega-Gutiérrez et al. 2008, Cerna et al. 2010). Molecular and biological studies showed *B. cockerelli* associated with phytopathogenic bacteria transmitted to *Capsicum annuum* L., *Solanum lycopersicum* (Mill), *Physalis ixocarpa* Brot., and *S. tuberosum* L. plants (Leyva-López et al. 2002, Santos-Cervantes et al. 2007). The psyllid impacts the United States, Mexico, Central America, and New Zealand by transmitting the bacterium "*Candidatus* Liberibacter solanacearum" (synonym "*Ca*. L. psyllaurous") (Rhizobiaceae) that causes “zebra chip” disease that results in dark stripes when potato tubers are fried during processing (Hansen et al. 2008, Liefting et al. 2008, Lin et al. 2009, Rehman et al. 2010, Sengoda et al. 2010, Crosslin et al. 2011) and is the most destructive disease of the crop (Lin and Gudmestad 2013). Use and potential of plant extracts in protecting crops against insect pests have been demonstrated (Berenbaum 1989, Abdullahi and Muhammad 2004). The main method of controlling the psyllid has been by synthetic insecticide, but because of adverse consequences, searching for natural methods is necessary for new management strategies. However, few references indicate toxicity of plant extracts against potato psyllid. Therefore, the purpose of this research was to determine the insecticidal effectiveness of botanical aqueous and ethanol extracts of *Ambrosia artemisiifolia* L. (Asterales: Asteraceae), *Argemone mexicana* L. (Papaveraceae), *Azadirachta indica* A. Juss. (Meliaceae), *Petiveria alliacea* L. (Phytolaccaceae), *Piper auritum* Kunth (Piperaceae), *Tagetes filifolia* Lag. (Asteraceae), and *Taraxacum officinale* F. H. Wigg (Asteraceae) on developmental stages of the potato psyllid.

Materials and Methods

A flexible-plastic mouth aspirator 60 cm long by 1.5-cm diameter was used to collect about 2,500 unsexed psyllid adults in a greenhouse of organic tomatoes, in the community of Zimatlán de Alvarez (16°52'23.85"N 96°46'31.07"O), Oaxaca, Mexico. Adults were placed into plastic containers of 5,000-ml capacity with leaves of tomato plants and wet cotton to prevent dehydratation and transported to a laboratory. Adults were deposited for oviposition on 8-week-old tomato plants inside 2 x 1 x 2-m entomological cages with covers of anti-aphid mesh. Rearing was in facilities of the Interdisciplinary Research Centre for Regional Integral Development (CIIDIR-OAX) at Santa Cruz Xoxocotlán, Oaxaca, Mexico. Infested tomato plants (approximately 7days) were shaken and removed from the cage and moved to a 3 x 3 x 3-m entomological cage where insects completed development.

Because psyllid adults were collected every 15 days, a seedbed of ‘Cid’ tomatoes was planted to provide hosts for the psyllids. The tomato plants were

transplanted 4 weeks after germination and sown in 20 x 10- and 40 x 20-cm plastic bags containing coconut shell substrate and compost 8:2 (v:v) as support inside the first and second entomological cages, respectively.

Fresh leaves of *A. artemisiifolia* (16º56'53.79"N, 96º45'06.31"O), *P. alliacea, P. auritum, T. filifolia* (16º56'53.79"N, 96º45'06.31"O), *A. indica, A. mexicana*, and *T. officinale* (17º01'08.50"N, 96º46'25.70"W) were collected in the state of Oaxaca, Mexico. Taxonomic identification was made by the curator of the Herbarium CIIDIR-OAX, and a sample for future reference was deposited in the research laboratory. The leaves were washed with tap water, placed on newspaper to dry indoors, and pulverized to powder by a mechanical mill (Granados-Echegoyen et al. 2014).

Twenty grams of powdered leaves were put with 100 ml of distilled water into a flask that was closed tightly and allowed to stand for 24 hours. Filter paper was used to remove the solids from the liquid, and residue was discarded to obtain crude extract for each aqueous treatment. Ethanol extracts were prepared by putting 100 g of powdered leaves into a flask with 250 ml of solvent, stirring, and letting stand for 72 hours. The solution was filtered and solvent evaporated completely by reduced pressure on a rotary evaporator to obtain crude extract for each plant. For the first part of the study, 20 ml of the crude aqueous solution was diluted in 100 ml of distilled water to obtain 0.2 g/ml from which 0.1 and 0.01 g/ml concentrations were prepared. From the crude ethanol extract, 2 g were diluted in 20 ml of distilled water with 0.01% of polysorbate 20 to emulsify the fats present in the ethanol extract, then centrifuged for 5 minutes to homogenize, and filtered to remove lumps, producing a concentration of 0.1 g/ml from which serial dilutions of 0.01 and 0.001 g/ml were produced. In the second part of the study, concentrations of 0.2, 0.1, 0.05, and 0.01g/ml were used for aqueous and ethanol extraction by the same method as the first part.

Cages of 6 cm in diameter by 2.5 cm tall were constructed according to Abdullah (2008) to confine psyllid eggs, nymphs, and adults on tomato leaves. The cages were made with clear plastic Petri dishes with a 4-cm hole in the top covered with anti-aphid mesh for ventilation. A 0.5-cm hole was made for later use with adult psyllids. A sponge at the edge of the Petri dish provided additional height. The bottom of the cage was covered with cardboard covered with yellow foam. An alligator-type hair clip was used to attach the outer surface to the tomato leaf. A wooden stake attached to the cage provided additional support.

Approximately 24 hours later, 100 freshly laid eggs were counted from an area 5 cm in diameter on four randomly selected tomato leaflets, and the remaining eggs were removed with an entomological brush. Plant treatments were applied and an entomological cage was attached. After 24 hours, the number of deformed or discolored eggs in each treatment was compared with the check.

Freshly infested tomato plants (about 48 hours old) were used to determine susceptibility of 1st and 2nd instar nymphs. One hundred eggs per leaflet were counted with the aid of a magnifying glass and allowed to hatch, from which 40 immatures of each instar were used and the remaining were removed. Older tomato plants were selected for 3rd, 4th, and 5th instar nymphs, from which 40 of each stage were counted, each treatment was applied, and an entomological cage was attached. At 24 hours, tomato leaves were cut and the number of dead insects was counted with the aid of a stereomicroscope. Nymphs of 1st, 2nd, 3rd, 4th, and 5th instar were selected according to size and shape as illustrated in the INIFAP (2007) manual for Mexico.

Twenty-five, unsexed, 3-day-old potato psyllid adults were kept without food for 45 minutes. Treatments were applied to tomato leaves and allowed to dry at room temperature; clipcages were placed on the leaves and attached to wooden stakes for support. Adults were introduced through the 0.5-cm hole in the clip cage and the number of dead adults was counted 24 hours later.

In the second part of the study, tomato leaves were submerged according to the method of Akhtara et al. (2012) in treatments for 15 seconds and allowed to dry at room temperature. An entomological brush was used to put 40 potato psyllid nymphs of 4th and 5th instar onto leaves. Numbers of dead psyllids were determined at 24, 48, and 72 hours. Tomato leaves were cut 24 hours after application and the number of dead insects was counted with the aid of a stereomicroscope. The leaves were put onto moistened filter paper in Petri dishes for counting nymphs during the next 2 days.

Analysis of variance and Tukey tests by SAS 9.0 were used to compare mean susceptibility ($p \leq 0.05$) of psyllid stages to plant extracts. Four replications of each treatment, a nontreated check (no botanical extracts were applied), and polysorbate 20 at 0.01% for ethanol extracts were used. Results of the second experiment were expressed cumulatively for the 2nd and 3rd days. Data were subjected to a test of normality and homogeneity of variance.

Results

No stage of psyllid in any check died. Aqueous extract of *A. artemisiifolia* was most toxic, *P. auritum* was intermediate, and *T. officinale* was slightly less toxic to nymphs treated with 0.2 g/ml (Table 1). Lesser concentrations were proportionally less effective. No treatment significantly affected psyllid eggs. *A. artemisiifolia* and *P. auritum* at 0.2 and 0.1 g/ml killed 20 and 10% of adults, respectively, while *T. officinale* had no significant effect on adults.

Concentrations of 0.1 and 0.01 g/ml of ethanol extract killed significantly more than did the greatest concentration of aqueous extract. Ethanol extract of *A.*

Table 1. Percentages of Developmental Stages of *Bactericera cockerelli* Killed by Aqueous Extracts of *A. artemisiifolia, P. auritum*, and *T. officinale*

	Concentration	Mortality (%)* / developmental stage						
Plant species	(g/ml)	Egg	1st	2nd	3rd	4th	5th	Adult
A. artemisiifolia	0.01	0.0 a	30.0 b	22.5 c	15.0 c	5.0 c	5.0 b	7.5 b
	0.1	0.0 a	60.0 a	57.5 b	40.0 b	25.0 b	20.0 b	10.0 b
	0.2	5.0 a	77.5 a	75.0 a	67.5 a	57.5 a	52.5 a	20.0a
	Check	0.0 a	0.0 c	0.0 d	0.0 d	0.0 c	0.0 b	0.0 c
P. auritum	0.01	0.0 a	30.0 b	17.5 bc	17.5 bc	10.0 bc	2.5 b	2.5 c
	0.1	5.0 a	37.5 b	35.0 b	30.0 b	20.0 b	15.0 b	10.0 b
	0.2	5.0 a	67.5 a	65.0 a	60.0 a	55.0 a	50.0 a	20.0 a
	Check	0.0 a	0.0 c	0.0 c	0.0 c	0.0 c	0.0 b	0.0 c
T. officinale	0.01	0.0 a	22.5 b	22.5 b	5.0 b	0.0 b	2.5 b	0.0 a
	0.1	0.0 a	32.5 b	27.5 b	15.0 b	7.5 b	5.0 b	0.0 a
	0.2	2.5 a	60.0 a	55.0 a	35.0 a	35.0 a	30.0 a	5.0 a
	Check	0.0 a	0.0 c	0.0 c	0.0 b	0.0 b	0.0 b	0.0 a

*Means for plant species and developmental stage followed by different letters are statistically different ($p < 0.05$).

artemisiifolia was most toxic, killing more than 50% (65.0, 62.5, and 67.5%) of 2nd, 3rd, and 5th instar nymphs treated with 0.001, 0.01, and 0.1 g/ml, respectively. *P. auritum* killed more than 50% of 3rd and 4th instars and *T. officinale* killed more than 50% of 5th and 3rd instars with 0.01 and 0.1 g/ml, respectively (Table 2). Ethanol extracts of all three plant species at 0.1 g/ml killed between 50 and 60% of psyllid adults and 30 to 45% with 0.01 g/ml.

Table 2. Percentages of Developmental Stages of *Bactericera cockerelli* Killed by Ethanol Extracts of *A. artemisiifolia, P. auritum*, and *T. officinale*

	Concentration	Mortality (%)* / developmental stage						
Plant species	(g/ml)	Egg	1st	2nd	3rd	4th	5th	Adult
A. artemisiifolia	0.001	2.5 bc	55.0 b	65.0 b	42.5 b	35.0 c	25.0 c	22.5 c
	0.01	7.5 ab	70.0a	70.0 b	62.5 a	62.5 b	47.5 b	45.0 b
	0.1	10.0 a	82.5 a	82.5 a	75.0 a	75.0 a	67.5 a	57.5 a
	Check	0.0 c	0.0 c	0.0 c	0.0 c	0.0 d	0.0 d	0.0 d
	Polysorbate 20	0.0 c	0.0 c	0.0 c	0.0 c	0.0 d	0.0 d	0.0 d
P. auritum	0.001	2.5 b	30.0 c	42.5 b	32.5 c	30.0 c	27.5 b	17.5 c
	0.01	5.0 ab	57.5 b	70.0 a	52.5 b	40.0 b	37.5 b	32.5 b
	0.1	10.0 a	72.5 a	70.0 a	70.0 a	67.5 a	67.5 a	60.0 a
	Check	0.0 b	0.0 d	0.0 c	0.0 d	0.0 d	0.0 c	0.0 d
	Polysorbate 20	0.0 c	0.0 c	0.0 c	0.0 c	0.0 d	0.0 d	0.0 d
T. officinale	0.001	0.0 a	12.5 b	30.0 b	32.5 c	27.5 b	25.0 b	10.0 c
	0.01	0.0 a	15.0 b	57.5 a	57.5 b	37.5 b	50.0 a	35.0 b
	0.1	0.0 a	65.0 a	60.0 a	72.5 a	70.0 a	57.5 a	50.0 a
	Check	0.0 a	0.0 c	0.0 c	0.0 d	0.0 c	0.0 c	0.0 c
	Polysorbate 20	0.0 c	0.0 c	0.0 c	0.0 c	0.0 d	0.0 d	0.0 d

*Means for plant species and developmental stage followed by different letters are statistically different ($p < 0.05$).

Table 3. Percentages of 4th and 5th instar Nymphs of *Bactericera cockerelli* Killed when Treated for 3 Days with Ethanol Extracts of *A. mexicana*

Concentration (g/ml)	Mortality (%)* / day (hour)		
5th instar	24	48	72
0.2	100.00 ± 0.00 a	100.00 ± 0.00 a	100.00 ± 0.00 a
0.1	80.40 ± 14.70 b	85.83 ± 14.36 a	85.83 ± 14.36 a
0.05	38.41 ± 15.72 c	45.07 ± 16.79 b	45.07 ± 16.79 b
0.01	0.00 ± 0.00 d	5.00 ± 0.00 c	5.00 ± 0.00 c
Check	0.00 ± 0.00 d	0.00 ± 0.00 c	0.00 ± 0.00 c
Polysorbate 20	0.00 ± 0.00 d	0.00 ± 0.00 c	0.00 ± 0.00 c
4th instar			
0.2	81.87 ± 14.71 a	93.83 ± 14.44 a	93.83 ± 14.44 a
0.1	58.89 ± 14.51 b	65.37 ± 16.13 b	71.83 ± 15.95 b
0.05	58.65 ± 17.27 b	67.74 ± 12.70 b	72.94 ± 12.83 b
0.01	0.00 ± 0.00 c	0.00 ± 0.00 c	0.00 ± 0.00 c
Check	0.00 ± 0.00 c	0.00 ± 0.00 c	0.00 ± 0.00 c
Polysorbate 20	0.00 ± 0.00 c	0.00 ± 0.00 c	0.00 ± 0.00 c

*Means followed by the same letter for an instar in a column are not significantly different ($p \leq 0.05$).

Aqueous extracts did not affect psyllids in the second study. But, ethanol extract of *A. mexicana* at 0.2 g/ml was100% effective after 24 hours and at 0.1 g/ml was 85% effective at 72 hours against 5th instar nymphs (Table 3). Ninety to 70% of 4th instar nymphs died at 72 hours with 0.2, 0.1, and 0.05 g/ml.

Ethanol extracts of *P. alliacea* at 0.2 and 0.1 g/ml killed more than 50% of 5th instar nymphs by 24 hours (Table 4). Eighty-two percent of 4th instars were dead at 24 hours with 0.2 g/ml, but 0.05 and 0.1 g/ml were less effective, killing between 10 and 30% at 72 hours. Ethanol extract of *T. filifolia* at 0.2 g/ml had killed 80% of 5th instar nymphs by 72 hours and 88% of 4th instar nymphs by 24 hours (Table 5).

Table 4. Percentages of 4th and 5th Instar Nymphs of *Bactericera cockerelli* Killed when Treated for 3 Days with Ethanol Extracts of *P. alliacea*

Concentration (g/ml)	Mortality (%)* / day (hour)		
5th instar	24	48	72
0.2	88.55 ± 8.66 a	88.55 ± 8.66 a	88.55 ± 8.66 a
0.1	70.05 ± 13.30 b	70.05 ± 13.30 b	70.05 ± 13.30 b
0.05	38.57 ± 13.06 c	50.51 ± 16.22 c	50.51 ± 16.22 c
0.01	0.00 ± 0.00 d	0.00 ± 0.00 d	0.00 ± 0.00 d
Check	0.00 ± 0.00 d	0.00 ± 0.00 d	0.00 ± 0.00 d
Polysorbate20	0.00 ± 0.00 d	0.00 ± 0.00 d	0.00 ± 0.00 d
4th instar			
0.2	82.00 ± 4.96 a	93.00 ± 7.16 a	93.00 ± 7.16 a
0.1	30.25 ± 9.06 b	36.75 ± 7.36 b	36.75 ± 7.36 b
0.05	11.50 ± 2.38 c	11.50 ± 2.38 c	11.50 ± 2.38 c
0.01	0.00 ± 0.00 d	0.00 ± 0.00 d	0.00 ± 0.00 d
Check	0.00 ± 0.00 d	0.00 ± 0.00 d	0.00 ± 0.00 d
Polysorbate 20	0.00 ± 0.00 d	0.00 ± 0.00 d	0.00 ± 0.00 d

*Means followed by the same letter for an instar in a column are not significantly different ($p \leq 0.05$).

Table 5. Percentages of 4th and 5th Instar Nymphs of *Bactericera cockerelli* Killed when Treated for 3 Days with Ethanol Extracts of *T. filifolia*

Concentration (g/ml)	Mortality(%)* / day (hour)		
5th instar	24	48	72
0.2	70.75 ± 13.5 a	87.50 ± 11.90 a	87.50 ± 11.90 a
0.1	21.25 ± 10.30 b	36.25 ± 10.30 b	36.25 ± 10.30 b
0.05	11.25 ± 6.29 bc	17.50 ± 8.66 c	17.50 ± 8.66 c
0.01	0.00 ± 0.00 c	0.00 ± 0.00 d	0.00 ± 0.00 d
Check	0.00 ± 0.00 c	0.00 ± 0.00 d	0.00 ± 0.00 d
Polysorbate 20	0.00 ± 0.00 c	0.00 ± 0.00 d	0.00 ± 0.00 d
4th instar			
0.2	88.00 ± 17.45 a	88.15 ± 17.38 a	88.15 ± 17.38 a
0.1	37.25 ± 13.45 b	37.39 ± 13.45 b	46.50 ± 14.47 b
0.05	8.50 ± 5.68 bc	16.75 ± 4.11 c	22.25 ± 4.19 c
0.01	0.00 ± 0.00 c	0.00 ± 0.00 d	0.00 ± 0.00 d
Check	0.00 ± 0.00 c	0.00 ± 0.00 d	0.00 ± 0.00 d
Polysorbate 20	0.00 ± 0.00 c	0.00 ± 0.00 d	0.00 ± 0.00 d

*Means followed by the same letter for an instar in a column are not significantly different ($p \leq 0.05$).

Ethanol extracts of *A. indica* at 0.2 and 0.1 g/ml killed more than 50% of 5th instar nymphs by 24 hours. On 4th instar nymphs, mortality at 72 hours was 85 and 77% at the same concentrations, while 0.05 g/ml killed only 30 to 45% of 4th and 5th instar nymphs (Table 6).

Table 6. Percentages of 4th and 5th Instar Nymphs of *Bactericera cockerelli* Killed when Treated for 3 Days with Ethanol Extracts of *A. indica*

Concentration (g/ml)	Mortality (%)* /day (hour)		
5th instar	24	48	72
0.2	76.87 ± 7.46 a	85.00 ± 10.80 a	85.00 ± 10.80 a
0.1	64.75 ± 8.05 b	82.00 ± 8.29 a	91.00 ± 6.37 a
0.05	27.50 ± 3.41 c	39.50 ± 4.20 b	45.00 ± 4.24 b
0.01	0.00 ± 0.00 d	0.00 ± 0.00 c	0.00 ± 0.00 c
Check	0.00 ± 0.00 d	0.00 ± 0.00 c	0.00 ± 0.00 c
Polysorbate 20	0.00 ± 0.00 d	0.00 ± 0.00 c	0.00 ± 0.00 c
4th instar			
0.2	69.50 ± 11.15 a	75.75 ± 9.94 a	84.75 ± 10.96 a
0.1	63.00 ± 13.63 a	77.50 ± 13.22 a	77.43 ± 13.32 a
0.05	24.00 ± 11.51 b	31.00 ± 11.63 b	30. 80 ± 11.73 b
0.01	0.00 ± 0.00 c	0.00 ± 0.00 c	0.00 ± 0.00 c
Check	0.00 ± 0.00 c	0.00 ± 0.00 c	0.00 ± 0.00 c
Polysorbate 20	0.00 ± 0.00 c	0.00 ± 0.00 c	0.00 ± 0.00 c

*Means followed by the same letter for an instar in a column are not significantly different ($p \leq 0.05$).

Discussion

Insecticidal effect of *A. artemisiifolia, A. indica, A. mexicana, P. alliacea, P. auritum, T. filifolia*, and *T. officinale* against *B. cockerelli* is reported for the first time in this investigation. Studies of the genus *Ambrosia* have focused on controlling the weed in crops and determining allergenic properties (Vincent et al. 1992, Kiss 2007, Erberet al. 2011), but species of *Ambrosia* contain sesquiterpene lactones (Rybalko 1978) that are antifeedants, toxins, and growth regulators of insects (Wheeler and Isman 2001). Repellent and deterrent activities interfere with production of molting and juvenile hormones and inhibit synthesis of chitin and digestive enzymes (Ave et al. 1987, Mordue and Blackwell 1993, Koul et al. 1996).

A. artemisiifolia is a widely distributed invasive plant easily established because it adapts to environmental conditions, causes severe allergic reaction by allergen isoforms that induce rhinitis, conjunctivitis, asthma, contact dermatitis, and urticarial (Kazinczi et al. 2008, Girodet 2013, Ognjenovica et al. 2013).

Parmar et al. (1997) described properties of the genus *Piper* including the effect of extracts of species of the genus on pests. Results of this study show potential for *P. auritum* to manage *B. cockerelli*. Variability in composition and chemical diversity of plants is genetically determined and related to species, and secondary metabolites vary quantitatively and qualitatively between individuals of the same botanical family (Barclay and Perdue 1976, Ayres and Loike 1990, Marotti et al. 2004). Matsui and Munakata (1975) mentioned that benzene extract of leaves

of *P. kadsura* Trel. and Yunck caused antifeedant behavior by larvae of *Spodoptera litura* F., and petroleum and dichloromethane extracts from leaves of *P. falconeri* C. were insecticidal against *Musca domestica* L. and *Aedes aegypti* L. (Parmar et al. 1993). Miyakado et al. (1979) isolated and determined that pipercide component (III) of *P. nigrum* L. was similar to pyrethrins against adult *Callosobruchus chinensis* L. Frequently, plants of the genus *Piper* have secondary compounds such as safrole, dillapiol, myristicin, and methylenedioxyphenyl (Parmar et al. 1997) known to be toxic (Buchanan 1978). We hypothesize the effect of botanical extracts on *B. cockerelli* is because of some of the compounds. Scott et al. (2004) determined the effectiveness of extracts of *P. nigrum* L., *P. guineense* Schum and Thonn, and *P. tuberculatum* Jacq. against common pests in gardens and concluded that the three species of Piperaceae contain alkaloids and isobutyl amides neurotoxicin in arthropods. Isman (2006) and Bernard et al. (1995) commented that many species of the Piperaceae family possess insecticidal properties and plant extracts that contain alkaloids, phenols, and terpenoids, are toxic by blocking a vital process of the insect. Secondary plant metabolites have different mechanisms of action on insects, which can be hormonal, reproductive, neurological, nutritional, or enzymatic. *P. auritum* is a perennial aromatic plant in tropical and subtropical regions and used for its therapeutic properties in traditional medicine. Secondary metabolites in extracts from various parts of the plant, are antifungal, insecticidal, antifeedant, bactericidal, and cytotoxic (Santos et al. 2001, Oliveira et al. 2004, Scott et al. 2008).

The chemical composition of extracts of *T. officinale* includes sesquiterpene lactones and phenylpropanoids believed to have medicinal properties (Yarnell and Abascal 2009). Compounds in *T. officinale* have not been identified and the mode of action is not known (Schutz et al. 2006). However, results of this study in which polar solvents were used are contrary to those reported by Souza and Vendramim (2004) who claimed polar extract of *Trichilia pallid* Swartz was more effective than chloroform or hexane extracts to control nymphs of *Bemisia tabaci* (Gennadius). Based on this information, several authors prefer to obtain botanical extracts with solvents of intermediate polarity such as ethanol (Gomez et al. 1997, Cubillo et al. 1999). *T. officinale* is a perennial weed (Moyer et al. 1990) with phenols, sesquiterpenes, triterpenes, and phytosterols (Schutz et al. 2006), and like *A. artemisiifolia* has not been evaluated against insect pests.

Flores-Davila et al. (2011) evaluated hexane and methanol extracts from vegetative structures of *Annona muricata* L., *Carica papaya* L., *Euphorbia dentate* Michx, *Thuja occidentalis* L., *Sapindus saponaria* L., and a commercial derivative from seeds of *A. indica* against *B. cockerelli* nymphs. They reported 91 and 100% efficacy at 72 hours with hexane extract from seeds of *A. indica* at concentrations of 2,000 and 2,500 ppm, respectively. *A. indica* contains bioactive substances such as “azadirachtin A”, salannin, and nimbin insecticidal against pests (Estrada 2008). Extracts from leaves and seeds of neem, control more than 200 species of pests, including those of economic importance (Adhel and Sehnal 2000). Effectiveness was evident in this research, with more than 50% of 4th and 5th instar nymphs killed with 0.05 g/ml by 24 hours.

The study reports for the first time the effectiveness of *A. mexicana* against *Bactericera*, killing 100% in 24 hours. The plant also is toxic against *Drosophila melanogaster* (Meigen) (Kukhopadhyay et al. 2002), *Culex quinquefasciatus* (Say) (Karmegam et al. 1997), *Aedes aegypti* L. (Sakthivadivel and Thilagavathy, 2003), and even the nematode *Meloidogyne javanica* (Trueb) (Shaukat et al. 2002).

P. alliacea leaves contain sulfur compounds (Kubec and Musah 2000, Kubecet al. 2003) that repel insects. Adebayo and Olaifa (1993) evaluated effectiveness of aqueous distillate of plant root and found more than 80% decrease in oviposition by *A. aegypti* and *C. pipiens fatigans* Wied. Aqueous root extract was insecticidal against *Ootheca mutabilis* (Sahlberg), *Maruca testulalis* (Geyer), *Zonocerus variegatus* L., and *Riptortus dentipes* (F.) that affect important crops in Nigeria (Adebayo et al. 2007).

Species of the genus *Tagetes* are effective against bacteria (Souza et al. 2000, Arenas et al. 2004), fungi (Zygadlo et al. 1994, Romagnoli et al. 2005), nematodes (Reynolds et al. 2000, Ball-Coelho et al. 2003), mites (Eguaras et al. 2005), Diptera (Perich et al. 1994, Nivsarkar et al. 2001), lice (Cestari et al. 2004), and stored grain weevils (Weaver et al. 1997). Extracts with active ingredients such as trans-anethole, allylanisole, β-caryophyllene, and tagetoneare toxic are repellents and inhibitors of reproduction and growth (Cestari et al. 2004, Tomova et al. 2005). Camarillo et al. (2009) evaluated aqueous extracts of *T. filifolia* and found insecticidal effect against *Trialeurodes vaporariorum* (Westwood), similar to data reported in this study on *Bactericera.*

In conclusion, ethanol extracts from plants were more effective than aqueous extracts against potato psyllid. Aqueous extracts of leaves of *A. artemisiifolia*, *P. auritum*, and *T. officinale* significantly affected nymphal stages but ethanol extracts were toxic to both nymphs and adults. Ethanol extracts of *A. mexicana, A. indica, P. alliacea,* and *T. filifolia* are an environmentally friendly alternative to control 4th and 5th instar nymphs of *B. cockerelli*.

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