

TOXICITY OF LEAF EXTRACTS FROM *Schinus molle* L. ONTO *Reticulitermes flavipes* Kollar (ISOPTERA: RHINOTERMITIDAE)

Amanda Huerta^{1*}, Ítalo Chiffelle², Scarlett Constenla¹, Tomislav Curkovic³, Jaime E. Araya⁴

¹Department of Silviculture and Nature Conservation, Faculty of Forestry and Nature Conservation, University of Chile. PO Box 9206. 8820808, Santiago, Chile

²Department of Agroindustry and Enology, Faculty of Agronomic Sciences, University of Chile. PO Box 1004. 8820808, Santiago, Chile

³Department of Crop Protection, Faculty of Agronomic Sciences, University of Chile. PO Box 1004. 8820808, Santiago, Chile

⁴Formerly, Faculty of Agronomic Sciences, Universidad of Chile, currently, consultant in Agriculture Entomology, Santiago, Chile

Abstract

The North American subterranean termite *Reticulitermes flavipes* Kollar (Isoptera: Rhinotermitidae) has a strong social and economic impact worldwide, damaging houses and wooden structures in urban environments, causing considerable losses. Infestation foci in central Chile in recent years have expanded. We evaluated the toxic effect of extracts from new leaves of *Schinus molle* L. (Anacardiaceae) onto *R. flavipes*. The extracts were prepared with two solvents, distilled water, and ethanol. The toxic effect of the extracts was evaluated by direct and indirect exposure tests, determining mortality caused by several concentrations, and analyzed with Anovas and Tukey multiple comparison tests, and Probit analysis to obtain the mean lethal concentrations (LC₅₀). The extracts, particularly the ethanol one, had clear toxic effects on the termite, and increased with concentration. The least LC₅₀ obtained on the 7th day after treatment was 0.59% w/v by direct exposure to the ethanolic extract. These results demonstrate the effectiveness of the extracts on *R. flavipes*, so the leaves from *S. molle* could be used in biopesticide preparations for integrated management of this pest, previous field evaluation and economic studies.

Keywords: *Reticulitermes flavipes*, subterranean termites, *Schinus molle*, botanical insecticide

1. INTRODUCTION

Termites are eusocial arthropod decomposers that improve soil fertility and crop yields across the world. However, some species are a threat as they cause directly and indirectly major losses to agriculture, forestry and urban environments. It is estimated that termites cost the global economy more than \$40 billion USD annually, and considerable research has been done on their management (Ahmad et al. 2021).

Reticulitermes flavipes Kollar (Isoptera: Rhinotermitidae), a subterranean termite native to North America, is currently widespread, and has a strong social and economic impact. This xylophagous insect feeds on wood cellulose with the help of protozoa and bacteria found in its guts (Pearce 1997). The importance of this microbiome in the biology of termites is clear, as they exchange proctodeal food, allowing trophalaxy between individuals to maintain the colony (Boucias et al. 2012). Termite colonies are organized into various castes. These develop latter to workers, soldiers, supplementary king and queens, and reproductive winged adults (Edmonds et al. 2011). Recently, Funaro et al. (2018) have expanded understanding of chemically mediated recognition in this termite and helped to understand the evolution of insect societies. In urban environments this termite is a pest that damages houses and wooden structures, causing severe losses. Damage is characterized by internal wood galleries that keep humidity and temperature for development, with pellets of materials displaced (Ripa & Luppichini 2004). In Chile, the first detection of a *Reticulitermes* termite in 1986 in the

Metropolitan Region was identified as *R. flavipes* by genetic studies. Prevention and control methods have been studied by Ripa & Luppichini (2004), and Karsulovic et al. (2008).

Effective methods for reducing pests, most widely used for decades, have been synthetic insecticides. However, they have side effects such as acute and chronic poisoning of workers and consumers, death of fish, birds and other wildlife, disruption of biological control and pollination, and also produce insecticide resistance in pest populations. Botanical insecticides are increasingly important today to replace synthetic insecticides as they are less aggressive to the environment and are an alternative for integrated pest management (Amri et al. 2013, Isman 2020). These plant-derived pesticides, obtained from plant roots, stems, leaves, flowers, fruits, seeds, and wood, are considered potential substitutes of the highly harmful synthetic products. More than 2,000 species of plants in 60 families have pesticide activity, and many are used as insect growth regulators, ecdysone affecting substances, behavior modulators, feeding deterrents, repellents, attractants, and others (Verma et al. 2018). Botanical insecticides have been used in agriculture for at least 2,000 years, particularly in Asia and the Near East (Thacker 2002). The interest in plant compounds for pest control is based in their efficacy, degradability, and physiological activity (Isman 2020).

Molle or Bolivian pepper *Schinus molle* L. (Anacardiaceae), an evergreen tree from Peru, was introduced in Chile by the Incas (Silva et al. 2005). Its leaves and fruits contain terpenes, tannins, alkaloids, flavonoids, saponins, gums, linoleic acid, oleoresins, and essential oils (Ferrero et al. 2006, Alba et al. 2009). Extracts from this tree species have caused promising effects in *Cydia pomonella* L. (Lep.: Tortricidae) (Chirino et al., 2001), *Blattella germanica* L. (Dict.: Blattellidae) (Ferrero et al. 2007), *Nezara viridula* L. (Hem.: Pentatomidae) (Werdin et al. 2008), *Sitophilus oryzae* L. (Col.: Curculionidae) (Benzi et al. 2009), *Blatta orientalis* (Blat., Blattidae) (Deveci et al. 2010), *Xanthogaleruca luteola* Müller (Col.: Chrysomelidae) (Huerta et al. 2010, Chiffelle et al. 2013), *Gonipterus platensis* (ex *scutellatus*) Marelli (Col.: Curculionidae) (Chiffelle et al. 2017), among others.

Studies have been conducted with other plant extracts on *R. flavipes*, like Yuan & Hu (2012) from leaves of *Lantana camara* L. (Lamiales: Verbenaceae), and Huerta et al. (2015) from fruits of *Melia azedarach* L. (Meliaceae). The efficacy of leaf extracts from *S. molle* on insects mentioned above, and the lack of studies on *R. flavipes* led to conduct this study with the aim of developing an environmentally friendly alternative for integrated pest management.

2. MATERIAL AND METHODS

2.1. Materials

New leaves (Chiffelle et al. 2013) were collected at random from adult *S. molle* trees in the Antumapu Campus, University of Chile (33°34'S; 70°38'W), Santiago, Chile, in December (summer). Individuals of *R. flavipes* were collected in March from an outbreak in the Faculty Chemistry and Biology, University of Santiago, Chile. Workers were taken in containers in darkness with moist soil and wood chips, and temperature and humidity, to the laboratory of Forestry Entomology, Department of Silviculture and Nature Conservation, University of Chile, Santiago Chile.

2.2. Methods

The extracts were prepared in the Chemistry Laboratory, Department of Agriculture Industry and Enology, Faculty of Agronomic Sciences, University of Chile, Santiago. New leaves of *S. molle* were collected for two extracts, one in water and the other in 96% v/v ethanol, from which several concentrations were prepared. The leaves were first dried in a forced air oven (Thelco, Mod. 18, Colorado, US) at 45°C to constant weight. Then they were ground in a mechanical mill graduation with a sieve n° 60 (250 µm). This powder was mixed with distilled water or ethanol to obtain solutions at the highest possible concentrations, which were homogenized in a shaker (Heidolph®, MR 3001 K Schwabach, Germany) for 18 h, warming the first hour at 37°C. Then, the supernatant was filtered on a centrifuge (Sigma, Mod. 1-14, Osterode am Harz, Germany) at 1,500 rpm for 15 min. After this, the solutions were filtered again to obtain the extract. Finally, when the concentration of each stock

solution was determined, four concentrations were prepared by dilution at 1.6; 3.3; 4.9, and 6.5% w/v (water extract) and 2.9; 5.8; 8.6, and 11.5% w/v (ethanol extract).

The method in Manzoor et al. (2011) was used to determine the toxicity of the extracts. In the direct exposure test a red neutral solution (not toxic) was used at 0.5% w/v to evaluate digestive toxicity. This color is distinguished by transparency. A 3 cm diameter filter paper dyed in red was set on Petri dishes treated with one of the extracts, air dried 30 min, with four concentrations per extract, plus three controls, one with filter paper humidified with red stained ethanol, another wet with red stained water, and last, a starvation control; 3 g de moisted soil was set at the bottom of the dishes instead of the filter paper (Fig. 1).

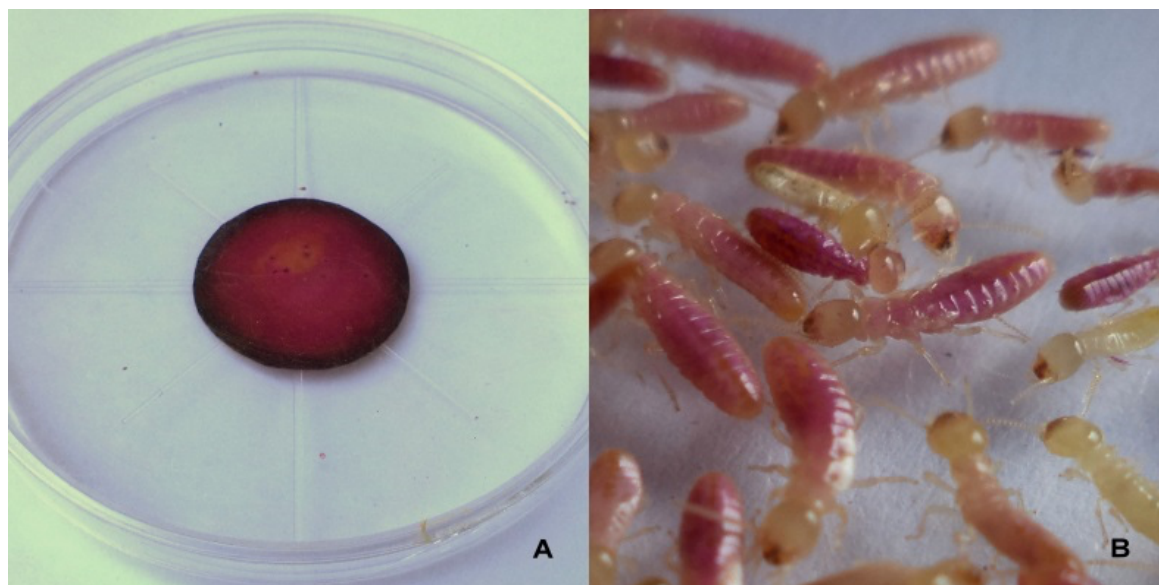


Fig. 1. Direct exposure test. A) Petri dish with the red stained filter paper. B) Termites red after eating the food treated with the dye.

For the indirect exposure test, 2 cm diameter filter paper discs added the extract at each concentration were set under the lid of the Petri dishes and air dried 30 min. Termites in this test had no direct contact with the extracts in the filter paper. Untreated 5 cm diameter filter paper discs were set at the bottom of each Petri, water moistened for water supply. Four concentrations were tested for each extract, plus controls with filter paper moistened with water or ethanol. The control dishes for the fasting test contained 3 g moisted soil at the bottom instead of filter paper.

Both tests had five treatment replicates, with 10 workers per Petri dish. These tests lasted 14 d for the indirect bioassay and 11 d for the direct exposure, and the daily percentage of mortality was determined on each. Results were normalized by Bliss ($\arcsin\sqrt{X(N^\circ \text{ of dead workers})/100}$) to ensure homoscedasticity and normality of the parametric tests. Mortality data were subjected to Anovas and Tukey tests. Also, the LC_{50} were determined by Probit analysis, adjusted with χ^2 tests. All statistical analysis were done using the InfoStat (2009) software.

3. RESULTS

3.1. Direct exposure test

At 6 d for the ethanol extract and 9 d for the water extract, mortality of the *R. flavipes* workers reached near 50% or greater mortality (Table 1). Both extracts presented significant differences between the

concentrations and the controls, demonstrating their insecticide effect ($F_{\text{ethanol } 5,24} = 7.14$; $P < 0.05$; $F_{\text{water } 5,24} = 5.14$; $P < 0.05$).

Table 1. Mortality (% $\pm$ SE) of *R. flavipes* workers exposed to the ethanolic (day 6) and aqueous (day 9) extracts in the direct bioassay tests at several concentrations of extracts from new leaf *S. molle*.

Ethanolic extract (%w/v)	Mortality on day 6 (%)	Aqueous extract (%w/v)	Mortality on day 9 (%)
11.5	92 $\pm$ 4 c	6.5	80 $\pm$ 2 b
8.6	80 $\pm$ 6 bc	4.9	54 $\pm$ 4 b
5.8	76 $\pm$ 7 bc	3.3	50 $\pm$ 2 ab
2.9	64 $\pm$ 9 bc	1.6	48 $\pm$ 2 ab
Starvation control (soil)	44 $\pm$ 7 ab	Starvation control (soil)	86 $\pm$ 6 b
Control (Only ethanol)	14 $\pm$ 4 a	Control (Only water)	10 $\pm$ 2 a

Mortality percentages with different letters in a column are significantly different, according to Tukey test ($p \leq 0.05$).

Mortality increased with concentration of both extracts. The greatest concentration of the ethanolic extract (11.5% w/v) caused 92% mortality at 6 d, and the aqueous extract (6.5% w/v) 80% mortality at 9 d. The least concentration of the ethanolic extract (2.9% w/v) caused 64% mortality at 6 d, and the aqueous extract (1.6% w/v) 48% at 9 d (Table 1).

3.2. Indirect exposure test

Mortality reached near 50% or greater at 11 d for the ethanolic extract and at 14 d for the water one. Both extracts presented significant differences between concentrations and controls (water $F_{5,24} = 61.52$; $P < 0.05$; ethanol $F_{5,24} = 60.60$; $P < 0.05$), demonstrating an insecticide effect (Table 2).

Table 2. Mortality (% $\pm$ SE) of *R. flavipes* workers exposed to the ethanolic (day 11) and aqueous (day 14) extracts in the direct bioassay tests at several concentrations.

Ethanolic extract (%w/v)	Mortality on day 11 (%)	Aqueous extract (%w/v)	Mortality on day 14 (%)
11.5	72 $\pm$ 4 b	6.5	56 $\pm$ 1 b
8.6	60 $\pm$ 3 b	4.9	54 $\pm$ 2 b
5.8	56 $\pm$ 2 b	3.3	52 $\pm$ 2 b
2.9	52 $\pm$ 1 b	1.6	44 $\pm$ 3 b
Starvation control (soil)	100 $\pm$ 0 c	Starvation control (soil)	100 $\pm$ 0 c
Control (Only ethanol)	12 $\pm$ 2 a	Control (Only water)	10 $\pm$ 3 a

Mortality percentages with different letters in a column are significantly different, according to Tukey test ($p \leq 0.05$).

The ethanol extract had a greater insecticide effect, as its lowest concentration (2.9% w/v) caused 52% mortality at 11 d, and this same percentage occurred with the aqueous extract at a greater concentration (3.3% w/v) and at day 14. Mortality with both extracts increased with concentration.

However, no significant differences between concentrations occurred in those days with the same extract, but they occurred with the controls, indicating an insecticide effect (Table 2).

3.3. Determination of the CL_{50}

In the same day, for both exposure tests, the concentrations causing 50% mortality were smaller with the ethanolic than the aqueous extract, thus the first one had a stronger effect (Table 3).

Table 3. LC_{50} of the extracts from new leaf *S. molle* on *R. flavipes*.

Bioassays	Extracts	Days	Slopes*	LC_{50} (% w/v)	χ^{2**}
Direct exposure	Ethanolic	5	22.70 ± 4	3.45	1.95
		6	18.81 ± 3	1.44	1.11
		7	15.14 ± 1	0.59	0.87
	Aqueous	5	15.88 ± 2	7.67	3.95
		6	16.90 ± 6	5.14	3.23
		7	20.56 ± 9	3.60	1.33
Indirect exposure	Ethanolic	9	18.06 ± 5	5.12	0.83
		10	18.62 ± 4	4.50	0.80
		11	12.90 ± 4	2.94	0.43
	Aqueous	9	15.52 ± 1	5.47	2.29
		10	15.52 ± 1	4.81	2.92
		11	10.82 ± 1	4.33	2.92

* Means $\pm$ SE. ** The χ^2 estimate calculated was lesser than that tabled ($df = 3$; $p \leq 0.05$) = 7.81, thus tests results were adjusted to the Probit model.

In the direct exposure test, at 6 d the ethanolic extract caused 50% mortality at 1.44% w/v, and the aqueous extract at 5.14% w/v, thus the first extract was more effective (Table 3).

In the indirect exposure test, the ethanolic extract caused 50% mortality at 11 d at the least concentration (2.94% w/v), and the extract had a lesser LC_{50} of 4.33% w/v, maintaining the trend of the direct exposure test, of the greater effectivity of the ethanolic extract, although at narrower level (Table 3).

4. DISCUSSION

In our study, 92% mortality of *R. flavipes* in the direct exposure test occurred at 11.5% w/v at 6 d, and 50% at 3.3% w/v at 9 d with the ethanolic and aqueous extracts, respectively. Using the same methodology, Huerta et al. (2015) evaluated extracts of immature fruits of *M. azedarach* on *R. flavipes* workers in a direct exposure test, obtaining 58% mortality with the ethanolic extract at 11.4% w/v, and 36% with the extract at 3.4% w/v, both at 5 d. Thus, both extracts prepared similarly from *S. molle* were more efficient than those from *M. azedarach*, especially the ethanolic extract. The extracts from both the fruits of *M. azedarach* and the leaves of *S. molle* were effective, probably because both plants contain limonoids, to which insecticide properties are attributed (Steinbauer & Wanjura 2002). Yuan and Hu (2012) assessed the toxic effect on *R. flavipes* workers using a similar method but with a chloroform extract from dry leaves from *L. camara*. Termite mortality was much greater in the exposure treatments than the controls. Filter paper treated at 0.03 and 0.015% w/v resulted at day 10 in

50 and 30% mortality, respectively. Those results were greater than those in our study when using much lower concentrations.

In our study, the indirect exposure test determined 72% mortality using the ethanolic extracts from new leaves of *S. molle* at the greatest concentration (11.5% w/v) at 11 d, and 52% with the aqueous extract at 3.3% w/v at 14 d. Similarly, in Huerta et al. (2015) with fruit extracts from *M. azedarach* using the same method, 86% mortality of *R. flavipes* was obtained with the ethanolic extract (11.4% w/v), and 62% with the aqueous extract (3.4% w/v), both at 11 d. Those results indicate that the ethanolic and extracts from *M. azedarach* were more toxic on *R. flavipes* than those from *S. molle*. Although the mortality levels caused in both studies are significant, indirect exposure was less effective than direct exposure, possibly because the active principles of both extracts from *M. azedarach* and *S. molle* act better directly on the termite through food consumption.

Huerta et al. (2010) evaluated also the toxicity of ethanolic and aqueous extracts from the leaves of *S. molle* onto adults of the elm leaf beetle *X. luteola* at 2.5-5.6% w/v for the aqueous extract and 2.0-4.7% w/v for the ethanol one, applied directly to the elm leaves used to feed the insects. Both extracts caused significant mortality of *X. luteola*, stronger with the ethanolic extract, 90% mortality at 2.5% w/v at 6 d, and near 50% with the aqueous extract at 3% w/v at 8 d. Herein, direct exposure of *R. flavipes* workers to the ethanolic extract caused only 64% mortality at 2.9% w/v at 6 d, and 50% at 3.3% w/v, a concentration slightly greater at 9 d. Thus, although both the ethanolic and aqueous extracts from *S. molle* were toxic, they are more effective against *X. luteola* adults than *R. flavipes* workers.

Using a similar method, Chiffelle et al. (2013) evaluated the insecticide effect of aqueous and ethanolic extracts from new and mature leaves of *S. molle* on larvae of *X. luteola* in direct exposure. The ethanolic extract from new leaves had a greater effect, with 81% mortality, at a lower concentration of 2.2% w/v at 12 d. The aqueous extract caused 72% mortality at 4.3% w/v at 12 d. Thus, both extracts were more effective on larvae of *X. luteola* than workers of *R. flavipes*.

Iannaccone & Alvarino (2010) evaluated the toxic effect of a aqueous extract from leaves of *S. molle* onto adults of *Orius insidiosus* (Say) (Hemiptera: Anthocoridae), and obtained 29.4% mortality at 5% w/v 48 h after exposure. Herein, the aqueous extract caused 54% mortality at 4.9% w/v, but at 9 d. From this, the toxic effect of this extract acts faster on *O. insidiosus* than *R. flavipes* at similar concentrations.

As per the LC_{50} , in our study with the ethanolic and aqueous extracts from new leaves of *S. molle* achieved LC_{50} of 0.59 and 3.6% w/v, respectively at 7 d, while Huerta et al. (2010) obtained LC_{50} of 0.19 and 8.52% w/v onto adults of *X. luteola* with the ethanolic and aqueous extracts at 8 d. Comparing results, the ethanolic extracts from leaves of *S. molle* were more effective onto adults of *X. luteola* than to workers of *R. flavipes*, although both extracts have toxic effects. Chiffelle et al. (2013) estimated the LC_{50} of extracts from new leaves of *S. molle* on larvae of *X. luteola*, obtaining with the ethanolic and aqueous extracts values of 1.28 and 2.56% w/v at 7 d, respectively, being again the ethanolic extract more effective against workers of *R. flavipes*, although both extracts had toxic effects.

5. CONCLUSIONS

Ethanolic and aqueous extracts from new leaves of *S. molle* had a toxic effect on *R. flavipes* workers, and mortality increased with concentration. The ethanolic extract had a greater toxic effect than the aqueous one, both in direct and indirect exposure tests in the laboratory, although these results should be validated in the field. Thus *S. molle* has potential as a bioinsecticide that could be used in integrated management of *R. flavipes*, after studying the market feasibility.

REFERENCES

1. Ahmad, F, Fouad, H, Liang, S, Hu, Y, Mo J 2021, 'Termites and Chinese agricultural system: applications and advances in integrated termite management and chemical control', *Insect Science*, vol., 28, pp. 2-20.
2. Alba, A, Bonilla, P, Arroyo, J 2009 'Actividad cicatrizante de una pomada con aceite esencial de *Schinus molle* L. "molle" en ganado vacuno con heridas infectadas y en ratones. Ciencia e Investigación Agraria 12(1): 29-36.
3. Amri, I, Hamrouni, L, Hanana, M, Jamoussi, B 2013, 'Reviews on phytotoxic effects of essential oils and their individual components: news approach for weeds management', *International Journal Applied Biology and Pharmaceutical Technology*, vol.4, pp. 96-114.
4. Benzi, V, Stefanazzi, N, Ferrero, A 2009, 'Biological activity of essential oils from leaves and fruits of pepper tree (*Schinus molle* L.) to control rice weevil (*Sitophilus oryzae* L.). ', *Chilean Journal Agricultural Research*, vol. 69, no 2, pp: 154-159.
5. Boucias, D, Cai, Y, Sun, Y, Lietze, V, Sen, R, Raychoudhury, R, Scharf, M 2012, 'The hindgut lumen prokaryotic microbiota of the termite *Reticulitermes flavipes* and its responses to dietary lignocelullose composition', *Molecular Ecology*, vol. 22, pp. 1836-1853.
6. Chiffelle, I, Huerta, A, Celis, M, Araya, J 2013, 'Proximal analysis and insecticidal effects of extracts from pepper tree (*Schinus molle*) leaves on elm leaf beetle (*Xanthogaleruca luteola*) larvae', *Industrial Crops and Products*, vol. 43, pp. 523-528.
7. Chiffelle, I, Huerta, A, Sandoval, C, Araya, J 2017, 'Insecticide effect of leaf extracts from *Schinus molle* on larvae of *Gonipterus platensis*', *Revista Facultad Nacional de Agronomía Medellín*, vol. 70, no 3, pp. 8263-8270.
8. Chirino, M, Cariac, M, Ferrero, A 2001, 'Actividad insecticida de extractos crudos de drupas de *Schinus molle* L. (Anacardiaceae) sobre larvas neonatas de *Cydia pomonella* L. (Lepidoptera: tortricidae)', *Boletín de Sanidad Vegetal, Plagas*, vol. 27, pp. 305-314.
9. Deveci, O, Sukan, A, Tuzun, N, Hames, E 2010, 'Chemical composition, repellent and antimicrobial activity of *Schinus molle* L.', *Journal of Medicinal Plants Research*, vol. 4, no 21, pp. 2211-2216.
10. Edmonds, R, Agee, J, Gara, R 2011, *Forest health and protection*, 2nd ed., Long Grove, Illinois.
11. Ferrero, A, Sánchez, C, Werdin, J, Alzogaray, A 2007, 'Repelencia y toxicidad de extractos de *Schinus molle* en *Battella germanica*', *Fitoterapia*, vol. 78, pp. 311-314.
12. Ferrero, A, Werdin, J, Sánchez, C 2006, 'Biological activity of *Schinus molle* on *Triatoma infestans*', *Fitoterapia*, vol. 77, no 5, pp. 381-383.
13. Funaro, CF, Böröczkyb, K, Vargoc, EL, Schal C 2018, 'Identification of a queen and king recognition pheromone in the subterranean termite *Reticulitermes flavipes*', *Proceeding of the National Academy of Sciences*, vol. 115, no.15, pp. 3888-3893.
14. Huerta, A, Chiffelle, I, Puga, K, Azúa, F, Araya, J 2010, 'Toxicity and repellence of aqueous and ethanolic extracts from *Schinus molle* on the elm leaf beetle *Xanthogaleruca luteola*', *Crop Protection*, vol. 29, pp. 1118-1123.
15. Huerta, A, Rubio, B, Chiffelle, I 2015, 'Toxic effect of *Melia azedarach* L. unripe fruit extracts onto *Reticulitermes flavipes* Kollar (Isoptera: Rhinotermitidae)', *Proceeding 46th The International Research Group on Wood Protection (IRG) Annual Meeting*. Section 1 Biology. Viña del Mar, Chile. 10-14 May. 6p. IRG/WP 15-10850.
16. Iannacone, J, Alvaríño, L 2010, 'Toxicidad de *Schinus molle* L. (Anacardiaceae) a cuatro controladores biológicos de plagas agrícolas en el Perú', *Acta Zoológica Mexicana*, vol. 26, no 3, pp. 603-615.

17. InfoStat 2009, *Infostar versión 2009*, Grupo InfoStat, FCA, Universidad Nacional de Córdoba, Córdoba, Argentina.
18. Isman, M 2020, 'Botanical Insecticides in the Twenty-First Century-Fulfilling Their Promise?', *Annual Review of Entomology*, vol. 65, pp. 233-249.
19. Karsulovic, J, Bozo, A, Araya, JE, Vargas, Y, Gaete, V, Tejer, B 2008, 'Aplicación de ondas sónicas y ultrasónicas como medio de control del ataque de termitas subterráneas *Reticulitermes flavipes* (Kollar) en madera de pino radiata', *Maderas. Ciencia y Tecnología*, vol. 10, no. 2, pp. 99-111.
20. Manzoor, F, Pervez, M, Hassan, M, Malik, S 2011, 'Effects of three plant extracts on the repellency, toxicity and tunneling of subterranean termite *Heterotermes indicola* (Wasmann)', *Journal Applied Environmental Biological Sciences*, vol. 1, no.7, pp. 107-114.
21. Pearce, M 1997, *Termites: Biology and pest management*. CAB International, Wallingford, UK.
22. Ripa, R, Luppichini, M 2004, 'Termitas de importancia económica en Chile', *Tierra Adentro*, vol. 59, pp. 42-51.
23. Silva, S, Bozinovic, F, Jaksic, F 2005, 'Frugivory and seed dispersal by foxes in relation to mammalian prey abundance in a semiarid thornscrub', *Austral Ecology*, vol. 30, pp.739-746.
24. Steinbauer, M, Wanjura, W 2002, 'Christmas beetles (*Anoplognathus* spp., Coleoptera: Scarabaeidae) mistake peppercorn trees for eucalypts'. *Journal of Natural History*, vol. 36, pp. 119-125.
25. Thacker, JRM 2002, *An introduction to arthropod pest control*, Cambridge Univ. Press, Cambridge, UK.
26. Verma, M, Verma, S, Sharma, S 2018, *Eco-friendly termite management in tropical conditions. Termites and Sustainable Management*, Springer, Cham.
27. Yuan, Z, Hu, XP 2012, 'Repellent, antifeedant, and toxic activities of *Lantana camara* leaf extract against *Reticulitermes flavipes* (Isoptera: Rhinotermitidae)', *Journal of Economic Entomology*, vol. 105, pp. 2115–2121.
28. Werdin, J, Ferrero, A, Murray A 2008, 'Bioactividad de aceites esenciales de *Schinus molle* var. areira (Anacardiaceae) en ninfas II de *Nezara viridula* (Hemiptera: Pentatomidae)', *Boletín de Sanidad Vegetal, Plagas*, vol. 34, pp: 367-375.