Taylor & Francis
Taylor & Francis Group

Natural Product Research
Formerly Natural Product Letters

ISSN: 1478-6419 (Print) 1478-6427 (Online) Journal homepage: https://www.tandfonline.com/loi/gnpl20

Allelopathic activity of some Sri Lankan seaweed extracts and the isolation of a new brominated nonaromatic isolaurene type sesquiterpene from red alga *Laurencia heteroclada* harvey

Haroon M. Haniffa, H. Ranjith, W. Dharmaratne, Mohammad Yasin Mohammad & M. Iqbal Choudhary

To cite this article: Haroon M. Haniffa, H. Ranjith, W. Dharmaratne, Mohammad Yasin Mohammad & M. Iqbal Choudhary (2019): Allelopathic activity of some Sri Lankan seaweed extracts and the isolation of a new brominated nonaromatic isolaurene type sesquiterpene from red alga *Laurencia heteroclada* harvey, Natural Product Research

To link to this article: https://doi.org/10.1080/14786419.2019.1655023

View supplementary material

Published online: 20 Aug 2019.

Submit your article to this journal

View related articles

View Crossmark data

Full Terms & Conditions of access and use can be found at
https://www.tandfonline.com/action/journalInformation?journalCode=gnpl20

NATURAL PRODUCT RESEARCH
https://doi.org/10.1080/14786419.2019.1655023

Taylor & Francis
Taylor & Francis Group

Check for updates

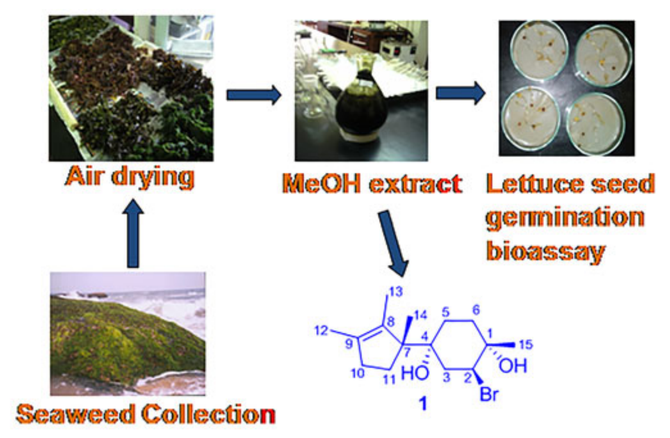
Allelopathic activity of some Sri Lankan seaweed extracts and the isolation of a new brominated nonaromatic isolaurene type sesquiterpene from red alga *Laurencia heteroclada* harvey

Haroon M. Haniffa[a,b,c], H. Ranjith W. Dharmaratne[a],
Mohammad Yasin Mohammad[c] and M. Iqbal Choudhary[c,d]

[a]Natural Products Programme, Institute of Fundamental Studies, Kandy, Sri Lanka; [b]Faculty of Applied Sciences, South Eastern University of Sri Lanka, Oluvil, Sri Lanka; [c]H.E.J. Research Institute of Chemistry, International Center for Chemical and Biological Sciences, University of Karachi, Karachi, 75270, Pakistan; [d]Department of Biochemistry, Faculty of Science, King Abdulaziz University, Jeddah, Saudi Arabia

ABSTRACT

This study investigated the allelopathic activity of sixteen seaweed extracts using lettuce seed germination bioassay. The results of the preliminary investigation suggested that the methanol extracts of seven seaweeds demonstrated significant properties inhibitory to seed germination. In addition, chemical investigation of an active extract of the alleopathic *Laurencia heteroclada* Harvey led to the isolation of four known compounds as well as a new brominated nonaromatic isolaurene type sesquiterpene. The structural elucidation of pure compounds was carried out using spectroscopic methods and by comparison with literature. As seaweeds are highly abundant around Sri Lanka, they could be developed as an ecofriendly natural herbicide in their crude form.



ARTICLE HISTORY
Received 20 March 2019
Accepted 30 July 2019

KEYWORDS
Seaweeds; brominated nonaromatic isolaurene; nonaromatic cuparane; allelopathic activity; lettuce seed germination bioassay

---

CONTACT Haroon M. Haniffa ✉ haroonmh@fas.seu.ac.lk

Supplemental data for this article can be accessed at https://doi.org/10.1080/14786419.2019.1655023.

© 2019 Informa UK Limited, trading as Taylor & Francis Group

1. Introduction

Plants produce specific compounds which affect the germination of other plant species growing in their surroundings. This phenomenon is called "allelopathy" (Namkeleja, Tarimo, & Ndakidemi, 2014), and it plays an essential role in both natural and cultivated ecosystems. Numerous plants are known to possess allelopathic properties and efforts have been made to utilize them for weed control. Although most common allelopathic plants have potential for weed suppression, their effects are usually short-lived and lack long term impact (Kaur, Aggarwal, Kumar, & Dhiman, 2014). Attempts have been made to isolate and identify allelochemicals in plants, but these allelochemicals were mostly found in low concentrations and were found to be interactive (Soltys, Krasuska, Bogatek, & Gniazdowska, 2013). The use of seaweeds to achieve this purpose is a relatively new and untouched area. "Seaweed" refers to the marine algae that grow almost exclusively in shallow waters at the edge of the world's oceans (Rinehart et al., 1981).

Red algae of the genus *Laurencia* Harvey (Ceramiales, Rhodomelaceae) encompass a widely distributed variety of morphologically-complex algal species with ambiguous taxonomy (Lyakhova et al., 2006). This genus has yielded diverse bioactive metabolites, that are usually characterized by the presence of halogen atoms (Shklyaev, Yeltsov, Rozhkova, Tolstikov, & Dembitsky, 2004; Vairappan & Tan, 2009; Cabrita, Vale, & Rauter, 2010; Yang et al., 2018) such as sesquiterpenes, diterpenes, triterpenes, and C_{15}- acetogenins. Currently, the genus *Laurencia* is the most studied of all the algal genera; the majority of its constituents are of terpenoidal nature (Cassano, De-Paula, Fujii, Da Gama, & Teixeira, 2008; Tiwari & Troy, 2015). In order to advance our efforts to identify biologically active compounds in Sri Lankan seaweeds (Haroon & Dharmaratne, 2013a; Haroon, Premaratne, Choudhry, & Dharmaratne, 2013b), we investigated the chemical composition of *Laurencia heteroclada* Harvey. This study led to the isolation of a new brominated nonaromatic isolaurene type sesquiterpene (**1**), along with four known compounds: nonaromatic cuparane (**2**), algoane (**3**), caulerpin (**4**), and cholesterol (**5**). Lettuce seed germination bioassay, which is widely used in the detection of allelochemicals, was successfully used to test the allelopathic activity of seaweed extracts (Khanh, Hong, Xuan, & Chung, 2005). The present study reports the isolation and identification of pure compounds together with lettuce seed germination bioassay for screening of seaweed extracts and pure compounds.

2. Results and discussion

Out of sixteen crude MeOH extracts of seaweeds, seven extracts exhibited significant differences in their mean radical length, compared to the control, sterile distilled water (Table S1). However, *Laurencia heteroclada* Harvey and *Caulerpa racemosa* (Forsskål) J. Agardh showed the lowest germination values of 17.5% and 18.0% respectively in the lettuce seed germination while *Caulerpa sertularioides* showed a 25% germination value and appeared to possess the smallest average radical length of 0.63 ± 0.197. Interestingly, *Caulerpa racemosa* f. *laxa* showed evidence of seed germination stimulation activity. Although other extracts did not inhibit lettuce seed germination at a significant level, reduced root lengths of lettuce seeds might increase the possibility of

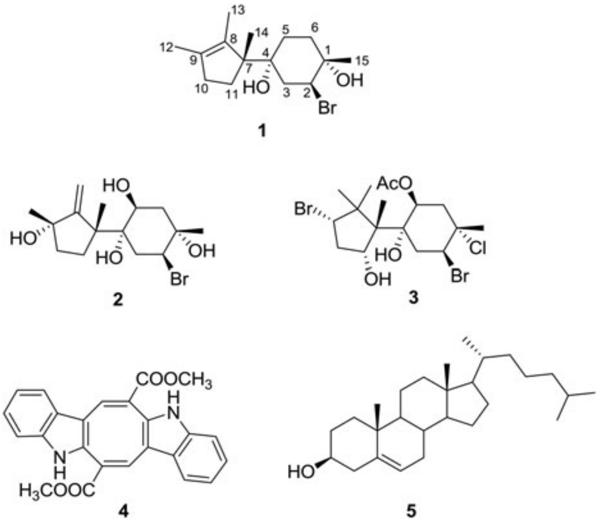


Figure 1. The structures of compounds **1** – **5**.

seedling desiccation prior to establishment of roots and may delay growth, since water intake is necessary for seedling growth.

The allelopathic MeOH extract of *L. heteroclada* Harvey was subjected to repeated column chromatography on flash silica gel, yielding five pure compounds. The chemical structures of these pure compounds (Fig. 1) were unambiguously confirmed by extensive spectroscopic analyses (including NMR, IR, and HREI-MS) and by comparison with related studies. Sesquiterpene (**1**) was obtained as white powder. The positive FAB MS of **1** showed the molecular ion peak $[M+H]^+$ at *m/z* 317 along with isotopic peak at *m/z* 319 (1:1), indicating the presence of a Br atom in the molecule. HREI-MS displayed the $[M]^+$at *m/z* 316.1032, supporting the composition of $C_{15}H_{25}O_2Br$ (Calcd.316.1038) with 3 degrees of unsaturation. Careful comparison of the ^{1}H NMR and ^{13}C NMR data of **1** with those of **3** suggested a similar sequiterpene skeleton in **1,** with a different substitution pattern and an unsaturation. The IR spectrum of **1** also showed absorption peaks at 1639 and 3467 – 3546 cm^{-1} indicating the presence of olefinic bond and hydroxyl groups.

The ^{13}C-NMR spectrum of compound **1**, in $CDCl_3$ showed 15 carbon signals. DEPT-135 and DEPT-90 spectra showed four methyl, five methylene and one methine carbons, while the rest of the five signals were detected as quaternary carbons. The quaternary olefinic carbons assigned to C-9 and C-8 in **1** were resonated at δ_C 135.2, and 133.6, respectively. Two oxygenated carbons appeared at δ_C 71.5 and 78.5 were assigned to C-1 and C-4 respectively while the bromine-bearing carbon atom resonated at δc 61.3 was assigned to C-2. Analysis of DEPT-135 spectra showed five methylene carbons resonated at δc 30.3, 33.7, 35.7, 38.0 and 41.8, assigned to C-5, C-11, C-10, C-6 and C-3 respectively.

The ^{1}H NMR ($CDCl_3$, 400 MHz) (Table S2) spectrum of **1** showed signals for four methyl, five methylene, and one methine protons. Methyl protons were resonated at δ_H 1.01 (3 H, s), 1.61 (6 H, s), and 1.64 (3 H, s), assigned to Me-14, Me-12/Me-13 and Me-15, respectively. The characteristic downfield proton at δ_H 4.71 (dd, $J = 12.5$, $J = 4.6$ Hz) was assigned to H-2, geminal to equatorial bromo substituent. Moreover, a hydrogen atom resonating at δ_H 1.32 as a singlet and another hydrogen atom resonating at δ_H 4.89 ($J = 2.5$) as a doublet assigned to the OH protons attached to C-4 and C-1 respectively. All of the hydrogen bearing carbons and their protons in **1** were assigned with the aid of HMQC experiments.

The assignments of methylene protons were further supported by the COSY experiments of **1**. The ^{1}H-^{1}H COSY experiments of **1** revealed that the methine H-2 [δ_H 4.71 (1 H, dd, $J = 12.5$, $J = 4.6$ Hz)] was coupled to the methylene H-3 which appeared at δ_H 2.18 (1Hb, m) and 1.98 (1Ha, t, $J = 13.4$ Hz). The COSY experiments also showed that the H-6 [δ_H 2.45 (1Hb, ddd, $J = 18.0$, $J = 13.2$, 5.2 Hz) and 2.14 (1Ha, m)] were coupled to the methylene H-5 which appeared at δ_H 1.57 (1Hb, m) and 1.65 (1Hb, m).

Similarly, in the cyclopentene ring, the methylene H-11 [δ_H 1.45 (1Ha, ddd, $J = 8.5$, $J = 7.0$, $J = 2.7$ Hz) and 1.85 (1Hb, sept, $J = 13.4$, $J = 8.8$, $J = 5.0$ Hz)] were coupled to the methylene H-10 which appeared at δ_H 2.15 (1Ha, m) and 2.20 (1Hb, m). Furthermore, cross peaks were also observed between Hb-3 (δ_H, 2.18) and Ha-3 (δ_H, 1.98), between Hb-6 (δ_H, 2.45) and Ha-6 (δ_H, 2.14), between Ha-11 (δ_H, 1.85) and Hb-11 (δ_H, 1.45). HMBC correlations of C-14 protons ($\delta_{H,}$ 1.01) with C-4 (δ_C, 78.5), C-7 (δ_C, 58.1), C-11 (δ_C, 33.7), and C-8 (δ_C, 133.6) were observed along with HMBC correlations of H-5 methylene protons (δ_H 1.57/1.65) with C-6 (δ_C, 38.0), C-4 (δ_C, 78.5) and C-7 (δ_C, 58.1). These correlations clearly indicated the connection between the two structural units in the molecule (Fig. S2).

The relative stereochemistry of **1** was deduced by the analysis of the coupling constants and NOESY correlations (Fig. S3). The NOESY interactions between H_3-14 (δ_H, 1.01) and Ha-3 (δ_H, 1.98) and between Ha-3 (δ_H, 1.98) and H_3-15 (δ_H, 1.64) showed that CH_3-14 and CH_3-15 are on the same side of the molecule. Additionally, the NOE interactions between H_3-14 (δ_H, 1.01) and Ha-11 (δ_H, 1.45) and between H_3-14 (δ_H, 1.01) and Ha-10 (δ_H, 2.15) were observed in the cyclopentene ring. The large coupling constants between H-2 and Ha-3 ($J = 12.5\, J = 4.6$ Hz) suggested that H-2 has an *axial* orientation. The orientation of the olefinic double bond in the cyclopentene ring was predicted based on the strong NOESY correlations between H_2-5 (δ_H, 1.57-1.65) and CH_3-13 (δ_H, 1.61)) and between H_2-10 (δ_H, 2.15-2.20) and CH_3-12 (δ_H, 1.61). The spectral data of **1** were similar to those of algoane (**3**), a sesquiterpene which has been previously reported in the South African sea hare, *Aplysia dactylomela* (McPhail, Davies-Coleman, Copley, & Eggleston, 1999) which feeds predominantly on the *Laurencia* species. A comparison of overall NMR spectroscopic data (COSY, HMQC and HMBC) and MS data of **1** and **3** revealed that **1** is a new brominated nonaromatic isolaurene type sesquiterpene. Among marine organisms, the red alga *Laurencia* is considered to be the main producer of laurane-type sesquiterpenes (Li, Miao, Li & Ji, 2012; Al-Massarani, 2014)

The absolute configurations at C-1, 2 and 4 were assigned as 1*S*, 2*S*, and 4*R* respectively by the NOESY experiment and by comparing with the structure of the algoane (**3**).This appears to be the first report of isolation of algoane (**3**) from a seaweed. Compound (**2**), the non aromatic cuparane, has been earlier reported by Haroon et al. from the same algal species. Caulerpin (**4**) has been previously reported from the green alga *Caulerpa racemosa* (Anjaneyulu, Prakash & Mallavadhani, 1991) and red alga *Chondria armata* (Govenkar & Wahidulla, 2000), while compound **5** was identified as cholesterol, which has been previously reported from red alga (Nasir, Saeidnia, Mashinchian-Moradi, & Gohari, 2011). The pure compounds **1**, **2** and **3** were tested against lettuce seed germination assay. The compound **3** showed moderate activity on seed germination inhibition at 1000 ppm while the compounds **1** and **2** were found to be inactive (Table S1). Previous phytochemistry research exhibited that compounds (5Z, 8Z, 11Z, 14Z, 17Z)-eicosapentaenoic acid had been isolated from red alga *Neodilesea yendoaana* (Suzuki, Wakana, Denboh, & Tatewaki 1996), and that methyllanosol isolated from *Odonthalia washingtoniensis* (Kubo, 1989) showed allelopathic activity against microalgae and lettuce seed germination bioassay respectively.

3. Experimental

3.1. Algae material

Fresh marine algae, *Ulva fasciata*, *Cladophora spp*, *Halimeda discoidea*, *Caulerpa racemosa* (Forsskål) J. Agardh, *Caulerpa sertularioides, Caulerpa racemosa* f. laxa (Greville) Weber-van Bosse, *Udotea flabellum*, *Padina pavonica, Dictyota kunethi*, *Amphiroa anceps*, *Cheilosporum cultratum*, *Laurencia ceylanica, Laurencia heteroclada, Gracilaria hikkaduwensis, Gymnogongrus pygmaeus,* and *Jania spp*. were collected between once a month and once every four months (March, 2006 – March, 2007), depending on availability, from four different locations, including, Arugambay, Hambantota, Krinda and Tangalle. They were identified through direct comparison with algal specimens and confirmed with the help of a taxonomist at the National Herbarium, Royal Botanic Gardens, Peradeniya, Sri Lanka. The voucher specimens were deposited by being fixed in 5% buffered formalin at the Natural Products Laboratory of the Institute of Fundamental Studies in Kandy, Sri Lanka. Algae attached to the rocks and other substrates were collected by hand, while certain algae like *Amphiroa anceps* were found at a depth of 400 m, and collected with the help of local fishermen. The red alga *Laurencia heteroclada* Harvey was collected in Tangalle on the southern cost of Sri Lanka in December 2006.

3.2. General procedure

Melting points were determined on a Büchi 535 melting point apparatus. Optical rotations were measured in MeOH on a Jasco DIP-360 digital polarimeter. IR spectra were recorded on a FT IR-8900 spectrophotometer. UV spectra were obtained on a Hitachi UV 3200 spectrophotometer. 1 D and 2 D NMR spectra were recorded in $CDCl_3$ and CD_3OD, Bruker Avance-400 and 500 operating at 400, and 500 MHz, respectively. The ^{13}C NMR experiments were conducted on the same instruments at 100 and 125 MHz, respectively. Chemical shifts (δ) were in ppm, relative to the chemical shift of tetramethylsilane (TMS), as internal standard and coupling constants J in Hz. The EI MS and CI-MS were measured on a Jeol JMS-600 mass spectrometer. FAB-MS was performed on a Jeol JMS HX 110 mass spectrometer by using glycerol as the matrix. Column chromatography was carried out using silica gel (E-Merck, 230-400 mesh size). TLC separations were performed on precoated plates (Silica gel 60, PF_{254}, 0.2 mm, E-Merck), and spots were detected using ceric sulphate as the spray reagent.

3.3. Extraction and isolation

Seaweed samples were carefully washed several times with fresh water to remove salt, sand particles and other debris. They were thoroughly air-dried and pulverized using a grinder. Powdered seaweeds (100 g) were separately extracted three times with methanol (250 ml) under sonication. The MeOH extracts were evaporated in a rotary evaporator to give crude extracts (6–10 g). Then the crude extracts of different seaweed species were tested in the lettuce seed germination bioassay. For the chemical investigation, the dried *L. heteroclada* (350 g) was finely powdered and extracted three times with methanol (750 mL) under sonication. After filtration, the MeOH extract was evaporated to give 15 g of dry extract. The MeOH extract was subjected to column chromatography (CC) on flash silica gel. The above column was eluted with gradient polarities of hexane, ethyl acetate, methanol, and water as eluants yielding seven major fractions: F-1 (300 mg), F-2 (50 mg), F-3 (200 mg), F-4 (30 mg), F-5 (25 mg), F-6 (40 mg), and F-7 (30 mg). Repeated flash silica CC of F-1 (5% EtOAc: *n*-hexane) yielded a pure compound **3** (70 mg, 0.02%). When 50 mg of F-2 (10% EtOAc: *n*-hexane) was subjected to CC, compound **1** (12 mg, 0.0034%) was obtained. Fraction F-3 (18% EtOAc: *n*-hexane), when subjected to CC, yielded two fractions F-31 (100 mg) and F-32 (18 mg). When 100 mg of F-31 (8% CH_2Cl_2: *n*-hexane) were subjected to column chromatography, compound **5** (60 mg, 0.017%) was obtained as a pure compound. Further, fraction F-4 (30% EtOAc: *n*-hexane) on CC afforded **4** (2.5 mg, 0.0007%) as a pure compound, and repeated CC of F-5 (40% EtOAc: *n*-hexane) yielded **2** (14 mg, 0.004%) as a pure compound.

3.4. Lettuce seed germination assay

In this study, seed germination bioassay was employed to determine the allelopathic potential of seaweed extracts and pure isolates (Piyasena and Dharmaratne, 2013).

2-Bromo-3,5,6-trihydro-1,4-dihydroxy isolaurene (**1**)

White powder (12 mg, 0.0034%), mp 70-72 °C, $[\alpha]^{25}{}_D$ +93° ($c = 0.06$, $CHCl_3$) UV (MeOH), λ_{max} nm 202; IR (KBr) ν_{max} 1639, 1713, 3467, 3546 cm^{-1}; FAB MS (positive mode) *m/z* 317 $[M+H]^+$, 319 $[M+2]^+$; HREI-MS: Calculated for $C_{15}H_{25}O_2Br$; 316.1038, Observed; 316.1032; ^1H NMR ($CDCl_3$, 400 MHz): δ 1.01 (3 H, s, H_3-14), 1.22 (1 H, s, OH-4), 1.45 (1 H, ddd, $J = 8.5$ Hz, $J = 7.0$ Hz, $J = 2.7$ Hz, Ha-11), 1.57 (1 H, m, Hb-5), 1.61 (6 H, s, H-12/13), 1.64 (3 H, s, H_3-15), 1.65 (1 H, m, Ha-5), 1.85 (1 H, sept., $J = 13.4$ Hz, $J = 8.8$ Hz, $J = 5.5$ Hz, Hb-11), 1.98 (1 H, t, $J = 13.4$ Hz, Ha-3), 2.14 (1 H, m, Ha-6), 2.15 (1 H, m, Ha-10), 2.18 (1 H, m, Hb-3), 2.20 (1 H, m, Hb-10), 2.45 (1 H, ddd, $J = 18.0$ Hz, $J = 13.2$ Hz, $J = 5.2$ Hz, Hb-6), 4.71 (1 H, dd, $J = 12.5$ Hz, $J = 4.6$ Hz, H-2), 4.89 (1 H, d, $J = 2.5$, OH-1); ^{13}C NMR ($CDCl_3$, 100 MHz): δ 12.7 (C-13), 14.4 (C-12), 20.3 (C-14), 23.3 (C-15), 30.3 (C-5), 33.7 (C-11), 35.7 (C-10), 38.0 (C-6), 41.8 (C-3), 58.1 (C-7), 61.3 (C-2), 71.5 (C-1), 78.5 (C-4), 133.6 (C-8), 135.2 (C-9).

4. Conclusion

In this study, a new brominated compound **1** has been isolated from *Laurencia heteroclada* and identified as 2-bromo-3,5,6-trihydro-1,4-dihydroxy isolaurene by using different spectroscopic techniques. Compound **3** showed moderate activity against lettuce seed germination bioassay. In addition, some of the seaweeds tested showed significant allelopathic activities and thus could potentially be used as sources of natural herbicides in their crude form.

Acknowledgments

HMH is thankful to the ICCBS for the fellowship for six months to conduct a research at the H. E. J. Research Institute of Chemistry, International Center for Chemical and Biological Sciences, University of Karachi, Karachi, Pakistan.

References

Al-Massarani SM. 2014. Phytochemical and biological properties of sesquiterpene constituents from the marine red seaweed *Laurencia*: A review. Nat Prod Chem Res 2014. 2:1–13.

Anjaneyulu A, Prakash C, Mallavadhani U. 1991. Two caulerpin analogues and a sesquiterpene from *Caulerpa racemosa*. Phytochemistry. 30(9):3041–3042.

Cabrita MT, Vale C, Rauter AP. 2010. Halogenated compounds from marine algae. Mar Drugs. 8(8):2301–2317.

Cassano V, De-Paula JC, Fujii MT, Da Gama BAP, Teixeira VL. 2008. Sesquiterpenes from the introduced red seaweed *Laurencia caduciramulosa* (Rhodomelaceae, Ceramiales). Biochemical Systematics and Ecology. 36(3):223–226.

Govenkar MB, Wahidulla S. 2000. Constituents of *Chondria armata*. Phytochemistry. 54(8): 979–981.

Haroon M, Dharmaratne HRW. 2013a. New brominated sesquiterpenes from the red alga *Laurencia heteroclada* Harvey, and their immunosuppressive activity studies. *3rdInternational Symposium of South Eastern University of Sri Lanka*, 3, 59–62

Haroon M, Premaratne S, Choudhry MI, Dharmaratne HRW. 2013. A new β-glucuronidase inhibiting butyrolactone from the marine endophytic fungus *Aspergillus terreus*. Natural Product Research. 27(12):1060–1066.

Kaur M, Aggarwal NK, Kumar V, Dhiman R. 2014. Effects and management of *Parthenium hysterophorus*: A weed of global significance. International Scholarly Research Notices. :1. 2014

Khanh TD, Hong NH, Xuan TD, Chung IM. 2005. Paddy weed control by medicinal and leguminous plants from Southeast Asia. Crop Protection. 24:421–431.

Kubo I. 1989. Effect of a marine algal constituent on the growth of lettuce and rice seedlings. Pure and Applied Chemistry. 61(3):373–375.

Li XD, Miao FP, Li K, Ji NY. 2012. Sesquiterpenes and acetogenins from the marine red alga *Laurencia okamurai*. Fitoterapia. 83(3):518–522.

Lyakhova EG, Kalinovsky AI, Dmitrenok AS, Kolesnikova SA, Fedorov SN, Vaskovsky VE, Stonik VA. 2006. Structures and absolute stereochemistry of nipponallene and neonipponallene, new brominated allenes from the red alga *Laurencia nipponica*. Tetrahedron Letters. 47(37): 6549–6552.

McPhail KL, Davies-Coleman MT, Copley RC, Eggleston DS. 1999. New Halogenated Sesquiterpenes from South African Specimens of the Circumtropical Sea Hare *Aplysia actylomela*. J Nat Prod. 62:1618–1623.

Namkeleja HS, Tarimo MT, Ndakidemi PA. 2014. Allelopathic effects of *Argemone mexicana* to growth of native plant species. AJPS. 05(09):1336.

Nasir M, Saeidnia S, Mashinchian-Moradi A, Gohari AR. 2011. Sterols from the red algae, *Gracilaria salicornia* and *Hypnea flagelliformis*, from Persian Gulf. Phcog Mag. 7:97.

Piyasena KNP, Dharmaratne HRW. 2013. Allelopathic activity studies of *Mikania scandens*. Natural Product Research. 27(1):76–79.

Rinehart KL, Shaw PD, Shield LS, Gloer JB, Harbour GC, Koker MES, Samain D, Schwartz RE, Tymiak AA, Weller DL, et al. 1981. Marine natural products as sources of antiviral, antimicrobial, and antineoplastic agents. Pure and Applied Chemistry. 53(4):795–817.

Shklyaev YV, Yeltsov M, Rozhkova YS, Tolstikov A, Dembitsky V. 2004. A new approach to synthesis of 3, 3-dialkyl-3, 4-dihydroisoquinoline derivatives. Heteroatom Chem. 15(7):486–493.

Soltys D, Krasuska U, Bogatek R, Gniazdowska A. 2013. Allelochemicals as bioherbicides—Present and Perspectives. In: Price AJ, Kelton JA (Eds). Herbicides-Current Research and Case Studies in Use. In tech, pp 517–542

Suzuki M, Wakana I, Denboh T, Tatewaki M. 1996. An allelopathic polyunsaturated fatty acid from red algae. Phytochemistry. 43(1):63–65.

Tiwari BK, Troy DJ. 2015. Seaweed sustainability: Food and Non-Food Applications. 1st ed.; Academic Pres: Amsterdam, The Netherlands, pp. 1–6.

Vairappan CS, Tan KL. 2009. C-15 halogenated acetogenin with antibacterial activity against food pathogens. Malaysian Journal of Science. 28:263–268.

Yang XX, Su YZ, Tan J, Cai CE, He PM, Jia R. 2018. A new dimeric sesquiterpene and other related derivatives from the marine red alga *Laurencia okamurai*. Biochemical Systematics and Ecology. 79:57–59.

View publication stats