Rafidain Journal of Science

Vol. 30, No. 3, pp. 30-38, 2021

Review Article

DOI: 10.33899/rjs.2021.168909

https://rsci.mosuljournals.com

ISSN: 1608-9391
e-ISSN: 2664-2786

Received:5/4/2021
Accepted:15/6/2021

The Allelopathic in the Diatoms

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ABSTRACT

Diatoms considered as are a phytoplankton main group of in aquatic ecosystems abundance, diversity, and productivity. Allelopathic infractions, are an important part of phytoplankton competition, allelopathy may be one of the factors affecting the structure of phytoplankton. Diatoms are known to produce a number of allelopathic compounds, such as polyunsaturated fatty acids (PUFAs), polyunsaturated aldehydes (PUAs) and polyphenolic and halogenated compounds. However, Allelochemicals (AC) are chemical substances produced by diatoms and release which affecting microorganisms in their neighborhood. These chemicals are able to prevent or encourage the co-occurring phytoplankton species growth along other organisms. Such sintering behavior affecting not just each species that replying to or making a definite chemical, but as well functioning of communities, populations, and ecosystems including defense, reproduction, competition, and predator avoidance. The current review demonstrates work of Allelopathy in diatoms and stimulated or excreted chemicals via diatom direct or indirect way to environment for maintaining their domination.

Keywords: Diatoms, Allelopathy, Plankton community.

INTRODUCTION

Allelopathy takes place if one species of plant discharges chemical substances to the surrounding, indirectly or directly by decomposition of microbial residues which disturb other protists, plants (i.e., ciliates, microalgae, etc.), viruses or bacteria, (Zimdahl, 2018). The truth that in 1931, algae possibly have characteristics of allelopathic (AP) that suggested sporadically since Akehurst suggested proposed the non-nutritional presence of communications among phytoplankton intervened via compounds being organic (Maestrini and Bonin, 1981). Interactions of AP among phyto-plankton species are considered to be avital element that contributes to succession and competition of phytoplankton species.

Allelochemical (AC) is able to create blistering, lysis, inhibition of growth or objective cells death. AC might also positively affect other species of phytoplankton growth and other microorganisms. The materials might even encourage or prevent the organism being donor itself (Olli and Trunov, 2007). Allelochemicals are assumed to profit the donor organism in various behaviors.

Diatoms considered as actual significant as planktonic members of food chain for large earth part; they are recognized to establish biotic interactions with several plankton members. In the opposite to mostly plankton groups, on worldwide scale, diatoms show a greater negative correlation with other organisms, particularly in the direction of potential parasites and predators (Vincent and Bowler, 2020).

The Diatoms

Bacillariophyceae as class of diatoms considered as mostly diverse planktonic algae, distributed widely across all habitats as aquatic (Malviya *et al.,* 2016) which are plentiful, further common and diverse in rivers and streams. Currently, there are more than 500 diatoms genera (150 extinct and 350 living), of almost 17,000 species. These microorganisms are free-floating freely at freshwater or marine environments. Numerous diatoms epiphytically are living on aquatic organism's surface such as mollusks, plants, turtles, seaweeds, fishes, etc. (Hoek *et al.,* 2009). They are eukaryotic unicellular microalgae of Protista kingdom, having chlorophylls a and c besides accessory pigments i.e., xanthophyll and carotenoid. Cells as individuals are of size 2- 200 µm (Grethe *et al.,*2013). They are of significant ecological functions on worldwide scale. Diatoms are of responsibility of worldwide CO2 fixation as 20% and of marine main productivity as 40%, so diatoms are chief donors to processes of climate change, and create an extensive food web as aquatic basis. Wall of diatom cells have siliceous frequently extremely ornamented, their structures box-like, and each-one is somewhat greater than the other. Frustule is the term of cell that comprise two valves. As long diatoms "live in glass houses" there should be methods for them for nutrients taking up, metabolic wastes releasing, and keeping invaders physically at bay hence, walls of diatom cell are punctured via trivial holes (so called areolae or punctae) which then might by sieve plates be covered (in various forms, sometimes on cell wall outside or inside) of tiny holes which cover the areolae or punctae. Areolae into striae are aligned, and the striae and areolae patterns and structure help with fine and broad-scale taxonomic descriptions. In various forms, these holes are organized (as symmetry creating aesthetic diatoms beauty). The valve's structure renders diatoms light weight as well offering a high integrity degree of structure (Round *et al.,*1990).

Diatoms importance

Bacillariophyceae as diatoms encompass a global, extremely popular and unicellular algae as group being distinctive that have helped as mostly prized indicator to ecological rivers assessment round the world for the previous fifty decades (Srivastava *et al*., 2016). Diatoms have widely been utilized to follow changes in rivers and streams quality of water because of specific group sensibility to ecological conditions variety. Their preferences and tolerances for EC, pH, humidity, salinity, organic matter, saprobity, state of trophic, requirements of O_2, concentration of nutrients, and current velocity in streams of freshwater, spring, rivers, wetlands, lakes, and estuaries have been definite, and diatoms also have been utilized in studies as paleolimnological. Indices as biotic utilizing diatoms according to the relative species weighted abundance through their auto-ecological values that have been established globally though biotic integrity indices according to non-diatom and diatoms, periphyton, comprising macroinvertebrates, cyanobacteria, macrophytes and assemblages of fish that also have been established for monitoring biologically (Visco *et al.,* 2015). Diatoms take place in assemblages relatively being diverse, and species mostly, particularly the mutual ones, are relatively easily if comparing to other algae invertebrates and assemblages. Diatoms readily might be classified to levels as species and subspecies according to their exceptional characteristics morphologically, while several classes of algal have additional than one life cycle stage. In comparison to macro-invertebrates and fish, diatoms of life cycle shorter (≈ 2 week). They breed and quickly respond to changes of environment, thus offering prompt indicators of warning both for increase in pollution and restoration habitat success (Stevenson *et al.,* 2010). They are valuable environmental conditions indicators in streams and rivers because they are responding sensitively and directly to precise changes as chemical, physical, and biological (Stevenson and Sabater 2010). A river pollution and diatoms study review by Rimet (2012) explained that numerous taxa of diatom have documented as strong indicators pollution i.e., *Navicula, Gomphonema, Nitzschia, and Cocconeis*.

Diatomite which is termed diatomaceous earth is diatom shells collections create in the crust of earth which are soft, containing silica from sedimentation of rocks that are crumbled easily into a fine powder and naturally of 10-200 μm as size of particle.

Diatomaceous earth is utilized for a diversity of drives i.e., for filtration of water, as abrasive as mild and as a dynamite stabilizer. Also, in sediments, frustules of diatom are of a long-lasting permanence in which cores of sediment offer changes details in the overlying water quality along with the previous changes of climate (Lane *et al.,* 2009).

Diatoms defensing versus predation

Diatoms are able to generate huge blooms where biomass of diatom may upsurge three times in a couple of days (Platt *et al.,* 2009). Such achievement has partially been accredited to an extensive predation avoidance mechanisms range, i.e., their skeleton of hard mineral (Hamm and Smetacek, 2007), spine and chain formation in few species, and production of toxic aldehyde.

Diatoms yield and expel chemical materials which are distressing environment directly of other micro-organisms. Such materials are called as Allelochemicals (AC).

In community of marine microbial, AC can disturb directly and indirectly competitors, prey, and grazers i.e., in web of food in which abundance of prey is controlled by grazing, the direct negative AC effect on grazers will affect definitely their prey. Few experts debate that Allelochemicals are mainly considered as mechanisms of defense versus predators (Wolfe, 2000). The Allelopathy material is either predator-deleterious if ingested algae, or ingestion prevention via predator killing (Tillmann, 2003). At such case, observed influences on other micro-organisms than grazers may be bi-effects as irrelevant for species itself being donor; as the real chemicals target are alga predators, i.e., rotifers or copepods.

The ecologist’s interest which regarded such type kind of interactions of chemicals is being seasonal species drivers of succession, besides an element that may encourage diversity of phyto-plankton community (Felpeto and Vasconcelos,1 2016). Many studies results reveal that AC mainly behaves as micro-zooplankton herbivory deterrent on diatoms, whereas herbivory enhancing on picophytoplankton. Allelopathy (here chemicals production via algae to prevent the competitors’ growth and grazers deterioration) is spread widely among phyto-plankton (Van Donk *et al.,* 2011) and is believed to cause bloom expansion in diatoms.

Several species of diatom yield cytotoxic secondary metabolites series that termed collectively as oxylipins that resulting from the oxidative (PUFAs) cleavage if the cell is damaged or at stress

(Ianora *et al.,* 2012). Such micro-zooplankton, probably according to their abilities as chemosensory, might adjust likewise; it seems that species producing PUAs (PUA) able to minimize the population their competitors' size indirectly by re-directing micro-zooplankton in the direction of them. Molecules mostly as precursor of lipid are changed to PUA within minutes at cell membrane damage (Wichard *et al*., 2005), which indicate quick response grazing rate. It might be guessed that a feeding micro-zooplankton meeting with cells as cytotoxic diatoms resulting in an even selective robust influence. Prince *et al.,* (2008) stated that substances as extracellular released throughout dinoflagellate as toxic as *Karenia brevis* blooms repressed strongly the competing species growth leading to changes in the plankton community composition. Therefore, elements which boost the AP effect might change the balance that competitive in the direction of AP organisms. As long as whole algae are experiencing some stress kind throughout growth, it is possible that the stress elements interacting with AP, therefore altering the competition outcome (Fistarol *et al.*,2005).

In diatoms, PUA identified 1st and then in prymnesiophyte *Phaeocystis pouchetii* (Hansen *et al.,* 2004) which considered as the best phytoplankton-produced oxylipins studied team. Such chemicals including extremely un-saturated Fatty acid (FA) i.e., eicosanoid acid, that is just toxic following the un-saturated FA. It is in to the environment released and to aldehyde converted (Lee, 2008).

What is the Allopathy?

Allopathy (AP) is existing widely as normal phenomenon, refers to any indirect or direct, stimulatory and inhibitory micro-organisms or plants effects on others, via making compounds chemically freed into the surrounding (Meiners *et al.,* 2012). It is thought to be a strategy of competition to environment adaptation (Cummings *et al.,* 2012).

Allelochemical (AC) is able to create blistering, lysis, inhibition of growth or target cells death. Also, they might affect positively other micro-organisms and phytoplankton species growth. The materials might even inhibit or stimulate the organism as donor itself (Olli and Trunov, 2007). Mechanisms of defense that was proposed in phytoplankton are varied and including morphological (i.e., formation of colony, shell of silica), physiological (i.e., bioluminescence, toxicity), and behavioral (i.e., response of escape) traits (Pančić and Kiørboe, 2018).

In phytoplankton, numerous traits as physiological i.e., production of toxin and other chemical materials production, bioluminescence, and altered algae nutritional value, are offered to signify mechanisms as physiological defense. The defensive chemical materials production might be stimulated via a range of cues, by motion or grazing. Defensive chemical materials have been detected to minimize activity grazer of feeding or causing failure to reproductivity of grazing, and death even (Selander and Pavia, 2008).

AP is an interference competition form along with exploitation of resource; it is utilized for patterns explanation in dynamics competition of plant. Micro-organisms utilize chemicals for attracting, warning, deterring, or killing other micro-organisms (Keller and Surette, 2006). AP substances identification is of significant interest, as they might offer normal toxins for controlling injurious blooms of algae. Furthermore, frequently have action as multi-side, i.e., the cell structure destruction, photosynthesis inhibitors, protein and respiration production (Hong *et al.,* 2009). Solid proof has gathered on the previous decade that few species of algae are capable of killing not just their grazers but as well other species of algae, a procedure named AP. Killing the phytoplankton species as nutrient-competing make these species to utilize freely the resources being limited i.e., Nitrogen and Phosphorus. Whereas for few species of algal, i.e., the flagellate *Prymnesium*sp. diatoms are recognized to yield an AP compounds number i.e., (PUFAs), polyphenolic, (PUAs) and compounds being halogenated (Allen *et al.,* 2016).

Despite the chief such compounds effect is the copepod fecundity inhibition and larvae growth, in the previous decade, numerous reports recognized an adverse influence on species of phyto-planktonic (Gallina *et al.,* 2016). Lately, Pezzolesi *et al.* (2017) established that few benthic diatoms happening in *Ostreopsis* spp. Zones that blooming might yield PUAs. Pichierri *et al.* (2016) emphasized an obvious decline of growth, degradation of cell DNA and signals of stress in *O. cf.ovata*cultures wide-open to three commercial PUAs molecules (2E, 4E-octadienal, 2E, 4E-decadienal, and 2E, 4E-heptadienal) produced commonly via diatoms. Upto now, 23 out of 48asidentified *Pseudo-nitzschia* species as total able to release the neurotoxin domoic acid (DA) (Teng *et al.,* 2016). DA ($C_{15}H_{21}NO_6$) is H_2O solubletri-carboxylic AA with 4 constant dissociation and 8 diverse isomers. The structure of DA is like neuro-transmitter glutamic acid, but of receptor of strong affinity compared to glutamic acid. Therefore, it is causing neurons depolarization and then their death. DA is capable to intoxicate marine mammals and birds by bio-accumulation in fish, crustaceans and shell fish (Trainer *et al.*, 2012). Amusingly, PUFAs and PUAs appear to have complex functions in interactions as inter- and intraspecific, besides predatory processes of defense Fig. (1).

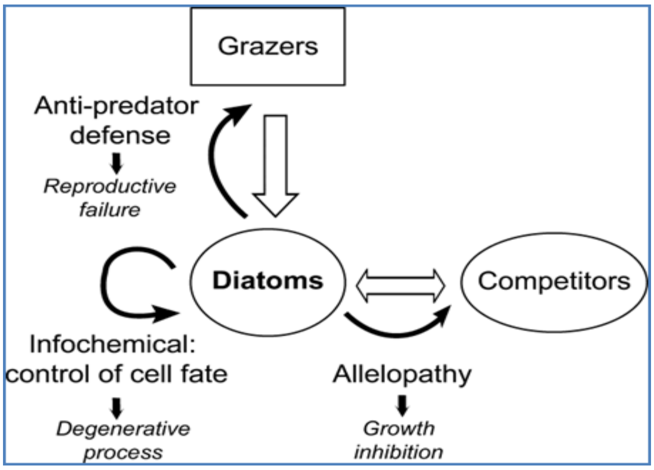

Fig. 1: Schematic representation of the interactions between diatoms and competitors or predators (white arrows) that may be mediated by polyunsaturated aldehydes produced by diatoms, such as 2E,4Edecadienal (black arrows). The main effects of the aldehydes are shown in italics (Vardi *et al.*, 2006).

How do Allelochemicals affect plankton communities?

Algal species competition is a vital process ecologically determines algal community functions and structure in ecosystems being aquatic. Algae not just experience competition of growth at resources being limited but as well are interacting with one another by competition of interference that influences the competitor's growth (Gomes *et al.*,2015).

Biologically active compounds, i.e., dimethylsulphide formed through phyto-plankton, are of effects indirectly on the ecosystems and community's evolution and ecology (McClintock and Baker, 2001). Such form of competitions considered as mechanism ecologically permits several species of alga for coexisting, but it is as well a process where definite species of alga are dominating the habitat at specific conditions of environment. Certain algal dominance of species via competition frequently disturbs the species balance in environments being aquatic and prevents the ecological community function (Barraquand *et al.*, 2018).

The micro-organisms sensitivity towards AC varies among functional species or groups, the plankton community structure capable of change in AC presence. By trophic cascades, the microbial grazers removal i.e., ciliates, may influence the lowest levels of trophic in the food web of microbes, that including bacteria and phytoplankton. Moreover, because of micro-organisms lysis, inorganic and organic nutrients are freed with AC, altering the availability of nutrient in the community of plankton. AP might be adaptation of competition which clarifies the dinoflagellates success in populations building up which dominates frequently the spring phytoplankton community in Sea of Baltic (Suikkanen *et al.,* 2011).

How Allopathy is working?

The AP substances documentation is of significant interest, as they might offer toxins being natural for algal blooms harmful control. By comparing to herbicides being synthetic, AC frequently aim organisms as specific (Weissbach *et al.,* 2010) and more often possess multi-side function, i.e., the cell structure destruction, production inhibition of protein, respiration, and photosynthesis (Hong *et al*., 2009).

Despite it was suggested that stress up surges the target sensitivity organisms to AC (Reigosa *et al.,* 1999), the mechanisms as biochemical which leads to such elevation have not demonstrated. Nevertheless, the general micro-organisms physiological responses to limitation of nutrient are the calcium accumulation in cells, 1^{st} as carbohydrate and then as lipid, whereas contents of protein / AA as cellular decline as cell division does (Healey, 1973). Because of the tremendously significant functions which proteins (including enzymes) have a rule in regulating all functions of cell, it is at stand able that a decline in protein content might distress resistance of cell. To influence the target cell physiology, AC must penetrate membrane of cell that behaves as a barrier versus compounds being toxic. Once membranes of cell are formed through a thin lipid bilayer film along with molecules of protein, held mainly together via interactions as non-covalent (Alberts *et al.,* 1994), variations in the lipid and protein concentrations along with their production are destined to have plasma membrane consequences. Moreover, proteins are of responsibility for most functions of membrane, i.e., specific molecules transporting, or reactions catalyzing i.e., synthesis of ATP (Alberts *et al*., 1994). Therefore, when there is a decline in content of cell protein because of limitation of nutrient, it is not just having effect on membrane structure but numerous functions also will be compromised.

Numerous compounds being bio-active fitting to the family of oxylipin are formed through diatoms. This compounds family has numerous diverse metabolites having oxygenase-catalysed PUFAs oxidation. Oxylipins of Diatom include epoxy and keto-hydroxy derivatives of FA, un-saturated short-chain hydroxy and aldehydes (Fontana *et al.,* 2007). Diatoms producing PUAs un-doubted harm numerous organisms' reproduction by which they are consumed potentially.

Pichierri *et al.*,2017 clarified among the investigated diatoms, maximum influence as inhibitory was noticed for the *Proschkinia complanatoides* filtrates. The unique report on AP compounds created through such species proved that *P. complanatoides* is capable to yield long-chained (PUFAs) and PUAs molecules of high amounts (Pezzolesi *et al.*, 2017), of having effects as cytotoxic on invertebrates, phytoplankton, and as well on *Ostreopsis cf. ovata* (Pichierri *et al.*, 2016). DNA and analysis as morphological exposed some significant anomalies being cytosolic, i.e., a gradual nucleus enlargement and the occurrence of few forms being abnormal with cytoplasm contracted and structures as vesicle-like in the peripheral portion. Such forms being abnormal are associated clearly with cellular stress state and were detected in all *Ostreopsis*. *cf. ovata* cultures grown in filtrates where inhibition of growth was noticed. Nucleus size changes is resulting from fragmentation of chromatin, besides a clear DNA release into the cytoplasm outlying noticed in exposed cells to *Navicula sp.* and *P. complanatoides* filtrates. All such effects being cytotoxic, although extra intense, were highlighted previously in cells of *O. cf. ovata* that subjected to commercial PUAs concentrations being high (3-36 mmol/L) (Pichierri *et al.*, 2016).

Allelopathy regulating factors

Exudation, synthesis, degradation rate and stability of AC might be influenced by biotic and abiotic conditions of environment. In general, AC production is improved if stress is applied on organism (Graneli and Hansen, 2006). For example, deficiency of nutrient as stress factor being abiotic has been verified to up surge AC production in numerous algae. Never the less, owing to the aquatic environment characteristics, both target and donor organisms are under similar stress elements effect (e.g., limitation of nutrient). Factors of stress distress the species of donor i.e., AC production increase (Granéli and Johansson 2003). Also, it has been proposed that stress could affect the target organism via rendering it extra sensitive to AC (Tang *et al.* 1995). Numerous cells of phytoplankton are recognized to release high amounts of compounds being organic at limitation of nutrient. Eutrophication changes the balance of N-to-P and if availability of nutrient is un-balanced, limitation of nutrient might result. Species of algae which are able to successfully compete for available nutrient growth-limiting have the power to blooms forming and become dominant. The conditions of stress forced via the nutrient shifted resource ratios able in few algae, stimulate AC production of which inhibit potential competitors. Fistarol *et al*., 2005 have established that limitation of N and Penlarged the *Thalassiosira weissflogii* sensitivity to AC produced through *Prymnesium parvum.*

Moreover, regarding Raphidophytes, it is recognized that effects of salinity on AC production with salinities being low causing higher AP levels of diverse combinations of compound environmental elements can resulting in toxic Pseudonitzschia blooms i.e., an upsurge in the *Pseudo-nitzschia* abundance with salinity was stated in regions that up-welling (Trainer *et al.,* 2012). Species of phytoplankton are not just controlled via salinity but as well via different factors i.e., light, temperature, and nutrients, thus, other factors of environment might also affect the *Pseudo-nitzschia* abundance. Nevertheless, a positive association between *Pseudo-nitzschia spp.* abundance was observed with temperature besides an adverse association with levels of nutrients (Tas *et al.,* 2016).

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الـ Allelopathic في الدايتومات

الملخص

تعتبر الدايتومات من المجاميع الرئيسية للهائمات النباتية في الانظمة البيئة المائية من حيث وفرتها وتنوعها وإنتاجيتها. تعتبر التفاعلات الاليلوباثية جزءاً مهماً من منافسة الهائمات النباتية phytoplanton. وقد يكون الاليلوباثي allelopathy أحد العوامل التي تؤثر على بنية الهائمات النباتية. من المعروف أن الدايتومات تنتج عددًا من مركبات allelopathic، مثل الأحماض الدهنية المتعددة غير المشبعة (PUFAs) والألدهيدات المتعددة غير المشبعة (PUAs) والمركبات متعددة الفينول والهالوجينية. ان المواد الأليلوكيميائية (AC) التي تنتجها وتفرزها الدايتومات تؤثر على الكائنات الحية الدقيقة المجاورة لها. هذه المواد الكيميائية المنتجة من قبل الدايتومات قادرة على منع أو تشجيع نمو أنواع من الهائمات النباتية والكائنات الدقيقة الأخرى التي تعيش معها في نفس البيئة. ان التداخل في هذا السلوك الكيميائي لا يؤثر فقط على الأنواع التي تستجيب أو تصنع مادة كيميائية محددة، بل تؤثر أيضًا على أداء المجتمعات والسكان والنظام البيئية بشكل مؤثر بما في ذلك الدفاع والتكاثر والمنافسة وتجنباً لمفترس. توضح المراجعة الحالية عملAllelopathy في الدايتومات والمواد الكيميائية المحفزة أو المفرزة من قبل الدايتومات الى البيئة بطريقة مباشرة أو غير مباشرة للحفاظ على هيمنتها وسيادتها.

الكلمات الدالة: الدايتومات، الاليلوباثي، مجتمع الهائمات.