

Supplementary Information

Marine Natural Products in the Battle against Dengue, Zika, and Chikungunya Arboviruses

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Larvicidal and antiviral activities against Dengue, Zika, and Chikungunya and their main vector *Aedes aegypti* reported for crude marine extracts

Table S1. Larvicidal activity of marine microorganisms crude extracts against *Aedes aegypti*

Species	Organism	Extract	Larvicidal activity	Reference
<i>Bacillus subtilis</i>	bacteria	water	LC ₅₀ = 3.74 µL mL ⁻¹	1
<i>Bacillus thuringiensis</i>	bacteria	water	LC ₅₀ = 2.36 µL mL ⁻¹	
<i>Bacillus sphaericus</i>	bacteria	water	LC ₅₀ = 3.25 µL mL ⁻¹	
<i>Bacillus cereus</i>	bacteria	water	LC ₅₀ = 4.37 µL mL ⁻¹	
<i>Streptomyces alboflavus</i>	actinobacteria	EtOH	LC ₅₀ = 1.48 ppm	2
<i>Bacillus thuringiensis</i>	bacteria	water	LC ₅₀ = 4.00 µg mL ⁻¹	3
<i>Bacillus amyloliquefaciens</i>	bacteria	water	LC ₅₀ = 20.50 µg mL ⁻¹	4
<i>Moorea producens</i>	cyanobacteria	DCM	100%	5
<i>Phormidium submembraneum</i> /Symploca hydroides consortium	cyanobacteria	DCM	100%	
<i>Lyngbya</i> spp./Oscillatoria spp. consortium	cyanobacteria	DCM	90%	
<i>Bacillus thuringiensis</i>	bacteria	water	LC ₅₀ = 5.82 × 10 ⁸ cfu mL ⁻¹	6
<i>Streptomyces</i> sp.	actinobacteria	EtOAc	LC ₅₀ = 112.78 ppm	7

LC₅₀: 50% lethal concentration; DCM: dichloromethane; EtOAc: ethyl acetate.

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Table S2. Larvicidal activity of seaweeds extracts against *Aedes aegypti* mosquito

Species	Organism	Extract/fraction	Larvicidal activity	Reference
<i>Gracilaria firma</i>	seaweed	MeOH	LC ₅₀ = 0.251%	8
<i>Padina gymnospora</i>	seaweed	HEX	LC ₅₀ = 29.02 µg mL ⁻¹	9
		CHL	LC ₅₀ = 17.230 µg mL ⁻¹	
<i>Halymenia palmata</i>	red seaweed	MeOH	LC ₅₀ = 23.69 µg mL ⁻¹	10
<i>Caulerpa scalpelliformis</i>	seaweed	ACE	synergistic activity with synthetic insecticides decreasing their LC ₅₀	11
<i>Dictyota dichotoma</i>	seaweed	ACE		
<i>Champia parvula</i>	red seaweed	EtOH	LC ₅₀ = 43 ppm	12
<i>Sargassum wightii</i> and <i>Halimeda gracilis</i>	seaweed	ACE, CHL, MeOH, EtOH, and water	LC ₅₀ = 43.96 µg mL ⁻¹	13

MeOH: methanol; LC₅₀: 50% lethal concentration; HEX: hexane; CHL: chloroform; EtOH: ethanol; ACE: acetone.

Table S3. Larvicidal activity of mangrove plant crude extracts against *Aedes aegypti*

Species	Plant part	Extract	Larvicidal activity	Reference
<i>Rhizophora apiculata</i>	bark	EtOH	LC ₅₀ = 0.0943 µg mL ⁻¹	14
	leaf	EtOH	LC ₅₀ = 0.085 µg mL ⁻¹	
	hypocotyl	EtOH	LC ₅₀ = 0.083 µg mL ⁻¹	
	collar	EtOH	LC ₅₀ = 0.0846 µg mL ⁻¹	
<i>Rhizophora mucronata</i>	leaf	EtOAc	LC ₅₀ = 0.305 mg mL ⁻¹	15
	leaf	petroleum benzene	LC ₅₀ = 0.502 mg mL ⁻¹	
	leaf	MeOH	LC ₅₀ = 0.154 mg mL ⁻¹	
	leaf	MeOH	LC ₅₀ = 347.5 ppm	16
	leaf	EtOH	LC ₅₀ = 0.078 µg mL ⁻¹	14
	hypocotyl	EtOH	LC ₅₀ = 0.053 µg mL ⁻¹	
	collar	EtOH	LC ₅₀ = 0.0673 µg mL ⁻¹	
	bark	EtOH	LC ₅₀ = 0.03 µg mL ⁻¹	
<i>Bruguiera cylindrica</i>	hypocotyl	EtOH	LC ₅₀ = 0.082 µg mL ⁻¹	14
	leaf	EtOH	LC ₅₀ = 0.091 µg mL ⁻¹	17
	leaf	water	LC ₅₀ = 160.06 ppm	
<i>Ceriops decandra</i>	leaf	EtOH	LC ₅₀ = 0.0892 µg mL ⁻¹	14
	collar	EtOH	LC ₅₀ = 0.082 µg mL ⁻¹	
<i>Avicennia germinans</i>	leaf	Water	LC ₅₀ = 40.0%	18
	leaf	MeOH	LC ₅₀ = 10.46 mg mL ⁻¹	
<i>Avicennia marina</i>	bark	EtOH	LC ₅₀ = 55.1 mg mL ⁻¹	19
	leaf	EtOH	LC ₅₀ = 77.4 mg mL ⁻¹	20
	leaf	EtOAc	LC ₅₀ = 0.571 mg mL ⁻¹	
	leaf	MeOH	LC ₅₀ = 0.909 mg mL ⁻¹	20,21
	leaf	petroleum benzene	LC ₅₀ = 0.516 mg mL ⁻¹	20
	root	EtOH	LC ₅₀ = 79.1 mg mL ⁻¹	19
<i>Acanthus ilicifolius</i>	leaf	EtOH	LC ₅₀ = 74.7 mg mL ⁻¹	19
<i>Laguncularia racemosa</i>	leaf	water	LC ₅₀ = 62.5%	18
<i>Lumnitzera racemosa</i>	flower buds	water	LC ₅₀ = 1.34 mg mL ⁻¹	22
<i>Excoecaria agallocha</i>	leaf	EtOH	LC ₅₀ = 67.1 mg mL ⁻¹	19
<i>Sonneratia alba</i>	leaf	Water	LC ₅₀ = 192.03 ppm	23
<i>Suaeda maritima</i>	leaf	EtOH	LC ₅₀ = 135.034 ppm	24
<i>Heritiera fomes</i>	leaf	Water	LC ₅₀ = 102.115 ppm	25

EtOH: ethanol; LC₅₀: 50% lethal concentration; EtOAc: ethyl acetate; MeOH: methanol.

Table S4. Larvicidal activity of miscellaneous marine organisms' crude extracts against *Aedes aegypti*

Species	Organism	Extract	Larvicidal activity	Reference
<i>Himerometra magnipinna</i> <i>Comatella maculata</i>	lily	MeOH and EtOAc	MIC = 12.5 ppm ^a	26
<i>Didemnum bistratum</i>	ascidian	MeOH	LC ₅₀ = 0.44 mg mL ⁻¹	27
<i>Psammaphysilla purpurea</i> <i>Haliclona cribricutis</i>	sponge	MeOH: DCM (1:1)	LC ₅₀ = 25.90 ppm LC ₅₀ = 31.46 ppm	28

^aEqual for both species. MeOH: methanol; EtOAc: ethyl acetate; MIC: minimum inhibitory concentration; LC₅₀: 50% lethal concentration; DCM: dichlorometane.

Table S5. Antiviral activity of marine organisms crude extracts against Chikungunya (CHIK) and Dengue (DENV-2) virus

Species	Organism	Extract	Antiviral activity		Reference
			Virus type	Potency	
<i>Streptomyces</i> sp.	actinobacteria	EtOH	DENV-2 DENV-2	0.0612 g of MAE7 ^a 0.0323 g of MAE13 ^a	29
<i>Bryothamnion triquetrum</i>	seaweeds	DCM	CHIK	EC ₅₀ = 3.30 µg mL ⁻¹	30

^aThe extracts MAE7 and MAE13 were processed for PRNT (plaque reduction neutralization test) assay and the results showed that the both crude extracts had potent antiviral activity against dengue-2 virus. EtOH: ethanol; DCM: dichloromethane; EC₅₀: 50% effective concentration.

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