Chemico-Biological Interactions 243 (2016) 135–147

Contents lists available at ScienceDirect

Chemico-Biological Interactions

journal homepage: www.elsevier.com/locate/chembioint

Mini-review

Significance of investigating allelopathic interactions of marine organisms in the discovery and development of cytotoxic compounds

Anshika Singh, Narsinh L. Thakur*

Academy of Scientific and Innovative Research (AcSIR), CSIR – National Institute of Oceanography, Dona Paula, Goa 403 004, India

ARTICLE INFO

Article history:
Received 20 December 2014
Received in revised form
1 July 2015
Accepted 4 September 2015
Available online 9 September 2015

Keywords:
Marine sessile organisms
Competition for space
Allelopathic interactions
Allelochemicals
Cytotoxic compounds

ABSTRACT

Marine sessile organisms often inhabit rocky substrata, which are crowded by other sessile organisms. They acquire living space via growth interactions and/or by allelopathy. They are known to secrete toxic compounds having multiple roles. These compounds have been explored for their possible applications in cancer chemotherapy, because of their ability to kill rapidly dividing cells of competitor organisms. As compared to the therapeutic applications of these compounds, their possible ecological role in competition for space has received little attention. To select the potential candidate organisms for the isolation of lead cytotoxic molecules, it is important to understand their chemical ecology with special emphasis on their allelopathic interactions with their competitors. Knowledge of the ecological role of allelopathic compounds will contribute significantly to an understanding of their natural variability and help us to plan effective and sustainable wild harvests to obtain novel cytotoxic chemicals. This review highlights the significance of studying allelopathic interactions of marine invertebrates in the discovery of cytotoxic compounds, by selecting sponge as a model organism.

Contents

* Corresponding author.
E-mail address: thakurn@nio.org (N.L. Thakur).

http://dx.doi.org/10.1016/j.cbi.2015.09.009

1. Introduction

Living space is one of the basic requirements of any organism. In regions such as coral reefs and rocky intertidal areas, diverse sessile marine organisms share a limited space. Most of these organisms require space on hard substrata for the settlement and metamorphosis of their larvae. In the harsh intertidal environment, the space they occupy should be suitable in terms its exposure to water currents carrying food and sufficient irradiance in the case of phototrophic sessile organisms. Thus, suitable space on shallow marine substrata often is a limiting resource for the settlement, growth, and reproduction of tropical marine organisms [1–4]. Spatial competition among sessile marine invertebrates is a major process, which not only controls the patterns of diversity and abundance of these organisms, but also zonation in intertidal organisms and structure of an ecosystem [5,6]. Thus, spatial competition has gained the attention of several investigators, who are interested in understanding community structure [1,7,8]. The competitive interactions among sessile organisms are mediated by 1) their relative growth rates and 2) release of toxic chemicals. Growth-mediated interactions are well documented in literature [9–11] whereas chemically-mediated interactions have not received enough attention. These chemically-mediated interactions are the source of novel bioactive metabolites [12]. A wide range of natural products have been obtained from marine invertebrates [13–23]. However, only a few have been explored for their ecological role in spatial competitions [12,24–26]. To the best of our knowledge, there is no report so far where the understanding of the ecological function of the compound has been utilized for its development as a potential drug. This review includes 1) examples of chemically-mediated spatial competition of sponges with other sessile invertebrates, 2) various factors affecting the production of chemicals involved in spatial competition and 3) significance of studying chemically-mediated interactions to utilize the knowledge in the discovery and development of drug molecules. This paper emphasizes the need of linking chemical ecology to drug discovery for sustainable utilization of marine natural resources with special reference to the marine sponges.

2. Strategies to compete for space

Marine invertebrates acquire living space by using various offensive and defensive strategies like (1) growth interactions (e.g., overgrowth by corals) [27], (2) aggressive behaviour (e.g., induced development of sweeper tentacles by bryozoans) [28], (3) feeding interactions (e.g., extracoelenteric digestion via mesenteries filaments by scleractinian corals) [29] and (4) allelopathy [12]. Allelopathy may be defined as the direct inhibition of one species by another by using toxic chemicals [30]. These allelochemicals belong to the class of secondary metabolites which are not directly involved in growth and reproduction of the organisms. However, these allelochemical provide interspecies defences in terms of occupied space by affecting metabolic and physiological processes in the competitors. The allelochemicals can either be released into the water column or transferred by direct cell to cell contact between donor and recipient [31]. Chemically-mediated interactions are often difficult to notice. Standoff interactions, where no clear outcome, such as a win or loss is observed, are very common in marine hard substratum communities [32]. Amongst above four defensive strategies discussed, allelopathy or chemical defence is the most important in case of soft-bodied sessile invertebrates such as sponges, octocorals and ascidians which lack proper physical defences [33]. The knowledge of chemical defences of these organisms is very useful for obtaining novel bioactive compounds (secondary metabolites) of therapeutic value. However, the production of secondary metabolites in the organisms does not occur continuously and is subjected to spatio-temporal variation [34]. Various reports have postulated two prominent hypotheses to explain variability in the production of secondary metabolites: 1) growth-differentiation balance hypothesis (GDBH) and 2) optimal defence theory (ODT). The GDBH assumes that an organism maintains a balance between resources invested in primary and secondary functions, whereas ODT postulates that allelochemical production is primarily restricted to areas that are under threat (e.g., outer surfaces) or areas of higher importance (e.g., reproductive organs) [35,36]. The ODT is applicable to various marine invertebrates, including sponges [37]. According to ODT, the production of allelochemical is a costly process. The total energy reservoirs of the organisms are limited and the production of any secondary metabolites takes place at the expense of other primary functions such as growth and reproduction [38].

2.1. The sponge as a model organism

Most of the ecologists have investigated 'sponge-coral interactions' to understand the mechanism of spatial competition in sessile invertebrates [31], factors affecting the competitive outcomes [39] and chemicals involved in defending the occupied space or acquiring new space [12]. The use of allelopathy to occupy substrata has been reported in several other groups of sessile marine organisms like anemones, soft corals (Coelenterata, Alcyonacea), tunicates etc. [32,40]. Several bioactive compounds have been detected in a variety of cnidarians including soft corals, zoanthids and sea anemones [41,42]. Besides the chemical defences, cnidarians, tunicates and bryozoans employ a variety of alternative mechanisms (faster growth rate, early sexual maturity, high fecundity, presence of sweeper polyps, sweeper or marginal tentacles) to protect their occupied area [43–45]. Among all above soft-bodied sessile organisms, the sponges are noteworthy because they inhabit multiple, diverse ecosystems, from equator to poles and from shallow waters to the highest depths [46]. Most of the sponges have siliceous spicules which provide an advantage over other