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National Academy of Agricultural Science (NAAS) Rating : 3. 03

Insecticidal Activity and Structure Activity Relationship of Natural Cinnamoyl Amides and their Synthetic Analogues against Cowpea Aphid, *Aphis craccivora* Koch (Aphididae: Homoptera)

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ABSTRACT: *Cowpea aphid, Aphis craccivora is one of the most important polyphagous sucking insect pests of legumes. Besides causing direct damage to the host by sucking the plant sap from various plant parts, they may reduce the yield, quality and marketability of crops by transmitting plant viruses. Due to indiscriminate use of synthetic insecticides for the control of aphids which results in the development of resistance and affecting the natural enemies of aphids in the field. Cinnamoyl amide conjugates of phenyl ethylamine derivatives isolated from Zanthoxylum armatum or any other plant have not been investigated previously for their insecticidal activities. Keeping in view the great potential of cinnamoyl amides of plant origin, present study was aimed to identify such compounds for their insecticidal activity and determine structure activity relationship (SAR). Results indicate that, all the compounds showed insecticidal activity to A. craccivora. Among them, compound* ***6****, N-(3-bromophenethyl)cinnamamide exhibited good control (LC_{50} =109.21 mg/L) followed by* ***4****, N-(3,4-dimethoxyphenethyl)cinnamamide (LC_{50} = 206.31 mg/L) and* ***5****, N-(2-bromophenethyl)cinnamamide (LC_{50} =241.98 mg/L). Compound* ***6****, displayed best insecticidal activity against A. craccivora due to 3-Br substituent (ring B) among all the tested compounds.*

Key words: Cinnamoyl amides, Zanthoxylum armatum, insecticidal activity

INTRODUCTION

Cowpea aphid, *Aphis craccivora* Koch (Aphididae: Homoptera), is one of the most important polyphagous sucking insect pest of legumes (Palumbo & Tickes 2001). Besides causing direct damage to the host by sucking the plant sap from various plant parts, they may reduce the yield, quality and marketability of crops by transmitting plant viruses (Schreiner 2000). It secretes honey dew on plants in severe infestation which results in development of sooty mold (Welty & Murphy 1991; Shetlar 2001). The control of aphid depends on the use of different groups of chemical pesticides (Shetlar 2001), which besides causing resistant development in the target population (Hollingsworth *et al.* 1994; Han & Li 2004), affect adversely the natural enemies of aphids in the field (Holland *et al.* 2000; Jansen 2000). In addition, increasing documentation of negative environmental and health impact of synthetic insecticides and increasingly stringent environmental regulation of pesticides (Isman 2000) have resulted in renewed interest in the development and use of botanical products for controlling aphid pest.

Zanthoxylum armatum DC (Rutaceae) is found abundantly throughout the western Himalayas at altitudes of 1200 to 3000 m and is extensively used in the Indian system of medicine as carminative, stomachic and anthelmintic. The extracts of this plant are known to possess insecticidal, anti-fungal and anti-microbial activities (Singh & Singh 2011). Various pharmacological activities of this plant are attributed to the presence of amides as cinnamoyl amides isolated from various *Zanthoxylum* species and other plants have shown a wide spectrum of biological

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activities such as anti-inflammatory, antiplasmodial, antiviral, antibacterial, ant platelet aggregation, eukotriene biosynthesis in human polymorph nuclear leukocytes and anticancer activities (Ross *et al.* 2004; Wu *et al.* 2012).

Insecticidal activity of several amides has been reported against various insects (Ewete *et al.* 2000; Park *et al.* 2002; Dyer *et al.* 2003; Batista-Pereira *et al.* 2006; Clark *et al.* 2008; Wu *et al.* 2012). However, cinnamoyl amide conjugates of phenyl ethylamine derivatives isolated from *Z. armatum* or any other plant have not been investigated previously for their insecticidal activities. Keeping in view the great potential of cinnamoyl amides of plant origin, present study was aimed to identify such compounds for their insecticidal activity and determine structure activity relationship (SAR).

MATERIALS AND METHODS

General

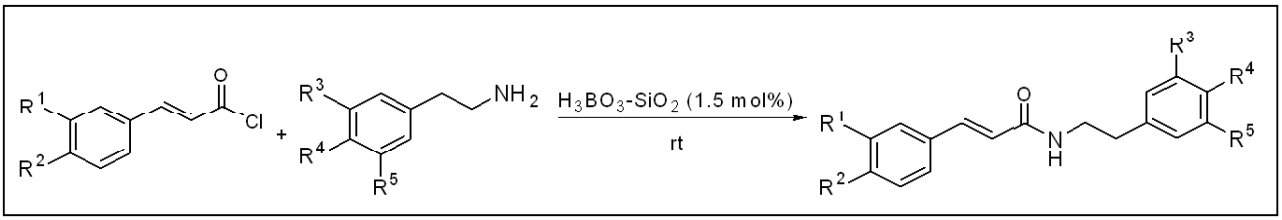
Boric acid used for the synthesis of silica-supported boric acid (H_3BO_3-SiO_2) was purchased from Ranbaxy Chemicals Ltd. Silica gel (60-120 mesh) used for preparation of H_3BO_3-SiO_2 catalyst and column chromatography, was purchased from Sisco Research Laboratories Pvt. Ltd., India. The course of the reactions was monitored by TLC on pre-coated aluminium plates (silica gel 60 F_{254}) purchased from Merck, Germany. All other chemicals were purchased from Sigma-Aldrich, USA and were used without further purification. NMR spectra were recorded on Bruker Avance-300 and 600 spectrometers at room temperature using $CDCl_3$ or DMSO as solvents and TMS as internal standard.

Isolation of cinnamoyl amides (10, 12 and 13) from *Z. armatum*

Air dried bark (1.0 Kg) of *Z. armatum* was powdered and then extracted with 80% aqueous methanol (3 4L, 12 h) in a percolator at room temperature. All percolations were combined and dried under vacuum to yield crude extract (238.2 g). The obtained extract was suspended in water and sequentially fractionated with *n*-hexane, chloroform, ethyl acetate and *n*-butanol and dried under vacuo to get corresponding fractions: *n*-hexane (12.5 g), chloroform (34.3 g), ethyl acetate (12.1 g), *n*-butanol (92.4 g) and H_2O (78.1 g). $CHCl_3$ fraction (25.0 g) was subjected to column chromatographic purification over silica-gel (60-120 mesh) and eluted with 10, 20, 30, 50, 75 and 100% ethyl acetate in *n*-hexane (5 x 200 mL each). Repeated column chromatography of fractions obtained in 50% ethyl acetate/*n*-hexane led to the isolation of *armatamide* (**12**, 480 mg). Chromatographic purification of fractions eluted in 75% ethyl acetate/*n*-hexane resulted in the isolation of *zanthosin* (**10**, 57 mg) and *rubimamin* (**13**, 23 mg).

Synthesis of silica-supported boric acid (H_3BO_3-SiO_2)

H_3BO_3-SiO_2 was synthesized by following our previously reported procedure (Kumar et al. 2011).



Scheme 1. H_3BO_3-SiO_2 catalyzed synthesis of cinnamoyl amides of phenethylamine derivatives.

Experimental procedure for the synthesis of amides 1-14

To a stirred suspension of silica-supported boric acid (H_3BO_3-SiO_2, 1.5 mol %) in toluene at room temperature, phenethylamine derivative (1 µmol) and cinnamoyl chloride derivative (1.1 mmol) were added. The reaction was kept at room temperature and progress of the reaction was monitored by TLC. After completion of the reaction, 5 mL of ethyl acetate was added and the catalyst was separated by filtration. The filtrate thus obtained was washed with brine (3¡Á5 mL) and dried over anhydrous Na_2SO_4. The solvent was removed under reduced pressure and the product was purified by crystallization with ethanol. Isolated compounds were characterized by ^1H and ^{13}C NMR spectroscopy.

***N*-(Phenylethyl)cinnamamide (1)** ^1H NMR (300 MHz, CD_3OD) δ_H 2.84-2.89 (m, 2H), 3.51-3.56 (m, 2H), 6.60 (d, 1H, *J* = 15.8 Hz), 7.20-7.23 (m, 1H), 7.26-7.29

(m, 4H), 7.36-7.41 (m, 3H), 7.51-7.56 (m, 3H); ^{13}C NMR (75 MHz, CD_3OD) δ_C 35.5, 41.2, 120.8, 126.3, 127.8, 128.5, 128.8, 128.9, 129.7, 135.2, 139.5, 140.6, 167.6.

***N*-(4--Methoxyphenylethyl)cinnamamide (2)** ^{1}H NMR (300 MHz, CD_3OD) δ_H 2.88-2.93 (m, 2H), 3.47-3.52 (m, 2H), 3.79 (s, 3H), 6.61 (d, 1H, *J* = 15.7 Hz), 6.84-6.92 (m, 2H), 7.14-7.21 (m, 3H), 7.37-7.41 (m, 2H), 7.50-7.51 (m, 3H); ^{13}C NMR (75 MHz, CD_3OD) δ_C 33.7, 39.6, 55.2, 114.4, 120.9, 127.8, 128.6, 128.9, 129.7, 129.8, 135.3, 140.6, 159.3, 167.6.

***N*-(2-Methoxyphenylethyl)cinnamamide (3)** ^{1}H NMR (300 MHz, CD_3OD) δ_H 2.86-2.90, 3.49-3.53 (m, 2H), 3.83 (s, 3H), 6.59 (d, 1H, *J* = 15.7 Hz), 6.87-6.95 (m, 3H), 7.14-7.20 (m, 2H), 7.36-7.38 (m, 3H), 7.53-7.56 (m, 2H); ^{13}C NMR (75 MHz, CD_3OD) δ_C 30.3, 39.8, 54.7, 110.4, 120.5, 120.9, 127.4, 127.8, 127.9, 128.9, 129.7, 130.4, 135.3, 140.5, 158.1, 167.6.

***N*-(3,4-Dimethoxyphenethyl)cinnamamide (4)** ^{1}H NMR (300 MHz, CD_3OD) δ_H 2.89-2.94 (m, 2H), 3.50-3.55 (m, 2H), 3.82 (s, 3H), 3.84 (s, 3H), 6.61 (d, 1H, *J* = 15.9 Hz), 6.78-6.94 (m, 3H), 7.37-7.39 (m, 3H), 7.50-7.56 (m, 3H); ^{13}C NMR (75 MHz, CD_3OD) δ_C 33.1, 41.0, 55.5 (2 O$\underline{C}H_3$), 112.4, 112.8, 121.2, 127.8, 128.3, 128.9, 129.8, 132.4, 135.2, 140.6, 148.8, 149.8, 167.6.

***N*-(2-Bromophenethyl)cinnamamide (5)** ^{1}H NMR (300 MHz, CD_3OD) δ_H 3.01-3.06 (m, 2H), 3.54-3.59 (m, 2H), 6.60 (d, 1H, *J* = 15.6 Hz), 7.13-7.24 (m, 2H), 7.29-7.32 (m, 2H), 7.36-7.40 (m, 3H), 7.50-7.61 (m, 3H); ^{13}C NMR (75 MHz, CD_3OD) δ_C 33.9, 39.5, 120.8, 124.2, 128.3, 128.9, 129.3, 129.8, 131.1, 132.9, 133.3, 135.2, 138.7, 140.7, 167.7.

***N*-(3-Bromophenethyl)cinnamamide (6)** ^{1}H NMR (300 MHz, CD_3OD) δ_H 2.98-3.02 (m, 2H), 3.56-3.61 (m, 2H), 6.58 (d, 1H, *J* = 15.5 Hz), 7.17-7.26 (m, 3H), 7.36-7.45 (m, 3H), 7.52-7.58 (m, 4H); ^{13}C NMR (75 MHz, CD_3OD) δ_C 34.0, 39.3, 121.3, 125.4, 127.1, 128.5, 128.9, 129.3, 130.9, 133.0, 133.8, 135.2, 137.9, 140.1, 167.5.

***N*-(4-Bromophenethyl)cinnamamide (7)** ^{1}H NMR (300 MHz, CD_3OD) δ_H 2.96-3.01 (m, 2H), 3.55-3.59 (m, 2H), 6.63 (d, 1H, *J* = 15.9 Hz), 7.21-7.28 (m, 3H), 7.41-7.50 (m, 3H), 7.54-7.59 (m, 4H); ^{13}C NMR (75 MHz, CD_3OD) δ_C 33.4, 39.0, 119.2, 126.2, 127.4, 128.2, 129.3, 130.0, 130.5, 134.6, 137.3, 139.2, 167.2.

***N*-(3-Bromo-4-methoxyphenethyl)cinnamamide (8)** ^{1}H NMR (300 MHz, CD_3OD) δ_H 2.84-2.89 (m, 2H), 3.46-3.52 (m, 2H), 3.90 (s, 3H), 6.63 (d, 1H, *J* = 15.7 Hz), 6.75 (d, 1H, *J* = 7.9 Hz), 7.13-7.19 (m, 2H), 7.28-7.36 (m, 3H), 7.46-7.53 (m, 3H); ^{13}C NMR (75 MHz, CD_3OD) δ_C 33.8, 39.7, 55.6, 108.4, 113.4, 120.1, 127.9, 128.2, 128.9, 129.3, 129.7, 130.2, 132.0, 136.5, 141.3, 167.5.

***N*-(2-Fluorophenethyl)cinnamamide (9)** ^{1}H NMR (300 MHz, CD_3OD) δ_H 3.05-3.11 (m, 2H), 3.54-3.60 (m, 2H), 6.56 (d, 1H, *J* = 15.3 Hz), 7.01-7.07 (m, 1H), 7.18-7.29 (m, 3H), 7.35-7.46 (m, 3H), 7.56-7.64 (m, 3H); ^{13}C NMR (75 MHz, CD_3OD) δ_C 34.7, 40.5, 121.8, 121.9, 124.4, 128.0, 128.4, 129.1, 129.7, 131.5, 131.7, 132.6, 132.7, 135.7, 138.3, 141.8, 143.2, 167.9.

Rubimamin (10) ^{1}H NMR (300 MHz, $CDCl_3$) δ_H 2.83 (t, 2H, *J* = 6.9 Hz), 3.62-3.66 (m, 2H), 3.83-3.93 (m, 12H), 6.24 (d, 1H, *J* = 15.5 Hz), 6.74-6.84 (m, 4H), 6.99 (d, 1H, *J* = 1.8 Hz), 7.05 (dd, 1H, *J* = 1.8 Hz, 8.1 Hz), 7.56 (d, 1H, *J* = 15.5 Hz); ^{13}C NMR (75 MHz, $CDCl_3$) δ_C 35.6, 41.3, 56.3 (4 O$\underline{C}H_3$), 110.1, 111.5, 111.8, 112.4, 118.9, 121.0, 122.3, 128.1, 131.8, 141.2, 148.1 149.4, 149.5, 150.9, 166.6; HR-ESI-MS calcd. for $C_{21}H_{26}NO_5$ $[M + H]^+$ *m/z* 372.1811, found 372.1802.

***N*-(Phenylethyl)-3,4-methylenedioxycinnamamide (11)** ^{1}H NMR (300 MHz, CD_3OD) δ_H 2.83-2.88 (m, 2H), 3.49-3.54 (m, 2H), 5.97 (s, 2H), 6.40 (d, 1H, *J* = 15.6 Hz), 6.82 (d, 1H, *J* = 8.0 Hz), 7.01 (dd, 1H, *J* = 1.5 Hz, 8.0 Hz), 7.07 (d, 1H, *J* = 1.5 Hz), 7.19-7.29 (m, 5H), 7.44 (d, 1H, *J* = 15.6 Hz); ^{13}C NMR (75 MHz, CD_3OD) δ_C 35.6, 41.2, 101.8, 106.0, 108.3, 118.7, 124.0, 126.3, 128.5, 128.8, 129.6, 139.5, 140.5, 148.8, 149.6, 167.8.

Armatamide (12) ^{1}H NMR (300 MHz, DMSO-d_6) δ_H 2.70 (t, 2H, J = 6.9 Hz), 3.72 (s, 3H), 3.73-3.78 (m, 2H), 6.06 (s, 2H), 6.45 (d, 1H, *J* = 15.5 Hz), 6.88 (d, 2H, *J* = 7.0 Hz), 6.94 (d, 1H, *J* = 8.0 Hz), 7.05 (d, 1H, *J* = 8.0 Hz), 7.13-7.15 (m, 3H), 7.33 (d, 1H, *J* = 15.5 Hz); ^{13}C NMR (75 MHz, DMSO-d_6) δ_C 33.7, 39.9, 54.3, 100.8, 105.6, 107.9, 113.1, 119.7, 122.5, 128.7, 128.9, 130.7, 137.7, 147.3, 147.8, 157.1, 164.4; HR-ESI-MS calcd. for $C_{19}H_{20}NO_4$ $[M + H]^+$ *m/z* 326.1392, found 326.1377.

Zanthosin (13) ^{1}H NMR (300 MHz, $CDCl_3$) δ_H 2.84 (t, 2H, J = 6.9 Hz), 3.61-3.65 (m, 2H), 3.86 (s, 6H), 5.98 (s, 2H), 6.18 (d, 1H, *J* = 15.5 Hz), 6.74-6.88 (m, 4H), 6.95-7.00 (m, 2H), 7.53 (d, 1H, *J* = 15.5 Hz); ^{13}C NMR (75 MHz, $CDCl_3$) δ_C 35.6, 41.3, 56.2, 56.3, 101.8, 106.7, 108.8, 111.8, 112.4, 119.1, 121.0, 124.1, 129.6, 131.8, 141.1,148.1, 148.6, 149.4, 149.5, 166.4; HR-ESI-MS calcd. for $C_{20}H_{22}NO_5$ $[M + H]^+$ *m/z* 356.1498, found 356.1481.

***N*-(1-Hydroxy-1-phenylethyl)cinnamamide (14)** ^{1}H NMR (300 MHz, CD_3OD) δ_H 3.57-3.60 (m, 2H), 4.82-4.89 (m, 1H), 6.67 (d, 1H, *J* = 15.7 Hz), 7.28-7.57 (m, 11H); ^{13}C NMR (75 MHz, CD_3OD) δ_C 46.4, 70.0, 120.7, 125.9, 126.1, 127.6, 128.3, 128.9, 129.8, 135.2, 140.8, 142.9, 167.9.

BIOLOGICAL ASSAY

A. craccivora used for the experimental study was collected from infested field, reared on kidney bean, *Phaseolus vulgaris* for more than 50 generations on plants grown in plastic cups (9 x 8 cm) and maintained at 25 ± 2°C, 60 ± 5% RH and a photoperiod of 16: 8 (L: D) under laboratory conditions Wingless adults were used for the experiments.

INSECTICIDAL ACTIVITY AGAINST *A. CRACCIVORA*

Test compounds were subjected to dose response bioassay to determine lethal concentration at which larvae showed 50% (LC_{50}) mortality level. Test samples (materials) were prepared at different concentrations (62.5 to 1000 mg/L) by serial dilution from the solution of higher concentration. Briefly, 15 mg of the test samples were diluted in 15 mL distilled water containing 0.05% Triton®-X 100 LR spreader (SD Fine Chemicals Limited, *www.sdfine.com*) and ultra-sonicated for complete dissolution. From stock solutions five different concentrations of test solutions were prepared in distilled water containing 0.05% Triton®-X 100 for dose response bioassay studies. For control, leaf disks were treated with distilled water containing 0.05% Triton®-X 100. Neem ban, azadirachtin based commercially available formulation for aphid control was used as a positive control in the range of 100 to 1600 mg/L to determine LC_{50} value.

POTTERS SPRAY METHOD FOR *A. CRACCIVORA*

Fresh bean discs were prepared (3 cm diameter) and pressed over the water-agar medium in Petri plates sprayed with 2 mL of the compound at different concentrations under Potters spray tower operated at 1.1 Kg/cm^2 pressure and the solvent was evaporated under a fume hood for 2 h. In each Petri dish, 10 numbers of wingless adult aphids were released then sealed with para film and kept in the laboratory conditions at 25 2°C temperature, 60 5% relative humidity and a photoperiod of 16 : 8 (L : D) for observations. Moisture build up inside the Petri dishes, if any had accumulated was blotted using tissue paper then sealed with para film. All the treatments including control were replicated three times. Mortality was determined after 72 h of treatment. The aphid that did not show any movement when probed with a camel hairbrush was considered dead.

WATER-AGAR MEDIUM FOR MAINTAINING FRESHNESS OF LEAF DISCS

Water agar technique was employed to retain the vigour and succulence of detached bean leaves for more than a week. Water agar (1.5%) was prepared by adding 3 g agar-agar powder in 200 mL hot water (50°C) and the mixture was autoclaved at 121°C for 15 min in glass beaker. The solidified water agar was melted and 20 mL was poured into each Petri dish (10 x 1.5 cm). Three minutes after pouring, required number of fresh bean leaves were pressed on to the surface of water-agar media with the upper surface of leaf being in contact with agar-medium. Such plates were used for toxicological experiments. The Petri dishes were kept open for a few minutes every day to avoid formation of water droplets and development of fungi. Data from all bioassays were corrected for control mortality using Abbot formula (Abbot 1925) and analyzed using SPSS 7.5 for calculating LC_{50} values.

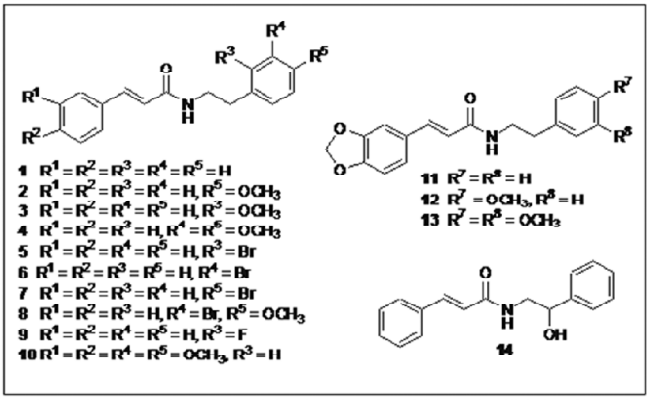


Figure 1. Structures of cinnamoyl amides 1-14

RESULTS AND DISCUSSION

Insecticidal activity against A. craccivora

The activity of the test compounds against *A. craccivora* in terms of lethal concentration to kill 50% of the test & insect relative to control (LC_{50}) values and other statistical parameters generated by linear regression analysis is summarized and presented in Table 1. It is evident that most of the test compounds showed promising activity against *A. craccivora*. However, the activities of different compounds varied depending on the presence of different substituents at various positions of both the aromatic rings A and B (Fig. 2).

As indicated in Table 1, most of the test compounds exhibited insecticidal activity against *A. craccivora* at 62.5 to 1000 mg/L. Probit analysis results

Table 1
Insecticidal activities of different compounds against *Aphis craccivora*

Compound	*LC_{50} (mg/ L)*	*95% Confidence limits*	*Regression equation*	*χ^2*	*P value*
1	684.67	449.14–1509.91	y = 3.29 + 1.16x	0.19	0.98
2	475.26	304.77–872.93	y = 2.96 + 1.10x	1.96	0.58
3	645.44	342.93–4015.06	y = 2.19 + 0.78x	1.05	0.78
4	206.31	46.17–539.63	y = 1.44 + 0.63x	0.70	0.87
5	241.98	155.59–371.20	y = 2.93 + 1.23x	0.52	0.91
6	109.21	65.42–153.04	y = 3.27 + 1.61x	0.23	0.97
7	686.95	371.27–3777.33	y = 2.34 + 0.82x	0.09	0.99
8	1250.90	762.25–4363.91	y = 3.88 + 1.25x	1.56	0.66
9	375.83	182.12–1675.74	y = 1.77 + 0.69x	1.03	0.79
10	1652.57	813.05–13268.29	y = 3.44 + 1.07x	0.36	0.94
11	678.39	390.51–2493.93	y = 2.65 + 0.94x	0.34	0.95
12	1225.55	490.13–8307.49	y = 1.91 + 0.62x	0.40	0.94
13	301.83	166.09–646.74	y = 2.15 + 0.87x	0.66	0.88
14	677.41	349.18–8063.30	y = 2.02 + 0.71x	0.09	0.99
Positive control (Neemban)	1047.11	584.76–9116.48	y = 2.75 + 0.91 x	0.46	0.79

showed that, among the tested compounds, **6**, *N*-(3-bromophenethyl)cinnamamide was most active against adults of *A. craccivora* with an LC_{50} = 109.21 mg/L after 72 h followed by **4**, *N*-(3,4-dimethoxy-phenethyl)cinnamamide (LC_{50} = 206.31 mg/L) and **5**, *N*-(2-bromophenethyl)cinnamamide (LC_{50} = 241.98 mg/L) as compared to neem ban (1047.11 mg/L). The LC_{50} values for the other compounds **1, 2, 3, 7, 8, 9, 10, 11, 12, 13** and **14** were 684.67, 475.26, 645.44, 686.95, 1250.90, 375.83, 1652.57, 678.39, 1225.55, 301.83 and 677.41 mg/L, respectively (Table 1).

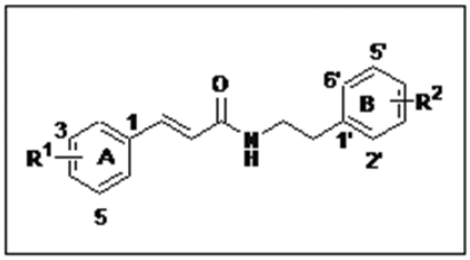


Figure 2. Basic structure of cinnamoyl amides of *Zanthoxylum armatum*

STRUCTURE ACTIVITY RELATIONSHIP (SAR)

The unsubstituted amide **1** showed significant activity (LC_{50} = 684.67 mg/L) after 72 h treatment. Compound **2** having a 4-OCH_3 (ring B) was found to be 1.5 times more active (LC_{50} = 475.26 mg/L) than **1**. The presence of 2-OCH_3 on ring B (**3**) resulted a slight increase in the activity (LC_{50} = 645.44 mg/L). The presence of two methoxy groups at 3 and 4-positions of ring B led to increase in the activity (**4** and **13,** LC_{50} = 206.31 and 301.83 mg/L, respectively). No significant influence on activity was observed for 3,4-methylenedioxy (ring A) substituted derivative (**11**, LC_{50} = 678.39 mg/L). Surprisingly, in case of **10** (3,4-methylenedioxy on ring A and 4-methoxy on ring B) and **12** (3,4,3,4-tetramethoxy) decrease in activity was observed as compared to unsubstituted amide **1** (LC_{50} = 1652.57 and 1225.55 mg/L, respectively). Halogen substituent at 2-position (ring B) such as 2-F and 2-Br showed positive influence on activity as **5** (2-Br) and **9** (2-F) were found to be 3 and 1.4 times more active than **1** with LC_{50} values of 241.98 and 375.83 mg/L, respectively. Compound **6** having 3-Br substituent (ring B) was found to be most active (LC_{50} = 109.21 mg/L) among all the tested compounds. Although, 3-Br and 4-OCH_3 (ring B) increased the activity when present individually, however, the presence of both these substituents on same molecule (**8**) resulted a decrease in activity (LC_{50} = 1250.90 mg/L). The presence of an ¨COH substituent on aliphatic chain of phenethylamine unit (**14**, LC_{50} = 677.41 mg/L) did not show any significant effect on activity as compared to unsubstituted amide **1**. Similar reports of toxicity of different amides also showed insecticidal activity against different groups of insects (Singh & Singh 2011; Ross et al. 2004; Wu et al. 2014; Ewete et al. 2000; Park et al. 2002; Dyer et al. 2003).

CONCLUSIONS

Bioassay results indicated that, all of the compounds exhibited promising insecticidal activities against *A. craccivora*. Among the tested compounds, **6**, *N*-(3-bromophenethyl)cinnamamide was most active

against *A. craccivora* with an LC_{50} = 109.21 mg/L. In particular, the LC_{50} values of compounds **4, 5, 9** and **13** were 206.31, 241.98, 375.83 and 301.83 mg/L respectively.

ACKNOWLEDGEMENTS

Authors are grateful to Director, CSIR-IHBT, Palampur for encouragement and support. Mr. VK is grateful to UGC for Senior Research Fellowship. Financial assistance from CSIR under the project °PROMOTE± (BSC-0213) expand duly acknowledged.

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