Bioefficacy of *Alpinia galanga* (Zingiberaceae) Rhizome Extracts, (E)-*p*-Acetoxycinnamyl Alcohol, and (E)-*p*-Coumaryl Alcohol Ethyl Ether Against *Bactrocera dorsalis* (Diptera: Tephritidae) and the Impact on Detoxification Enzyme Activities

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**ABSTRACT** The application of insecticides to control oriental fruit fly, *Bactrocera dorsalis* Hendel (Diptera: Tephritidae), is a principal component of the current management of these fruit flies. However, we evaluated four extracts of *Alpinia galanga* Wild Linn (Zingiberaceae) rhizomes against adult flies and found hexane and ethanol extracts to be most effective (LC$_{50}$ = 4.866 and 6.337 ppm, respectively, after 24 h). This suggested that both nonpolar and polar compounds could be active in the candidate plant. Accordingly, the hexane extract was further processed to isolate nonpolar active compounds from this plant source. Two compounds, (E)-*p*-acetoxycinnamyl alcohol and (E)-*p*-coumaryl alcohol ethyl ether, were identified as active ingredients and found to be more active than total hexane extract (LC$_{50}$ = 3.654 and 4.044 ppm, respectively, after 24 h). The data suggested that the compounds were not synergistic but may have some additive effect in a mixture. The activity of the hexane extract against detoxification enzymes, carboxylesterase (CE) and glutathione transferase (GST) also was determined in vitro. CE was inhibited by 70%, whereas GST was not significantly inhibited. Insect CEs mediate insecticide resistance via their induction; therefore, inhibition of these enzymes by plant allelochemicals could be a useful alternative approach for the management of the pest in the field.

**KEYWORDS** *Bactrocera dorsalis*, *Alpinia galanga*, toxicity, carboxylesterase, glutathione transferase

Oriental fruit fly, *Bactrocera dorsalis* Hendel (Diptera: Tephritidae), is endemic to Southeast Asia and Pacific (Christenson and Foote 1960). It is one of the major pest species in the genus *Bactrocera*, with a broad host range of cultivated and wild fruit, such as sweet apple, *Annona squamosa* L., jackfruit, *Artocarpus heterophyllus* L. am ex. Lamarr, mango, *Mangifera indica* L., and orange, *Citrus sinensis* (L.) Osbeck. The species is considered as one of the important quarantine pests in the tropical and subtropical areas of the world, and it is one of the most economically damaging pests in Thailand. Use of synthetic insecticides has been a common method of control, but reports of resistance and cross-resistance to insecticides such as organophosphates, carbamates, pyrethroids, are also well known (Hsu et al. 2004, Hsu and Feng 2006; Chou et al. 2010). Control measures adopted are mostly the use of contact poisons or bait traps for adult flies (Vargas et al. 2003), but such applications affect nontarget beneficial fauna including some parasitoids (Khan et al. 2007). Sterile insect technique has been another important component of integrated approach to control fruit flies (Wong et al. 1992, Hendrichs et al. 2002), which has been successful, for example, in Okinawa, Japan (Koyama et al. 2004). However, there have been some constraints to this approach due to the polyandrous and long-distance migratory abilities of the flies under high population densities throughout the years; therefore, it is not suitable for continental areas (Khan et al. 2007). The use of botanical pesticides is an effective alternative approach for controlling many pest insects. Plants produce allelochemicals to protect themselves from herbivore attack and many phytochemicals are known to affect insects (Dev and Koul 1997, Koul 2005). Many phytochemicals from Thai plants are also known to control various insect species in Thailand (Bullangpoti 2009). Accordingly, *Alpinia galanga* (Zingiberaceae), or greater galangal, was selected for the purpose specifically due to its wide cultivation in Southeast Asia and because its rhizomes are extensively used as a flavoring spice and it has medicinal properties as well. Recent studies also show that this plant has antibacterial (Khattak et al. 2005), antiplasmodium (Latha et al. 2009), antioxidant and anti-microbial (Wong et al. 2009) properties. The essential oil (Raina

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et al. 2002) and compounds therein, like phenylpropo-
noids (Zhu et al. 2006), 1’-acetoxychavicol acetate
(Latha et al. 2009), p-hydroxycinnamaldehyde and
[di-(p-hydroxy-cis-styryl)] methane (Barik et al.
1987) are responsible for such activities.

In the current study, we report the effect of rhizo-
me extracts, and two isolated compounds from Alpinia
galanga Wild Linn (Zingiberaceae) rhizomes for the
control of B. dorsalis. The studies also demonstrate
the impact on detoxification enzymes such as carboxy-
lesterase (CE) and glutathione transferase (GST) in
these fruit flies.

Materials and Methods

Insect Rearing. A laboratory colony of B. dorsalis
was reared at the Zoology Department, Faculty of
Science, Kasetsart University, in a cage (39 by 19 by 6
cm) at 25 ± 2°C and a photoperiod of 12:12 (L:D) h.

Newly emerged adults (up to 500 flies per cage) were
provided with water and a standard laboratory diet.

For each experiment 3- to 5-d-old adult flies were
randomly used for the toxicity assay.

Extraction and Isolation Method. The extraction
method was modified from Bullangpoti et al. (2007).
Dried rhizomes of A. galanga (2 kg) were taken from
Suratthani Province, Thailand (50 km south of Bang-
kok), and they were extracted by a Soxhlet apparatus
(15 g per thimble) by using the solvents in sequential
order: hexane, dichloromethane, ethyl acetate, and
ethanol. Each crude extract was dried using a rotary
evaporator (R-215, Buchi, Thailand) and stored at 4°C
until further use in the experiments.

The most active crude hexane extract (51.40 g) was
fractionated using vacuum silica gel column chroma-
tography (Kiesel gel 60G, Merck, Thailand) and eluted
with elution in sequential order: hexane, dichloromethane, ethyl acetate, and ethanol. Each crude extract was dried using a rotary
evaporator (R-215, Buchi, Thailand) and stored at 4°C.

Fraction 1 (2.16 g), the most effective in the bio-
assays, was subjected to column chromatography (Kiesel gel 60G) and eluted with hexane/ethyl acetate
(5:1) to give two subfractions, 1-1 (0.37 g) and 1-2
(0.33 g). Both subfractions were further purified by
preparative TLC (Silica gel 60 PF254, Merck) by using
hexane and ethyl acetate as elutents.

Spectral Analysis. The purified subfractions were
subjected to nuclear magnetic resonance (NMR)
analysis. Proton (1H) and carbon (13C) NMR spectra
were recorded on a Varian Inova 400 (Varian, Inc.,
Palo Alto, CA) operating at 400 (1H) and 100 MHz
(13C). The chemical shifts (δ) are reported in parts
per million relative to tetramethylsilane. Splitting pat-
tems are designated as s, singlet; d, doublet; t, triplet;
g, quartet; m, multiplet; and br, broad.

Toxicity Bioassays. Adult fruit flies (3 to 5 d old)
were used to determine median lethal concentration
(LC90) by a spray method. Seven concentrations were
prepared in 20% aqueous acetone. For each extract,
the concentration range was 2,000–14,000 ppm. How-
ever, for the moderately active dichloromethane and
ethyl acetate extracts, concentrations beyond 14,000
ppm also were used to determine the LC90 values for
these extracts. For spraying, the solution was taken in
glass spray bottle with small spray nozzle and sprayed
on the insects placed in a petri dish (9 cm in diameter)
at a pressure of ~10 psi. A volume of 1 ml per replicate
in each treatment was used for the experiment (30
adults per replicate, five replicates). Mortality was
recorded after 24 and 48 h posttreatment, and control
mortality was taken into account in deriving dose
response. Data were analyzed by Probit analysis using
StatPlus version 2008 (Analystsoft, Inc., NY) to
calculate LC90. Adult fly behavioral responses after treat-
ment, such as paralysis or knockdown, were noted. In
case of two pure compounds isolated, a similar pro-
cedure of evaluation was followed as mentioned above,
and six concentrations in the range of 1,000–6,000
ppm for each compound, were used to determine
the LC90 values.

In vivo Assay of Extracts on B. dorsalis Enzyme
Activity. B. dorsalis adults treated at the LC90 level
and a control group of flies were used for enzyme prepa-
ration in vitro. In treatment group 5 surviving flies
after 24-h treatment were pooled from each replicate
(weight = 100 ± 10 mg) and homogenized in a mortar
and pestle at 4°C in 0.1 M potassium phosphate buffer,
ph 8.0, containing 1 mM EDTA and 10 mM glutathi-
one in reduced form. After centrifugation at 10,000
rpm for 5 min at 4°C, the clear supernatant was col-
clected and used as an enzyme source for the analysis
of GST and CE enzyme activities. All procedures were
conducted on ice to minimize loss of enzyme activity.

The method adopted for determining GST activity
was that of Oppenooorth (1979). The reaction solution
contained 20 μl of enzyme solution, 1.150 μl of 0.1 M
potassium phosphate buffer, pH 7.3, and 10 μl of 150
mM 1-chloro-2,4-dinitrobenzene (CDNB). Optical
density was recorded at intervals of 30 s for 3 min at
25°C and 340 nm with a spectrophotometer (Lamda
25, Perkin Elmer Life and Analytical Sciences, Boson,
MA). The GST activity was determined from the ex-
tinction coefficient of 0.000137 for CDNB. CE activity
was determined using the methods of Han et al.
(1998). Enzyme solution (50 μl) was mixed with p-
nitrophenylacetate (pNPA) (50 μl, 0.12 M) and phos-
phate buffer (2.9 ml, 0.1 M; pH 7.5). Enzyme activity
was measured at 400 nm and 25°C for 3 min with the
spectrophotometer in the kinetic mode. The activity
of CE was determined by using the extinction coeffi-
cient of 176.4705 for pNPA. Total protein content for
each enzyme solution was determined using a Bradford
kit (Bio-Rad Laboratories, Hercules, CA) with
bovine serum albumin as the standard and analyzed
with the spectrophotometer at 600 nm.
Results

The various extracts obtained after sequential solvent extractions showed that maximum yield was in ethanol (10.24%) and the least in dichloromethane (0.27%) (Table 1). Overall, the toxicity of these extracts was dose dependent with hexane and ethanol extracts being the best (Fig. 1). Very moderate activity was recorded in ethyl acetate and dichloromethane extract treatments (Table 2). Ethanol extract treatment was the second best but significantly different from hexane extract toxicity (Table 2). Obviously, the hexane extract being the most potent material was indicative of nonpolar compounds to be active, and ethanol extract is expected to contain equally potent polar compounds. However, in the current study, most active hexane extract was processed further to isolate active compounds as the first step of investigation of the active ingredients in this plant material.

The crude hexane extract was further fractionated using silica gel chromatography with a series of solvents (Table 3). Among the seven fractions separated by this technique, fraction 7 showed the highest yield by weight. The toxicity of each fraction was tested against *B. dorsalis* adults by using the spray method (Table 4) at the LC50 level of total extract to determine that which fraction possessed the maximum activity. Fraction 1 showed the highest toxicity; there-

### Table 1. Characteristics and amount of crude extract of *A. galanga* rhizomes obtained in different solvent extractions

<table>
<thead>
<tr>
<th>Extract</th>
<th>Wt (g)</th>
<th>Yield (%)&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hexane</td>
<td>51.40</td>
<td>2.57</td>
<td>Yellow-brown oil</td>
</tr>
<tr>
<td>Dichloromethane</td>
<td>5.45</td>
<td>0.27</td>
<td>Dark brown gum</td>
</tr>
<tr>
<td>Ethyl acetate</td>
<td>10.97</td>
<td>0.55</td>
<td>Dark brown powder</td>
</tr>
<tr>
<td>Ethanol</td>
<td>204.87</td>
<td>10.24</td>
<td>Dark brown gum</td>
</tr>
</tbody>
</table>

<sup>a</sup> Weight of crude extract/wt of dried plant) × 100.

### Table 2. Toxicity of *A. galanga* extracts to *B. dorsalis* adults

<table>
<thead>
<tr>
<th>Extraction</th>
<th>LC50 ± SD (ppm)&lt;sup&gt;b&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>24 h</td>
</tr>
<tr>
<td>Hexane</td>
<td>4,866 ± 184d</td>
</tr>
<tr>
<td>Dichloromethane</td>
<td>24,156 ± 880a</td>
</tr>
<tr>
<td>Ethyl acetate</td>
<td>16,744 ± 641b</td>
</tr>
<tr>
<td>Ethanol</td>
<td>6,337 ± 145c</td>
</tr>
<tr>
<td></td>
<td>48 h</td>
</tr>
<tr>
<td>Hexane</td>
<td>4,357 ± 194d</td>
</tr>
<tr>
<td>Dichloromethane</td>
<td>22,599 ± 915a</td>
</tr>
<tr>
<td>Ethyl acetate</td>
<td>14,778 ± 584b</td>
</tr>
<tr>
<td>Ethanol</td>
<td>6,012 ± 137c</td>
</tr>
</tbody>
</table>

<sup>b</sup> Within each column means followed by different letter are significantly different (*P* < 0.05; Duncan’s multiple range test).

Fig. 1. Mean ± SE mortality of *B. dorsalis* adults after 24-h (A) and 48-h (B) exposure to *A. galanga* extracts.
fore, it was further purified by using column chromatography to obtain subfractions 1-1 and 1-2. Each subfraction was purified further by preparative TLC to obtain 90% pure compounds, which were subsequently subjected to spectral analysis.

Subfraction 1-1 separated by hexane/ethyl acetate (3:1) was identified as (E)-p-coumaryl alcohol ethyl ether (43.50 mg) (Fig. 2), a colorless oil; 1H NMR (100 MHz, CDCl₃) δ 7.35 (2H, d, J = 8.4 Hz, H3 and H5), 6.62 (1H, d, J = 16 Hz, H7), 6.13 (1H, dt, J = 16, 6.4 Hz, H8), 4.02 (2H, dd, J = 6.4, 1.2 Hz, H9), 3.56 (2H, q, J = 7.2 Hz, H10), 1.25 (3H, t, J = 7.2 Hz, H11); 13C NMR (100 MHz, CDCl₃) δ 155.7 (C4), 132.5 (C7), 129.2 (C1), 127.8 (C2 and C6), 115.5 (C3 and C5), 71.4 (C9), 65.6 (C10), 15.1 (C11). NMR data were consistent with the data from Whitaker et al. (2001).

Subfraction 1-2 separated by hexane/ethylacetate (3:1) was characterized as (E)-p-acetoxyaminomethyl alcohol (35.50 mg) (Fig. 3), a pale yellow solid; 1H NMR (400 MHz, CDCl₃) δ 7.35 (2H, d, J = 8.4 Hz, H2 and H6), 7.02 (2H, d, J = 8.4 Hz, H2 and H6), 6.13 (1H, d, J = 16 Hz, H7), 6.13 (1H, dt, J = 16, 6.4 Hz, H8), 4.02 (2H, dd, J = 6.4, 1.2 Hz, H9), 3.56 (2H, q, J = 7.2 Hz, H10), 1.25 (3H, t, J = 7.2 Hz, H11); 13C NMR (100 MHz, CDCl₃) δ 155.7 (C4), 132.5 (C7), 129.2 (C1), 127.8 (C2 and C6), 123.4 (C8), 115.5 (C3 and C5), 71.4 (C9), 65.6 (C10), 15.1 (C11). NMR data were consistent with those from Paraskar and Sudalai (2000). Both compounds were toxic to the flies and comparable with the toxicity obtained with the crude hexane extract (Table 5). The insects showed initial knockdown and subsequently flies were paralyzed.

Because hexane extract contained the active compounds, this extract was used to determine whether there was any activity against the detoxification enzymes of the flies. These experiments revealed that CE activity of B. dorsalis was inhibited (Table 6), but there was no significant effect on GST (P > 0.05). The ratio of control group activity to treated group activity was 0.31 for CE and 0.87 for GST, suggesting CE activity was significantly inhibited by 70% (Table 6), but GST was inhibited by 13% only with an enzyme activity of 0.33 ± 0.03 CDNB conjugated product/mg protein/min, which was similar to controls (0.39 ± 0.03).

**Table 3. Characteristics of each fraction from hexane crude extract separated by column chromatography**

<table>
<thead>
<tr>
<th>Fraction</th>
<th>Solvent system Characteristics</th>
<th>Wt (%, wt:wt)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>100% hexane-10% ethyl acetate-dichloromethane</td>
<td>Yellow gum</td>
</tr>
<tr>
<td>2</td>
<td>20% ethyl acetate-dichloromethane-30% ethyl acetate-dichloromethane</td>
<td>Yellow gum</td>
</tr>
<tr>
<td>3</td>
<td>40% ethyl acetate-dichloromethane</td>
<td>Yellow gum</td>
</tr>
<tr>
<td>4</td>
<td>50% ethyl acetate-dichloromethane</td>
<td>Yellow gum</td>
</tr>
<tr>
<td>5</td>
<td>60% ethyl acetate-dichloromethane-70% ethyl acetate-dichloromethane</td>
<td>Brown-yellow gum</td>
</tr>
<tr>
<td>6</td>
<td>80% ethyl acetate-dichloromethane-100% ethyl acetate</td>
<td>Yellow gum</td>
</tr>
<tr>
<td>7</td>
<td>10% ethanol-ethyl acetate-100% ethanol</td>
<td>Light brown gum</td>
</tr>
</tbody>
</table>

**Table 4. Mortality of B. dorsalis treated with various fractions of hexane extract at LC₅₀ level of crude extract (4866 ppm)**

<table>
<thead>
<tr>
<th>Fraction</th>
<th>Mortality (% ± SD)a,b</th>
<th>24 h</th>
<th>48 h</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>71.33 ± 2.97a</td>
<td>74.67 ± 2.98a</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>41.33 ± 3.98b</td>
<td>42.00 ± 2.98b</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>33.67 ± 2.78c</td>
<td>34.00 ± 2.78b</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>26.00 ± 2.79d</td>
<td>28.67 ± 1.82d</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>14.00 ± 2.79e</td>
<td>14.67 ± 3.0f</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>19.33 ± 2.78f</td>
<td>22.00 ± 1.82e</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>20.67 ± 2.78e</td>
<td>22.66 ± 1.48f</td>
<td></td>
</tr>
</tbody>
</table>

*a n = 30 per replicate (five replicates).  
bWithin each column means followed by same letter are not significantly different (P > 0.05; Duncan’s multiple range test).

**Discussion**

Zingiberaceae is one of the major tropical plant families, the members of which are used as spices and as medicinal herbs. Rhizomes of several species also are used as insect repellents, and many compounds with novel structures and a large number of biologically active compounds have been identified from these plants (Panchareon et al. 2000). *A. galanga* is one such plant of this family, rhizomes of which have medicinal properties, and many compounds of this plant have various biological activities (Panchareon et al. 2000). *A. galanga* is a very safe plant, with no oral mammalian toxicity up to 300-g/kg dose (Mokkhasmit et al. 1971), which is much safer than other known insecticidal plants such as *Annona squamosa* L. (LD₅₀ to mice = 1 g/kg; Bhakuni et al. 1969) or *Derris elliptica* (Wallich) Benth. (LD₅₀ = 132–1,500 mg/kg; Wongthong and Pimsarn 2007).

There are very scanty reports to demonstrate insecticidal activity of this plant species (Chandel and Trevedi 2010). Here, we have for the first time shown that hexane and ethanol extracts of rhizomes of *A. galanga* are toxic to the fruit fly *B. dorsalis* by using direct spray procedure against the adult flies, which could be handy for use in field conditions. The two extracts seem to be almost at par in their activity, but apparently with different nonpolar and polar compounds as active ingredients. We have chosen first to isolate nonpolar compounds in the current study from

![Fig. 2. (E)-p-Coumaryl alcohol ethyl ether.](Image)
the hexane extract of rhizomes. Although the total hexane extract was effective at 4,866 ppm (LC50) against the adult flies, the individual compounds were effective at lower concentrations [(E)-p-coumaryl alcohol ethyl ether, LC50 = 4044 ppm and (E)-p-acetoxycinnamyl alcohol, LC50 = 3827 ppm], which is expected for isolated pure compounds (Xie et al. 1995). However, present data suggest that these compounds may not be potentially synergistic to each other, but to some extent could have additive effect when in a mixture. It is useful to use the compounds in a combination that reduces the chance of resistance (Koul and Walia 2009). There are other reports that also suggest that crude hexane extracts from plants, such as A. squamosa, Sapindus rarak Dc. Derris elliptica, and Piper nigrum L., are toxic to B. dorsalis (Antarasane et al. 2007, Thong and Bullangpoti 2009) in a similar manner.

Flies treated with either hexane extract or isolated compounds from A. galanga showed knockdown and paralytic effects, indicative of action at neurotransmitter level. In view of variable modes of action of phytochemicals (Bullangpoti et al. 2007, Nathan et al. 2007, Koul et al. 2008, Koul and Walia 2009, Muralidhara 2009), no generalization can be made for the A. galanga compounds in the current study until detailed investigation to understand the mechanism of action is established.

It is well known that herbivorous insects use detoxification enzymes, including cytochrome P450 monoxygenases, GST, and carboxyl/cholinesterases, to metabolize otherwise deleterious plant secondary metabolites (Ramsey et al. 2010). However, these enzymes also are induced by xenobiotics; the mechanism responsible for the development of resistance in insects (Simon and Hsu 1993, Li et al. 2007). However, enzyme based experiments in the current study revealed that CE activity of B. dorsalis was inhibited by A. galanga hexane extract treatments by ≈70%, whereas GST activity was not significantly affected. CEs normally play an important role in allelochemical metabolism and tolerance, although the roles have been validated only at the biochemical level in a few cases (Li et al. 2007). The inhibition of CEs in the present case could probably be attributed, although theoretically, to the interference with hydrolytic process of neurotransmitter acetylcholine or juvenile hormone, which are among the specific functions served by CEs (Taylor and Radic 1994, Riddiford et al. 2003). This, however, needs to be established in future studies. In fact, only other reports to show that inhibition of detoxification enzymes do occur by crude plant extracts is that of Melia, Amaranthus, and Derris against Spodoptera exigua (Hübner) (Rachokarn et al. 2008, Rattanapan 2009) and Melia toosendan Sieb. et Zucc. Pron. against Spodoptera littura (F.) and Melanoplus sanguinipes (F.) (Feng et al. 1995).

Thus, the present results demonstrate the potential of A. galanga extracts or its active compounds to control B. dorsalis, but they also show that the inhibition of CEs has been established. Given that CEs can mediate insecticide resistance via their induction (Li et al. 2007), inhibition of these enzymes by plant allelochemicals may constitute a useful alternative approach for pest management. Our ongoing studies with ethanol extracts should give us more insight into these allelochemicals for pest control.

Acknowledgments

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References Cited


Table 5. Toxicity of E-p-coumaryl alcohol ethyl ether and (E)-p-acetoxycinnamyl alcohol to B. dorsalis adults after 24 and 48 h posttreatment

<table>
<thead>
<tr>
<th>Extraction</th>
<th>LC50 ± SD (ppm)xy</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>24 h</td>
</tr>
<tr>
<td>(E)-p-Coumaryl alcohol ethyl ether</td>
<td>4,044 ± 174a</td>
</tr>
<tr>
<td>(E)-p-Acetoxycinnamyl alcohol</td>
<td>3,654 ± 166b</td>
</tr>
</tbody>
</table>

x n = 30 per replicate (five replicates).

y Within each column means followed by different letter are significantly different (P < 0.05; Duncan’s multiple range test).

Table 6. Carboxyl esterase (CE) activity of B. dorsalis after 24-h exposure to hexane extract at LC50 level of treatment

<table>
<thead>
<tr>
<th>Concen (ppm)</th>
<th>CEa (nM paranitrophenol/mg protein/min ± SD)</th>
<th>T/Cb</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>4.91 ± 1.17a</td>
<td>1.00</td>
</tr>
<tr>
<td>4866</td>
<td>1.52 ± 0.20b</td>
<td>0.31</td>
</tr>
</tbody>
</table>

a Means followed by different letters within the same column are significantly different (P < 0.05; Duncan’s multiple range test).

b T/C = the ratio of the enzyme activity of treated group over the control group.

Control is 20% acetone in distilled water.

Table 5. Toxicity of E-p-coumaryl alcohol ethyl ether and (E)-p-acetoxycinnamyl alcohol to B. dorsalis adults after 24 and 48 h posttreatment

<table>
<thead>
<tr>
<th>Extraction</th>
<th>LC50 ± SD (ppm)xy</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>24 h</td>
</tr>
<tr>
<td>(E)-p-Coumaryl alcohol ethyl ether</td>
<td>4,044 ± 174a</td>
</tr>
<tr>
<td>(E)-p-Acetoxycinnamyl alcohol</td>
<td>3,654 ± 166b</td>
</tr>
</tbody>
</table>

x n = 30 per replicate (five replicates).

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