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EFFICACY OF SELECTED PIPERACEAE, ASTERACEAE, AND ZINGIBERACEAE PLANT EXTRACTS AGAINST *Helopeltis antonii* Sign.

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ABSTRACT

Synthetic insecticides are used to control *Helopeltis antonii*, one of the important pests of cacao and other agricultural crops. The intensive and excessive use of insecticides cause insect resistance, health problems, and environmental hazards. Therefore, environmentally friendly alternative control strategies need to be developed, such as the development of botanical insecticides. This study sought to evaluate the insecticidal, feeding inhibition, and oviposition deterrent activities of *Piper retrofractum*, *Piper aduncum*, *Tagetes erecta*, *Tithonia diversifolia*, *Curcuma xanthorrhiza*, and *Alpinia galanga* against *H. antonii*. The LC_{50} and LC_{95} values were estimated using probit analysis. *P. retrofractum* extract was the most toxic compared to the other extracts. The LC_{50} and LC_{95} of *P. retrofractum* extract were 0.07% and 0.26% against the third instar nymphs of *H. antonii* at 72 hours, respectively. While, the LC_{50} and LC_{95} of *P. retrofractum* extract were 0.06% and 0.26% against the adults, respectively. *P. retrofractum* extract at LC_{25} inhibited 80% and 90% feeding activity of the third instar nymphs and adults, respectively. The highest oviposition deterrent activity was also shown by *P. retrofractum* extract at more than 80% at LC_{25} level. The results of this research indicate that *P. retrofractum* has great potential for further development as a botanical insecticide to control *H. antonii*.

Key words: botanical insecticide, feeding inhibition, oviposition deterrent, mortality, toxicity

INTRODUCTION

Helopeltis antonii Sign. (Hemiptera: Miridae) is one of the most important insect pests on cocoa, quinine, cashew, cinnamon, tea, and cayenne pepper plants (Kalshoven 1981). Nymphs and adult *H. antonii* attack plants by piercing the stylet and sucking cell fluids on shoots, flowers and or young fruits, and releasing toxic liquids resulting in spotting, necrosis, withering, falling, until death on the damaged plant part (Indriati and Soesanthy 2014). The damage will be exacerbated by the arrival of secondary pathogens so that the infected part dies or is affected by leaf rot (Ranaweera 2000). Damage on young fruits cause fruit development to be stunted and even fall (Sulistyowati 2015). Fruits that survive are lesser in quality and quantity. The loss in cocoa production due to *H. antonii* attacks has reached 50-60% (Sulistyowati 2008).

The common strategy used by farmers to control *H. antonii* is the use of synthetic insecticides due to fast action or knockdown effect and efficiency. However, intensive and excessive

use of insecticides can cause insect resistance, chemical residues, and environmental pollution. The population of *H. antonii* from cocoa plantations in Bogor and Ciamis in West Java, Indonesia, are resistant to the pyrethroid insecticide lambda-cyhalothrin with resistance ratios of 4.2 and 10.8, respectively (Utami et al. 2017). Meanwhile, *H. theivora* in Kalchini tea plantations (Dooars, North Bengal, India) in 2007 were found to be resistant to lambda-cyhalothrin with a resistance ratio of 2,660 times (Roy et al. 2011). Therefore, more environmentally friendly control strategies need to be developed, and one strategy is utilizing plant secondary metabolites as botanical insecticides (Dadang 2015).

Several plants of the family Piperaceae, Asteraceae, and Zingiberaceae are reported as promising botanical insecticides. Javanese chili (*Piper retrofractum* Vahl., Piperaceae) can be used to control brown planthopper *Nilaparvata lugens* Stål (Hemiptera: Delphacidae) (Nuryanti et al. 2018) and spike pepper (*Piper aduncum* L., Piperaceae) against *Crocidolomia pavonana* F. (Lepidoptera: Crambidae) (Syahroni and Prijono 2013). Big marigold (*Tagetes erecta* L., Asteraceae) has insecticidal activity against *Spodoptera frugiperda* J.E. Smith (Salinas-Sánchez et al. 2012) and tree marigold (*Tithonia diversifolia* A. Gray, Asteraceae) against *Callosobruchus maculatus* F. (Coleoptera: Bruchidae) (Green et al. 2017). Several Zingiberaceous plants, such as *Curcuma xanthorrhiza* Roxb. and and *Alpinia galanga* (L.) Willd. are toxic against *C. pavonana* (Balfas and Mardiningsih 2016) and *Bactrocera dorsalis* (Hendel), respectively (Sukhirun et al. 2011).

The phytochemical content of the plants determine the biological activity against insect pests. *P. retrofractum* is known to contain piperidine alkaloid compounds, such as piperine, piperoctadecalidine, pipereicosalidine, and pipernonaline (Ahn et al. 1992). Meanwhile, the main component of the active fraction of *n*-hexane and ethanol extract of *P. aduncum* is dilapiol (Bernard et al. 1995). The chemical components found in *T. erecta* include quercetagetin, quercetagetin glucoside, phenolic, syringic acid, methyl-3, 5-dihydroxy-4- methoxy benzoate, quercetin, thienyl, ethyl gallate, lutein, and isoprenoid C-40 (Ghani 1998) while *T. diversifolia* leaves contain diversifolin, diversifolin methyl ether, and thyrotundin (Rüngeler et al. 1998).

Studies on the biological activity of Piperaceae (*P. retrofractum* and *P. aduncum*), Asteraceae (*T. erecta* and *T. diversifolia*), and Zingiberaceae (*C. xanthorrhiza* and *A. galanga*) against *H. antonii* is at present limited. Thus, this study sought to evaluate the toxicity, feeding inhibitory effects, and oviposition deterrent activity of *P. retrofractum*, *P. aduncum*, *T. erecta*, *T. diversifolia*, *C. xanthorrhiza*, and *A. galanga* extracts against *H. antonii*.

MATERIALS AND METHODS

Plant sources. *Piper retrofractum* fruits were collected from the field station of the Indonesian Industry and Freshener Crops Reseach Institute (IFCRI) Sukabumi (6°50'50.0"S and 106°45'10"E); *P. aduncum* fruits from around the Bogor Dramaga Campus of IPB University (6º33'15"S and 106°44'25"E); *T. erecta* and *T. diversifolia* flowers from Cipanas, Cianjur (6º43'38"S and 107°04'55"E); and rhizomes of *C. xanthorrhiza* and *A. galanga* from Anyar Market, Bogor, Indonesia.

Plant extraction. All plant materials were cut into pieces at a thickness of 3-8 mm, dried in an air-conditioned room for 7-14 day (T = 25±2 ºC), and oven-dried at 60 ºC (Hernani and Marwati 2012). After completely dry, the plant materials were ground with a mechanical grinder (Retsch GmbH 5667 HAAN Type SK1 Nr. 37535 capacity of 0.5 kg per hour) and sieved at 0.5 mm.

Extraction was done by maceration combined with stirring. Each powder was soaked in an organic solvent with 1:10 (w/v) for 48 hours (T 26±2 ºC; RH 66-86%). The powder of *P. retrofractum* and *P. aduncum* (fruits) were dissolved in ethyl acetate (Nailufar and Prijono 2017), *T. erecta* (flowers) in ethanol (Salinas-Sánchez et al. 2012), *T. diversivolia* (flowers) in methanol (Bernard et al.

2012), *C. xanthorrhiza* (rhizomes) in ethanol (de SouzaTavares et al. 2016), and *A. galanga* (rhizomes) powder also in ethanol (Dadang and Ohsawa 2001). After 48 hours, all the soaked plant materials were filtered with filter paper (Whatman No. 41). The filtrates were evaporated with a rotary evaporator (T 50±2 ºC; 50 rpm; pressure 240 mbar). The concentrated extracts (crude extracts) obtained was stored in a refrigerator (± 4 ºC) before use.

Mass rearing of *H. antonii*. Mass rearing of *H. antonii* was carried out in the laboratory (T 25±2 ºC; RH 66-86%) by using alternative cucumber feed (*Cucumis sativus* L.) (Kilin and Atmadja 2000).

Preliminary contact toxicity assay. A concentration range of extracts that caused 5-99% mortality was determined by bracketing test (Dadang and Prijono 2008). Five concentrations of the crude extract diluted in solvent (same solvent used in extraction) were 0.125, 0.25, 0.5, 1.0, 2.0%, and control (solvent and emulsifier without extract) were prepared for bioassay (Dadang and Prijono 2011). The concentrations were made by serial dilutions. Stock solutions were prepared by weighing the crude extract and diluting with a solvent containing 0.2% emulsifier (Tween 80) and 1% of organic solvent and making up to volume with distilled water. Each test solution was stirred using a magnetic stirrer at 750 rpm for 30 minutes.

Ten third instar nymphs and adults of *H. antonii* were introduced separately in a different cylinder plastic cage (5 cm in diameter, 8 cm in height), sprayed with 1 mL of each solution using a small hand sprayer and allowed to stand for five minutes. The test insects were then transfered into a jar (16 cm in diameter and 16.3 cm in height) with a whole cucumber fruit inside and covered with gauze. Each treatment was replicated five times. Whole cucumber fruits were replaced with untreated fresh ones after 48 hours. Mortality was assessed at 24, 48, and 72 hours after treatment (HAT). Mortality data were analyzed by probit analysis using the Polo PC program to determine the LC_{50} and LC_{95} values.

Advanced contact toxicity assay. Five concentrations used for advanced bioassay were equal to LC_{15}, LC_{35}, LC_{55}, LC_{75}, LC_{95}, and control of preliminary test results (Dadang and Prijono 2008). The method used was the same as the preliminary test. These values were determined using the POLO PC program.

Feeding inhibition assay. This assay used third instar nymphs and adults of *H. antonii* that were spaced apart by modifying the no-choice residual method by Indriati et al. (2015). The concentrations used were equivalent to the value of LC_{25}, LC_{50}, and LC_{90}, while solvent plus emulsifier, served as control. The preparation of the test solutions used was similar to the contact toxicity test. Whole cucumber fruit was dipped in the extract for five minutes and dried. The treated cucumber fruit was placed inside a jar that contained test insects and covered with gauze. The treatment was replicated five times using ten insects per replication (ten third instar nymphs or five pairs adult). Observations were made by counting the number of puncture marks on cucumber at 24 HAT. The percent feeding inhibition was calculated using the formula:

$$\text{FI} = \frac{\text{MC} - \text{MT}}{\text{MT}} \times 100\%$$

FI = Feeding inhibition (%)
MC = Total of puncture marks on the control treatment
MT = Total of puncture marks on extract treatment

The percent feeding inhibition of extracts against *H. antonii* was categorized based on Mokodompit et al. (2013) categories (Table 1):

Table 1. Percent feeding inhibition categories

Category	Feeding inhibition range (%)
Strong	FI ≥ 80
Medium	60 ≤ FI < 80
Weak	40 ≤ FI < 60
Very weak	0 < FI < 40
No inhibition	FI = 0

Oviposition deterrent test. This assay used five pairs of five-day-old *H. antonii* adults and concentrations equivalent to LC_{25}, LC_{50}, LC_{75}, and control (solvent and emulsifier). The preparation of the extract solution was the same way as in the toxicity test method, while the test method was the same way as the feeding inhibition test. Each treatment was repeated five times. Observations were made by counting the number of eggs-laying at 24, 48, and 72 HAT. The percentage of egg-laying was calculated using the formula:

$$OD = \frac{EC - ET}{EC} \times 100\%$$

OD = Oviposition deterrent (%)
EC = Total of eggs laid on the control treatment
ET = Total of eggs laid on extract treatment

All the experiments were conducted using a complete randomized design. Feeding inhibition and oviposition deterrent bioassays were analyzed statistically using the One-way ANOVA and the means were compared using the Tukey's Test using SAS 9.4 program.

RESULTS AND DISCUSSION

Contact toxicity. All extract treatments caused different mortality to the third instar nymphs and adults of *H. antonii*. The highest toxicity of plant extract was shown in the treatment of *P. retrofractum*. Since 24 HAT, that extract treatment has caused mortality for third instar nymphs and adults. The LC_{50} and LC_{95} of *P. retrofractum* extract to third instar nymphs were 0.07% and 0.26% at 72 HAT, respectively. Meanwhile, LC_{50} and LC_{95} of *P. retrofractum* extract to adults were 0.06% and 0.26%, respectively. The lowest toxicity was showed on the treatment of *T. erecta* extract to third instar nymphs and *A. galanga* extract to adults (Table 2).

P. retrofractum extract showed the highest toxicity both to the nymphs and adults of *H. antonii*. *P. retrofractum* extract caused the highest toxicity to *N. lugens* with LC_{50} and LC_{95} to nymphs were 0.07% and 0.71%, respectively (Nuryanti et al. 2018). Insects respond differently to plant extracts (Dadang and Prijono 2008). In this study, LC_{50} and LC_{95} were 3.20 and 1.79 times less than the results of Indriati et al. (2015). LC_{50} and LC_{95} of *P. retrofractum* extract against adults of *H. antonii* at 72 HAT were 0.21% and 0.47%, respectively (Indriati et al. 2015). Although *P. retrofractum* were collected from the same area, the toxicity test showed different results. The drying process of *P. retrofractum* fruits by Indriati et al. (2015) was carried out in a non-air conditioned room (Personal communication 2019), while this study was conducted in an air-conditioned room with controlled temperature. One of the determinants of bioactivity was the handling of plant materials, such as the stages of collection, drying, extraction, and storage (Dadang and Prijono 2008).

P. retrofractum fruit showed larvacidal activity against *Culex quinquefasciatus* Say (Diptera: Culicidae) (Wiwattanawanichakun et al. 2018). *P. retrofractum* fruit contains piperamide alkaloids, such as piperine, pipercide, pelitorine, guineensine, and retrofractamide A (Kikuzaki et al. 1993; Scott

et al. 2008; Cahyono et al. 2019). Furthermore, the piperamides in Piperaceae contain the isobutyl amide and methylenedioxyphenyl groups, which have strong neurotoxic activity with a rapid knockdown effect (Miyakado et al. 1989). The action of piperamides as nerve poisons are pyrethroid-like, which causes hyperexcitability stimulation of nerve axons (specifically sensory nerves, but less effective on motor nerves) (Lees and Burt 1988). As a result, it causes tremors, paralysis, and death. When impulses are transmitted to axons, impulses will occur repeatedly. The pipercide prevents the closing of the Na^+ ion channel, resulting in the continuous transmission of nerve impulses to the axons that can cause tremors and death.

Table 2. Contact **t**oxicity of selected Piperaceae, Asteraceae, and Zingiberaceae plant extracts against third instar nymphs and adults of *H. antonii* at 72 HAT

Insect growth stage	Plant Extract	a[a] ± SE	b[b] ± SE[c]	LC[d]$_{50}$ (CI[e] 95%) (%)	LC_{95} (CI 95%) (%)
Third instar nymphs	*P. retrofractum*	8.31 ± 0.50	2.85 ± 0.55	0.07 (0.04 – 0.09)	0.26 (0.20 – 0.42)
	P. aduncum	4.75 ± 0.12	1.85 ± 0.21	1.36 (0.33 – 2.83)	10.58 (4.45 – 327.75)
	T. erecta	4.84 ± 0.09	0.75 ± 0.12	1.62 (0.59 – 6.55)	259.15 (30.75 - 0.42E+06)
	T. diversifolia	4.90 ± 0.09	0.62 ± 0.10	1.46 (0.77 - 2.80)	673.78 (140.18 - 12258.00)
	C. xanthorrhiza	5.94 ± 0.14	2.63 ± 0.34	0.44 (0.16 - 0.78)	1.85 (0.96 - 28.15)
	A. galanga	8.83 ± 0.09	0.76 ± 0.13	1.69 (0.61 - 4.21)	248.77 (39.56 - 95750.00)
Adults	*P. retrofractum*	8.21 ± 0.47	2.70 ± 0.51	0.06 (0.04 - 0.08)	0.26 (0.20 - 0.43)
	P. aduncum	5.15 ± 0.09	1.34 ± 0.17	0.77 (0.29 - 1.90)	13.07 (3.92 - 1062.20)
	T. erecta	4.81 ± 0.12	0.67 ± 0.14	1.94 (0.89 - 8.54)	534.73 (58.91 - 87627.00)
	T. diversifolia	4.58 ± 0.10	0.94 ± 0.18	2.83 (1.75 - 6.01)	160.05 (39.79 - 3274.50)
	C. xanthorrhiza	5.77 ± 0.14	1.21 ± 0.18	0.23 (0.16 - 0.34)	5.34 (2.58 - 18.58)
	A. galanga	4.44 ± 0.12	0.73 ± 0.16	5.73 (3.22- 13.68)	997.58 (167.67 - 66149.00)

[a]a = intercept of probit regression line; [b]b = probit regression slope; [c]SE = Standard Error; [d]LC = Lethal Concentration; [e]CI = Confidence Interval.

C. xanthorrhiza extract was less toxic than *P. retrofractum* extract. The LC_{50} and LC_{95} values of *C. xanthorrhiza* extract were 0.44% and 1.85% for the third instar nymphs, whereas for the adults were 0.23% and 5.34%, respectively. This may be the first report of the contact toxicity of *C. xanthorrhiza* against *H. antonii*.

C. xanthorrhiza contains secondary metabolites, such as α, β, γ-curcumene, ar-curcumin, curcumin, curcuminoid, germacrene, dehydrocurdion, furanodienone, furanogermenone, xanthorrhizol, borneol, germacrene isomeric sesquiterpene, monoterpene, and bisabolane-type sesquiterpenes (Pandji et al. 1993; Afzal et al. 2013; Chearwae et al. 2004; Rukayadi and Hwang 2007; Prakash et al. 2011). Xanthorrhizol isolated from *C. xanthorrhiza* was one of the sesquiterpenoid compounds which showed the most significant toxicity to neonatal larvae of *Spodoptera littoralis* Boisduval (Lepidoptera: Noctuidae) with LC_{50} 6.92-8.13 µmol/kg fresh weight of larvae (Pandji et al. 1993). Three curcuminoid components, namely di-O-demethylcurcumin, di-O-methylcurcumin, and di-O-acetylccurcumin, which were isolated from *C. longa* were known to show

larvacidal activity against *Culex pipiens* L. (Diptera: Culicidae) with LC_{50} 12.42-19.07 mg/L (Sagnou et al. 2012).

P. aduncum has insecticidal activity against third instar nymphs and adults of *H. antonii*. The *n*-hexane extract of *P. aduncum* 0.29% resulted in 95% mortality of second instar *C. pavonana* (Hasyim 2011). Meanwhile, ethyl acetate extract of *P. aduncum* 2% could cause 100% mortality of *C. pavonana* at 72 HAT (Mendes 2016). *P. aduncum* contains dilapiol (phenylpropanoid group), which has an MDF (methylendioxyphenil) group which functions to reduce the toxicity of foreign compounds found in the insect's body through oxidation processes. The MDF group is an important characteristic of various compounds that are synergistic as insecticides (Bernard et al. 1995; Scott et al. 2008). Dilapiol derived from *P. aduncum* is known to inhibit the activity of cytochrome P450 enzyme in microsomal preparations of digestive tract cells of corn stem borer *Ostrinia nubilalis* Hubner (Lepidoptera: Crambidae) (Bernard et al. 1995).

Feeding inhibition activity. Feeding inhibition activity increased with increasing the concentration. *P. retrofractum* followed by *C. xanthorrhiza* extract displayed strong feeding inhibitory activity. This was consistent for each treatment concentration of *P. retrofractum* while *C. xanthorrhiza* started at a concentration of 0.44% and *P. aduncum* 3.15% (Table 3).

Table 3. Feeding inhibition of *H. antonii* third instar nymphs treated with test plant extracts.

Treatment (%)	Feeding inhibition (%) ± SE	Inhibition criteria
P. retrofractum		
LC_{25} (0.04)	86.91 ± 7.64	Strong
LC_{50} (0.07)	87.22 ± 8.87	Strong
LC_{75} (0.26)	98.92 ± 2.41	Strong
P. aduncum		
LC_{25} (0.59)	36.18 ± 13.15	Very weak
LC_{50} (1.36)	59.10 ± 24.60	Weak
LC_{75} (3.15)	80.24 ± 15.40	Strong
T. erecta		
LC_{25} (0.20)	52.34 ± 10.54	Weak
LC_{50} (1.62)	55.19 ± 20.98	Weak
LC_{75} (12.96)	62.74 ± 10.10	Medium
T. diversifolia		
LC_{25} (0.12)	41.23 ± 11.51	Weak
LC_{50} (1.46)	55.62 ± 33.43	Weak
LC_{75} (18.05)	71.01 ± 16.90	Medium
C. xanthorrhiza		
LC_{25} (0.24)	44.66 ± 16.75	Weak
LC_{50} (0.44)	91.68 ± 15.41	Strong
LC_{75} (0.79)	94.97 ± 11.25	Strong
A.galanga		
LC_{25} (0.20)	55.56 ± 7.48	Weak
LC_{50} (1.98)	59.10 ± 13.88	Weak
LC_{75} (12.20)	67.23 ± 20.12	Medium

Aside from being a contact poison, *P. retrofractum* also exhibits repellent and antifeedant activity (Scott et al. 2008). Antifeedant compounds are substances or chemical compounds when felt by insects, can produce a temporary or permanent cessation of feeding activities, depending on the potential or strength of the compound (Dadang and Prijono 2008). The active ingredients of Piperaceae which act as a feeding inhibitor, are sesquiterpenes, β-caryophyllene, limonene, and sabine contained in essential oils (Perakis et al. 2005).

The highest feeding inhibition extract against adults was displayed by *P. retrofractum* and the lowest in *A. galanga* (Table 4). As with nymphs, *P. retrofractum* 0.04% extract displayed 93.80% inhibition of adult feeding activity with strong criteria. In another study, *P. retrofractum* 0.18% extract was able to inhibit feeding activity by 86.40% against *N. lugens* (Nuryanti et al. 2018).

C. xanthorrhiza extract showed inconsistency in feeding inhibition to nymphs and adults at LC_{50} and LC_{75} levels. *C. xanthorrhiza* extract at LC_{50} and LC_{75} levels against nymphs showed strong criteria. Meanwhile, LC_{50} was weak and LC_{75} was medium criteria for adults (Table 4). The LC_{50} concentration used for nymphs was higher than adults. The inconsistency of feeding inhibition due to the treatment of *C. xanthorrhiza* extracts at LC_{50} and LC_{75} levels was due to nymphs being more sensitive than adults. Adults need more food to survive and produce offspring (Bernays and Chapman 1994).

Table 4. Feeding inhibition of adults *H. antonii* treated with test plant extracts.

Plant extracts (%)	Feeding inhibition (%) ± SE	Inhibition criteria
P. retrofractum		
LC_{25} (0.04)	93.80 ± 3.42 [b]	Strong
LC_{50} (0.06)	97.00 ± 2.83 [ab]	Strong
LC_{75} (0.12)	99.60 ± 0.55 [a]	Strong
P. aduncum		
LC_{25} (0.24)	39.80 ± 5.54	Very weak
LC_{50} (0.77)	53.20 ± 32.75	Weak
LC_{75} (2.46)	96.00 ± 1.22	Strong
T. erecta		
LC_{25} (0.19)	45.00 ± 10.58 [b]	Weak
LC_{50} (1.94)	55.60 ± 7.23 [b]	Weak
LC_{75} (19.46)	77.20 ± 13.10 [a]	Medium
T. diversifolia		
LC_{25} (0.54)	53.00 ± 10.37	Weak
LC_{50} (2.83)	76.60 ± 4.16	Medium
LC_{75} (14.80)	84.00 ± 8.60	Strong
C. xanthorrhiza		
LC_{25} (0.07)	59.80 ± 10.80	Weak
LC_{50} (0.23)	59.60 ± 13.52	Weak
LC_{75} (0.84)	79.80 ± 7.53	Medium
A.galanga		
LC_{25} (0.69)	28.60 ± 10.55	Very weak
LC_{50} (5.73)	36.80 ± 15.34	Very weak
LC_{75} (47.52)	52.20 ± 13.99	Weak

Oviposition deterrent activity. *P. retrofractum* extract, at all concentration levels, deterred oviposition by 100% at 24 HAT. The extract deterred oviposition by 95.57-100% and 88.06-99.05%, respectively, at 48 and 72 HAT. This was followed by *P. aduncum* which deterred oviposition by 100%, 38.42-100%, and 42.00-97.30% at 24, 48, and 72 HAT, respectively.

C. xanthorrhiza from Zingiberaceae caused high oviposition deterrent activity. The oviposition deterrent activity of LC_{25} extract was 100% at 24 HAT, while the oviposition deterrent activity of LC_{50} and LC_{75} were 74.79 and 80.40%, respectively at 48 HAT and were 51.52 and 70.60%, respectively at 72 HAT. *T. erecta* extract showed the lowest oviposition deterrent activity. *T. diversifolia* extract showed oviposition deterrent activity by more than 80% in LC_{75} at 72 HAT. *A. galanga* extract showed 90-100% oviposition deterrent at 24 HAT, but decreased at 48 and 72 HAT, especially at concentrations of LC_{25} which was only able to inhibit by 13.11% and 8.49%, respectively (Fig. 1).

Terpenoids and sesquiterpenes in all plant extracts are known to deter oviposition of adults, for other insects, such as *C. chinensis* (Chaubey 2013) and *P. xylostella* (Qiu et al. 1998). *C. xanthorrhiza* oil inhibited the oviposition of *C. pavonana* adults (Balfas and Mardiningsih 2016). *P. marginatum* Jacq. contains β-caryophillene, which is a sesquiterpenoid group, that can deter the oviposition of the two-spotted spider mite *Tetranychus urticae* Koch. (Acari: Tetranychidae) (Ribeiro et al. 2016).

CONCLUSION

The ethyl acetate extract of *P. retrofractum* fruit was the most potent treatment against *H. antonii.* It possesses high contact toxicity, oviposition deterrent activity, and feeding inhibition against third instar nymphs and adults of *H. antonii*. It possesses great potential for further development as a botanical insecticide to control this economically important pest.

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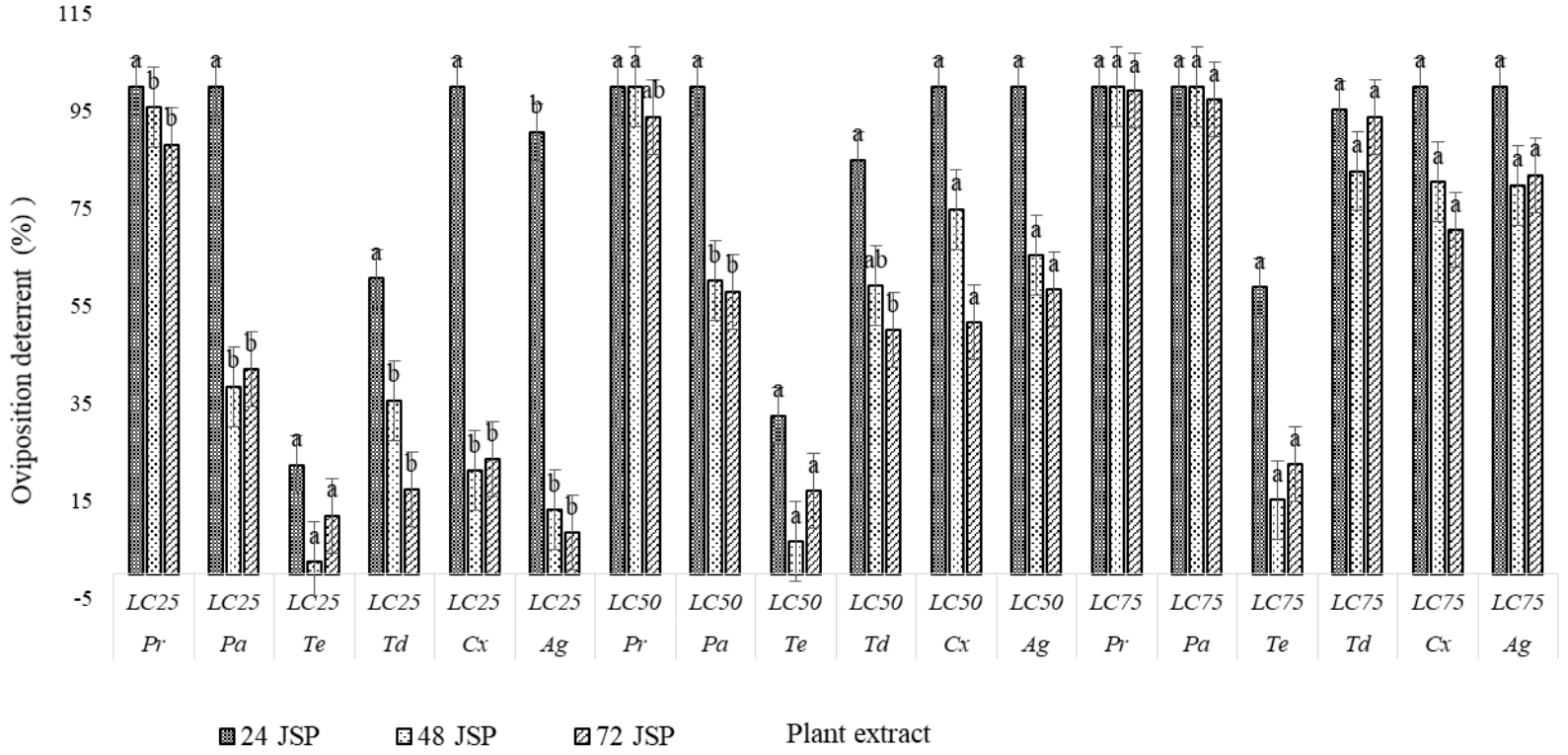

Fig. 1. Oviposition deterrent activity of *H. antonii* adults

Note:

1) *Pr = P. retrofractum*; *Pa = P. aduncum*; *Te = T. erecta*; *Td = T. diversifolia*; *Cx= C. xanthorrhiza*; *Ag= A. galanga*.
2) A bar chart containing the same letter in each extract at different LC levels showed that there was no significant difference based on the Tukey Test at 5% level.

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