Insecticidal activity of powder and essential oil of Cryptocarya alba (Molina) Looser against Sitophilus zeamais Motschulsky

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ABSTRACT

Cereals constitute a relevant part of human and domestic animal diet. Under storage conditions, one of the most significant problems of these crops is insect pests as the maize weevil (Sitophilus zeamais Motschulsky). This insect species is usually controlled by means of synthetic insecticides but problems as toxic residues and resistance has led to the search for more friendly control alternatives such as botanical insecticides. The aim of this research was to evaluate, under laboratory conditions, the insecticidal properties of the powder and the essential oil of peumo (Cryptocarya alba [Molina] Looser; Lauraceae) leaves against S. zeamais. The variables assessed were toxicity by contact and fumigant activity, adult emergence (F1), repellent effect, and impact on wheat (Triticum aestivum L.) seed germination. A completely randomized design was used with five treatments and 10 replicates. The higher mortality levels were obtained at 80 g powder kg⁻¹ grain and 40 mL essential oil kg⁻¹ grain of C. alba; in both cases, the mortality of adult S. zeamais surpassed 80%. The emergence of adults S. zeamais (F1) was reduced by 100% at 80 g powder kg⁻¹ grain and 40 mL essential oil kg⁻¹ grain. Germination of wheat seeds treated with C. alba powder and essential oil was not affected. Both, the powder and the oil treatments showed repellent effect, but not fumigant activity.

Key words: Bioinsecticide, maize weevil, peumo, stored grains.

INTRODUCTION

Because of the grain damage on stored conditions, the maize weevil (Sitophilus zeamais Motschulsky) is a key pest of cereals worldwide. This insect species is usually controlled by means of synthetic insecticides but according to the Arthropod Pesticide Resistance Database (www.pesticideresistance.org) of Michigan State University, S. zeamais has 32 reports of resistance to nine different insecticides used against this pest on rice (Oryza sativa L.), maize (Zea mays L.), and sorghum (Sorghum bicolor L.). Hence, the use of botanical insecticides should be considered as an alternative.

The botanical insecticides have been used as powders, extracts, and essential oils for many years. These pesticides have shown contact, fumigant, antifeedant, and repellent activity against insects (Silva et al., 2003). The easiest way to use botanical insecticides against stored grain pest consist on drying the foliage and then mixing it with the grain. However, if fumigant effect is required, the essential oil is a better option.

The Chilean research about insecticidal activity of native plants derivates is very limited and focuses on a reduced number of species as boldo (Peumus boldus Molina; Monimiaceae) (Betancur et al., 2010), Laurelia sempervirens (Ruiz & Pav.) Tul. (Monimiaceae) (Torres et al., 2014), Laureliopsis philippiana (Looser) Schodde (Monimiaceae) (Ortiz et al., 2012), and Drimys winteri J.R. Forst. & G. Forst. (Winteraceae) (Andrade et al., 2009). Hence, it is important to explore other Chilean plant species.

The peumo (Cryptocarya alba [Molina] Looser; Lauraceae), is a tree native from Chile that grows from southern Coquimbo to Los Lagos Region. It is a perennial tree with dense and dark foliage, reaching 15-20 m tall (Hoffmann, 1983). Its leaves contain 0.3% of essential oil, being the main components α-pinene, β-pinene, β-terpinene, cymol, terpinen-4-ol, and 1,8-cineole (Avello et al., 2012). Studies of essential oils extracted from other plants that contain terpinen-4-ol, 1,8-cineole or cymol as the main components, have shown insecticidal activity against insects pest of stored products as S. zeamais (Tapondjou et al., 2005; Kouninki et al., 2007), Sitophilus granarius L. (Coleoptera: Curculionidae) (Kordali et al., 2006) and Tribolium confusum Jacquelin du Val (Coleoptera: Tenebrionidae) (Tapondjou et al., 2005), among others. The aim of this research was to assess, under laboratory conditions, insecticidal properties of the powder and the essential oil from C. alba foliage against S. zeamais.
MATERIALS AND METHODS

Essential oil extraction and analysis

_Cryptocarya alba_ foliage was field-collected in December 2012 from Pinto county (36°42’ S, 71°54’ W, 286 m a.s.l.), Ñuble Province, Biobío Region, Chile, using the Vogel et al. (1997) criteria. The taxonomic identification of field-collected foliage was verified according to voucher CONC-CH 5488 and deposited in herbarium of Faculty of Agronomy of University of Concepcion at Chillan. Once field-collected, the leaves were dried out during 24 h in a stove (UNB 500, Memmert Gmbh, Schwabach, Germany) at 40 °C. After that, the foliage was ground in an electric coffee grinder (A5052HF, Moulinex, Aleçon, France) to obtain a fine powder which was sieved throughout a 20 mesh (0.841 mm) (Dual Manufacturing, Chicago, Illinois, USA). According to Silva et al. (2003) this granulometry has the highest level of grain adherence. The essential oils were obtained by steam distillation during 4 h using distilled water in a Clevenger type apparatus (Kouninki et al., 2007). Subsequently, the oil was stored in amber-colored glass containers at 4.5 °C. Previous to the bioassays and analysis by gas chromatography (GC), the essential oil was treated with sodium sulfate to eliminate water traces.

Chemical analysis of essential oil was assessed by GC coupled to mass spectrometry detection (GC-MS), using a high performance gas chromatography mass spectrometry (HPGC-MS series II 5890; Hewlett Packard, Palo Alto, California, USA). Separation was achieved using a 5% poly diphenyl 95% dimethylsiloxane bonded phase column (i.d. 0.25 mm, length 30 m, film thickness 0.25 µm). Operation conditions were as follow: injector temperature, 250 °C; carrier gas (helium), flow rate 1 mL min⁻¹ and split injection with a split ratio 1:20. Mass spectrometry conditions were as follows: ionization voltage 70 eV; emission current 40 mA; scan rate 1 scan s⁻¹; source temperature 285 °C. Mass range was 35-300 Da. The oven temperature was 2 min isothermal at 60 °C and then increased to 210 °C, at the rate of 10 °C min⁻¹, and to 260 °C, at rate of 10 °C min⁻¹. Samples (1 µL) were dissolved with CH₂Cl₂ (1:100 v/v). The MS fragmentation pattern was checked with the standards available in our laboratory, and by matching the MS data with the library NIST NBS54K (National Institute of Standards and Technology [NIST], Gaithersburg, Maryland, USA) or literature. The relative amounts of each component were obtained from GC analysis using flame ionization detector in the same experimental conditions described for GC-MS analysis. In these conditions the linear retention indices (RI) were calculated using a mixture of n-alkanes (C₈-C₂₈).

Insects and grain

The insects used in those study were obtained from stock cultures maintained in the Laboratory of Entomology of University of Concepcion, Campus Chillan, and they were reared in 1 L glass flasks containing wheat at 30 ± 1 °C, 60 ± 5% RH and total darkness in a bioclimatic chamber (IPS 749, Memmert Gmbh, Schwabach, Germany). The sex was determined using the criteria proposed by Halstead (1963).

Wheat for insect rearing and bioassay was obtained from the fruit and vegetable market of city of Chillan. Only healthy grain it was washed with drinkable water and dried in a stove (UNB 500, Memmert Gmbh) at 25 °C for 12 h and then frozen at -4 ± 1 °C for 48 h prior to its use.

Bioassays of contact toxicity

The bioassay with powder was carried out using the methodology of Silva et al. (2005). The respective treatment was added into 250 mL glass jars containing 100 g of wheat grains. Then the container was hand shaken during 1 min. After that, 20 insect couples, 48 h-old were added. Untreated control consisted in a jar with 100 g wheat grains infested with 20 pairs of insects. After insect infestation, containers were transferred to a bioclimatic chamber (30 ± 1 °C, 60 ± 5% RH and total darkness). The percentage of mortality was assessed at 7 d after infestation (DAI) and was corrected by means of the Abbott’s formula (Abbott, 1925), but if control exceeded 10% mortality, the whole respective replicate was discarded and repeated. An insect was considered dead when they failed to move after being prodded gently with a needle during 30 s. After recording the percent mortality, all insects were removed and the respective flasks returned to a bioclimatic chamber under previously described environmental conditions.

The contact toxicity bioassays with essential oil were carried out using the methodology of Obeng-Ofori and Reichmuth (1997). Solutions of 1 mL essential oil in acetone were applied to 400 mL glass flasks containing 200 g wheat grains. Then, the flasks were covered and hand shaken during 15 s to properly cover the grains with oil; then they uncovered and left for 2 h at room temperature (20 ± 5 °C) to allow the acetone to evaporate. After that, the flasks were infested with 20 insect couples, 48 h-old. The experimental units were stored in a bioclimatic chamber at 30 ± 1 °C, 60 ± 5% RH and total darkness. Mortality was assessed as previously described.

The evaluated treatments were 5.0, 10, 20, 40, and 80 g powder kg⁻¹ grain and 2.5, 5.0, 10, 20, and 40 mL essential oil kg⁻¹ grain. Every treatment had 10 replicates. To obtain the median lethal concentration (LC₅₀), data were subjected to Probit analysis using the PROC PROBIT procedure of Statistical Analysis System (SAS) software (SAS Institute, Cary, North Carolina, USA).

For both, the powder and the essential oil bioassays, after 36 (week 3), 50 (week 5) and 55 (week 7) DAI the emergence of the F₁ was assessed. The amount of F₁ adults were recorded and percent emergence was calculated, considering values of the untreated control as 100%.

The impact of the treatments on wheat germination was evaluated 55 DAI. To set up the experiment, 20 healthy wheat seeds per replicate were selected, then they were laid down on...
Bioassays of fumigant and repellent effect

The methodology to evaluate the fumigant effect of the *C. alba* powder was adapted from Tavares and Vendramim (2005). At the bottom of 200 mL plastic containers, a PVC tube of 5 cm long and 2.5 cm in diameter, containing the respective treatment, was stuck vertically with silicone. Then, the end of PVC tube was covered with a piece of fine organza fabric to prevent direct contact of insects with the powder, but allowing the release of volatile compounds into the environment. Then, the rest of the inner space between the container and the tube was filled with 20 g wheat grains, and infested with 20 unsexed insects. The untreated control consisted in plastic containers with 20 g wheat grains infested with 20 insects without powder in the tube. The mortality assessment by the fumigant effect was made 5 DAI. The treatments assessed were 5.0, 10, 20, 40, and 80 g powder kg⁻¹ grain and each treatment consisted of 10 replicates.

To carry out the bioassay to evaluate the fumigant toxicity of essential oil, we used the methodology of Pires et al. (2006), which consisted of applying 0 (control), 15, 20, 25, 30, and 35 μL of essential oil on a circular Whatman nr 10 filter paper (5.5 cm diameter; Whatman, Maidstone, Kent, UK). Then, the treated paper was attached to undersurface of screw caps of a 500-mL glass container (air volume equivalent to 0.5 L) and 200 g wheat grain was added and infested with 10 adult insects, 48-h old without sexing. Mortality was assessed 5 DAI and 10 replicates were run for each treatment.

The methodology proposed by Mazzonetto and Vendramim (2003) was used by repellent effect. The experimental unit was a choice arena consisting in a central Petri dish with 20 adults, 48 h-old of *S. zeamais* without sexing. This Petri dish was connected to four dishes using tubes (10 cm long and 0.5 cm diameter), two dishes contained 20 g treated grain and the other two 20 g of untreated grain (Procopio et al., 2003). The choice arenas were kept in a bioclimatic chamber (30 ± 1 °C, 60 ± 5% RH and total darkness), for 24 h and the number of insects that moved to each treatment was recorded. Each treatment had 10 replicates and in each replicate, the treatments were randomly rotated to avoid the possible interference of external factors. The repellent index was calculated with these results according to Mazzonetto and Vendramim (2003), who classified the treatment as neutral if the index = 1, attracting if > 1 and repellent if < 1.

Experimental design and statistical analysis

The experimental design was a completely randomized design. The variable percentage was transformed to the √x/100 arcsine function prior to carry out ANOVA (α = 0.05) test with the SAS program to determine if at least one treatment was different from the rest. If so, a Tukey means comparison test was used (p ≤ 0.05). Probit analysis responses were considered different when their respective fiducially limits did not overlap at a given mortality level (50%) (Robertson and Preisler, 1992).

RESULTS AND DISCUSSION

The principal constituents of the essential oil of *C. alba* were (E)-beta-bergamotene (15.6%), viridiflorol (8.5%), germacrene-D (7.65%), β-apo-13-carotenone (5.3%), linalool (4.4%), (-)-terpinen-4-ol (3.45%), 2-methyl-cyclopentane propanone (3.38%), α-farnesene (2.93%), β-himachelene (2.74%), 1,8-cineole (1.85%), β-cubebene (1.53), jasmolene 1 (1.47%), and safrole (1.1%) (Table 1). Our results do not agree with Niemeyer and Teillier (2007) and Avello et al. (2012), who mainly identified 1,8-cineole (21.4%) and 1-terpin-4-ol (28.19%), respectively. We attribute these differences to the fact that there are differences in the field-collection date and on the geographical zone where the plant material was field-collected. Niemeyer and Teillier (2007) collected foliage on April (fall season) in Ocoa (32°54.957’ S; 71°02.7080’ W), Valparaiso Region, and Avello et al. (2012) and we collected foliage in Biobío Region but Avello et al. (2012) in November (spring season) in Nonguen Valley wood (36°49’ S; 73°01’ W) and we in December (summer season) in Pinto county (36°42’ S; 71°54’ W), Ñuble Province foothills.

The main secondary metabolite identified with insecticidal properties is the (E)-beta-bergamotene which is a sesquiterpene identified as a volatile compound released by plants in response to insect herbivory (Zhuang et al., 2012) and as a male pheromone of ectoparasitoid *Melittobia digitata* Dahms (Hymenoptera: Eulophidae) (Consoli et al., 2002). Huang et al. (2002) indicated that safrole has insecticidal activity against *S. zeamais* and *Tribolium castaneum* (Herbst) (Coleoptera: Tenebrionidae) and according to Obeng-Oferi and Reichmuth (1997) this compound also affects *S. granarius, S. zemais, T. castaneum, and Prostephanus truncatus* (G.H. Horn) (Coleoptera: Bostrichidae). The other identified compounds are viridiflorol, germacrene-d, linalool, (-)-terpinen-4-ol and 1,8-cineole, which are components of the essential oils in other plant species, and have shown insecticidal activity against *S. zeamais* (Chu et al., 2012), *Sitophilus oryzae* L. (Coleoptera: Curculionidae) (Priet et al., 2011), and *Cacopsylla chinensis* (Yang & Li, 1981) (Hemiptera: Psyllidae) (Liu et al., 2014), among others.

Contact toxicity

The highest mortality reached by the use of the *C. alba* powder was obtained with the treatment of 80 g powder kg⁻¹ grain which caused 85% of mortality (Table 2), being...
significantly higher in comparison with the other treatments (p ≤ 0.05). The rest of treatments (5.0 to 40 g powder kg⁻¹ grain) showed a level of mortality lower than 30%. The LC₅₀ was 50 g powder kg⁻¹ grain and according to this results, we can infer that the powder of C. alba foliage has the potential to control S. zeamais only at concentrations higher than 80 g powder kg⁻¹ grain. Although, 80 g powder kg⁻¹ grain showed a mortality greater than 80%, our results exhibit a lower toxicity than other vegetable powders assessed against S. zeamais as D. winteri (Andrade et al., 2009) and P. boldus (Silva et al., 2003), which have 100% mortality with concentrations similar or lower than 4.0% (40 g powder kg⁻¹ grain). Moreover, a concentration of 8.0% should be considered impractical because of the high amount of required powder. For example, to protect 100 kg of cereal it will be required 8 kg of peumo powder; so we estimate that we required about 20 kg of Cryptocarya alba foliage. However C. alba shows better results than other essential oils evaluated against the same insect species as occurred with Salvia hyadranga DC. ex Benth. (Hydrangeaceae) that at the concentration of 4.0% (40 mL essential oil kg⁻¹ grain) led to 68.3% mortality (Kotan et

| Compound                  | RT†  | Relative content | Identification ¹  |
|---------------------------|------|------------------|------------------|
| Heptanal                  | 4.73 | 0.18             | MS, IK, S        |
| Isoterpinolene            | 5.55 | 0.27             | MS, IK, S        |
| Sabine 1                  | 6.17 | 0.50             | MS, IK, S        |
| α-Felandrene              | 6.43 | 0.77             | MS, IK, S        |
| β-Terpinene               | 6.63 | 1.64             | MS, IK, S        |
| 1,3,8-p-Menthatriene      | 6.76 | 0.15             | MS, IK, S        |
| 1,5-Dimethyl-1,5-cyclooctadiene | 6.83 | 0.43             | MS, IK, S        |
| 1-8-Cineole               | 6.89 | 1.85             | MS, IK, S        |
| Isoterpinolene            | 7.79 | 0.45             | MS, IK, S        |
| Linalool                  | 7.93 | 4.40             | MS, IK, S        |
| 3-Hopentyl isovalerate    | 8.13 | 2.20             | MS, IK, S        |
| Unknown                   | 8.18 | 0.26             | MS, IK, S        |
| cis-p-2-Menth-1-ol        | 8.33 | 0.22             | MS, IK, S        |
| Pinocarveol               | 8.63 | 1.84             | MS, IK, S        |
| (3Z,2,2,5,5-Tetra methyl hex-3-eno) | 8.86 | 0.58             | MS, IK, S        |
| (c)-Terpinen-4-ol         | 9.22 | 3.45             | MS, IK, S        |
| Terpinol                  | 9.40 | 0.87             | MS, IK, S        |
| Linalyl formate           | 10.27| 0.22             | MS, IK, S        |
| 7-Octen-2-one             | 10.60| 0.24             | MS, IK, S        |
| 2-Nonanone                | 10.82| 0.24             | MS, IK, S        |
| Safrone                   | 10.87| 1.01             | MS, IK, S        |
| α-Cubebene                | 11.69| 0.73             | MS, IK, S        |
| β-Phenylethyl butyrate    | 12.25| 0.32             | MS, IK, S        |
| (c)-Caryophyllene         | 12.27| 0.44             | MS, IK, S        |
| E-β-Bergamotene           | 12.81| 15.60            | MS, IK, S        |
| (c)-Aristolene            | 12.95| 0.28             | MS, IK, S        |
| β-Bisabolene              | 13.00| 0.22             | MS, IK, S        |
| α-Caryophyllene           | 13.13| 0.23             | MS, IK, S        |
| Isolatedene               | 12.22| 0.79             | MS, IK, S        |
| α-Cadinene                | 13.43| 0.18             | MS, IK, S        |
| Phenethyl isovalerate     | 13.44| 0.76             | MS, IK, S        |
| Germacrene-δ              | 13.47| 7.65             | MS, IK, S        |
| α-Cadinene                | 13.49| 0.16             | MS, IK, S        |
| α-Bulnesene               | 13.55| 0.25             | MS, IK, S        |
| δ-Elemene                 | 13.66| 0.29             | MS, IK, S        |
| Bicycloisquifeladrone     | 13.850| 0.81            | MS, IK, S        |
| β-Cubebene                | 13.944| 1.53           | MS, IK, S        |
| Cubinene                  | 14.070| 0.90            | MS, IK, S        |
| 2-(1,3-Butadienyl) mesitylene | 14.216| 0.25       | MS, IK, S        |
| α-Farnesene               | 14.330| 2.93            | MS, IK, S        |
| Unknown                   | 14.540| 0.52            | MS, IK, S        |
| 1,3,3-Trimethyl-2-(3-methyl-2-methylene-but-3-enyliden-1)     | 14.660| 0.15            | MS, IK, S        |
| cyclohexanone β-Apo-13-carotene | 14.710| 5.30       | MS, IK, S        |
| Jasminol 1                | 14.866| 1.47            | MS, IK, S        |
| 3-Decene                  | 15.060| 0.25            | MS, IK, S        |
| β-Himachelone             | 15.220| 2.74            | MS, IK, S        |
| β-Phenylethyl butyrate    | 15.280| 0.17            | MS, IK, S        |
| 3,9-Dodecadione           | 15.340| 0.28            | MS, IK, S        |
| α-Cubebene                | 15.410| 0.84            | MS, IK, S        |
| 2-Methyl-cyclopentane propanone | 15.470| 3.38       | MS, IK, S        |
| Veridi florol             | 15.570| 8.50            | MS, IK, S        |
| Dehydro-aromadendrene     | 16.105| 0.45            | MS, IK, S        |

¹Retention time.
²Compounds identified by comparison with mass spectra (MS) from database, Kovats retention indices (IK), and pure standards (S).

| Treatments | Concentration | Mortality* (%) |
|------------|---------------|---------------|
| Powder     |               |               |
| 5.0        | 11.2b         |               |
| 10.0       | 10.0b         |               |
| 20.0       | 15.4b         |               |
| 40.0       | 22.9b         |               |
| 80.0       | 84.6a         |               |
| n⁵       | 200           |               |
| b ± SE⁶    | 1.70 ± 0.55   |               |
| LC₅₀        | 50            |               |
| (95% CL)⁸  | 44.2-56.7     | 0.99          |
| R²          |               |               |

Essential oil

| Treatments | Concentration | Mortality* (%) |
|------------|---------------|---------------|
| 2.5        | 15.5c         |               |
| 5.0        | 13.0c         |               |
| 10.0       | 23.0c         |               |
| 20.0       | 59.5b         |               |
| 40.0       | 94.0a         |               |
| n           | 200           |               |
| b ± SE      | 1.33 ± 0.46   |               |
| LC₅₀        | 14.6          |               |
| (95% CL)⁸  | 12.8-16.2     | 0.99          |

|CONFIDENCE LIMITS AT 95% |
|------------------------|
| 44.2-56.7              |

| g kg⁻¹ grain; ††mL kg⁻¹ grain; †††Total number of insects treated.|
|²Probit adjustment slope (b) and standard error of slope (SE); ³Lethal concentration: g powder kg⁻¹ grain or mL essential oil kg⁻¹ grain; ⁴Confidence limits at 95%; ⁵Coefficient of determination.|

| Values within a column with the same letter are nonsignificantly different according to Tukey’s test (p ≤ 0.05).|

| Treatments (%) | Concentration | Mortality* (%) |
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| Powder        |               |               |
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| 10.0          | 10.0b         |               |
| 20.0          | 15.4b         |               |
| 40.0          | 22.9b         |               |
| 80.0          | 84.6a         |               |
| n            | 200           |               |
| b ± SE       | 1.70 ± 0.55   |               |
| LC₅₀         | 50            |               |
| (95% CL)⁸  | 44.2-56.7     | 0.99          |
| R²          |               |               |

| Values within a column with the same letter are nonsignificantly different according to Tukey’s test (p ≤ 0.05).|
al., 2008), 

Cupressus sempervirens L. (Cupressaceae) and Eucalyptus saligna Sm. (Myrtaceae) that at 5.0% (50 mL essential oil kg\(^{-1}\) grain) of essential oil reached a 25% and 10% of dead insects, respectively (Tapondjou et al., 2005).

The toxicity of the powder and the essential oil of C. alba against S. zeamais, is maybe due to the bioactivity compounds such as 1,8-cineole and terpineole. These compounds exist in other plant species with insecticidal activity. According to Calmasur et al. (2006), the essential oils of two species of the genus Achillea have 1,8-cineole and caused of 100% mortality against S. granarius and T. confusum. Furthermore, Clemente et al. (2007), using 1,8-cineole isolated from essential oil of Lavandula spica T. confusum and caused of 100% mortality against oils of two species of the genus Achillea activity. According to Calmasur et al. (2006), the essential compounds exist in other plant species with insecticidal compounds such as 1,8-cineole and terpineole. These compounds showed an F\(_1\) emergence higher than the one observed with the 40 and 80 g powder kg\(^{-1}\) grain treatments which caused an emergence of F\(_1\) adult S. zeamais of 10.5% and 0%, respectively. The F\(_1\) values obtained with treatments of 40 and 80 g powder kg\(^{-1}\) grain treatments which caused an emergence of F\(_1\) adult S. zeamais lower concentration of 1,8-cineole (1.85%) and safrole (1.01%). According to Lee et al. (2004) 1,8-cineole is one of the most promissory monoterpenes with fumigant activity against insect pest control in stored products, and Huang et al. (2002) obtained a significant fumigant toxicity with safrol and isosafrol against S. zeamais and T. castaneum.

All treatments with powder and essential oil of C. alba showed a germination percentage similar (p > 0.05) to the untreated control (Table 4). According these results, C. alba has advantages over other plant powder or essential oils that negatively affect germination. For example, according Pérez et al. (2007), P. boldus reduces maize germination. The higher germination values obtained (> 90%) in treatments of 20 and 40 mL essential oil kg\(^{-1}\) grain oil comply with the requirement to export seeds; thus increasing the possibility of using the more effective treatments to protect grain and seed.

### Fumigant and repellent effect

All assessed treatment of powder or essential oil of C. alba showed 0% mortality. These results are maybe due to the lower concentration of 1,8-cineole (1.85%) and safrole (1.01%). According to Lee et al. (2004) 1,8-cineole is one of the most promissory monoterpenes with fumigant activity against insect pest control in stored products, and Huang et al. (2002) obtained a significant fumigant toxicity with safrol and isosafrol against S. zeamais and T. castaneum.

All treatments with powder and essential oil of C. alba showed a repellence index < 1 (Table 5), which according Mazzonetto and Vendramim (2003) classifies as repellent activity. Although the indexes with lower values (> repellency) were registered in treatments with higher concentrations of

### Table 3. Emergence (F\(_1\)) of adults of Sitophilus zeamais to different concentrations of powder and essential oil of Cryptocarya alba.

| Treatments | Concentration | Insect emergence (%) |
|------------|---------------|----------------------|
| Powder     | 0.0\(^g\)     | 100.0d               |
|            | 5.0           | 74.1d                |
|            | 10.0          | 48.6c                |
|            | 20.0          | 51.4c                |
|            | 40.0          | 8.6b                 |
|            | 80.0          | 0.0a                 |
| Essential oil | 0.0\(^g\)   | 100.0d               |
|            | 2.5           | 20.7b                |
|            | 5.0           | 15.9a                |
|            | 10.0          | 8.2ab                |
|            | 20.0          | 0.0a                 |
|            | 40.0          | 0.0a                 |

\(^g\) kg\(^{-1}\) grain; \(^{1}\) mL kg\(^{-1}\) grain. Emergence of control treatment was considered as 100%. Values within a column with the same letter are not significantly different according to Tukey’s test (\(p \leq 0.05\)).

### Table 4. Germination of wheat mixed with different concentrations of powder and essential oil of Cryptocarya alba.

| Treatments | Concentration | Germination (%) |
|------------|---------------|-----------------|
| Powder     | 0.0\(^g\)     | 100.0a          |
|            | 5.0           | 82.1a           |
|            | 10.0          | 77.9a           |
|            | 20.0          | 86.3a           |
|            | 40.0          | 86.7a           |
|            | 80.0          | 88.3a           |
| Essential oil | 0.0\(^{1}\)  | 100.0a          |
|            | 2.5           | 95.0a           |
|            | 5.0           | 93.5a           |
|            | 10.0          | 86.5a           |
|            | 20.0          | 90.0a           |
|            | 40.0          | 96.0a           |

\(^g\) powder kg\(^{-1}\) grain, \(^{1}\) mL essential oil kg\(^{-1}\) grain. Values within a column with the same letter are not significantly different (Tukey, \(p \leq 0.05\)).
Table 5. Repellence index of powder and essential oil of Cryptocarya alba against adults of Sitophilus zeamais.

| Treatments     | Concentration | Repellence index (IR) | Effect |
|---------------|---------------|-----------------------|--------|
| Powder        | 5.0†          | 0.98                  | Repellent |
|               | 10.0          | 0.92                  | Repellent |
|               | 20.0          | 0.92                  | Repellent |
|               | 40.0          | 0.91                  | Repellent |
|               | 80.0          | 0.82                  | Repellent |
| Essential oil | 2.5††         | 0.28                  | Repellent |
|               | 5.0†          | 0.19                  | Repellent |
|               | 10.0          | 0.27                  | Repellent |
|               | 20.0          | 0.21                  | Repellent |
|               | 40.0          | 0.19                  | Repellent |

†g powder kg⁻¹ grain, ††mL essential oil kg⁻¹ grain, IR: neutral (IR = 1), repellent (IR < 1), attractive (IR > 1).

powder or essential oil, the repellent effect is detectable. According to Conti et al. (2010) this effect is directly related with monoterpenes concentration. Thus if the monoterpenes concentration is lower, usually the most abundant components in essential oils, the lower will be the repellency.

CONCLUSIONS

The powder and essential oil of foliage of Cryptocarya alba under laboratory conditions have contact insecticidal activity and repellence effect against adults of Sitophilus zeamais without affecting wheat germination. The essential oil C. alba may have potential to be developed as a new natural contact insecticide to control insects of stored products.

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