様　式　Ｃ－１９、Ｆ－１９－１、Ｚ－１９　（共通）

科研費
KAKENHI

科学研究費助成事業　　研究成果報告書

令和　６ 年　６ 月 １４ 日現在

機関番号：１２４０１
研究種目：若手研究
研究期間：2021～2023
課題番号：２１Ｋ１４２４８

研究課題名（和文）Complex research on the allelopathic effect of macrophytes on cyanobacteria and the effect of microplastics on macrophytes, cyanobacteria, and macrophytes allelopathy on cyanobacteria

研究課題名（英文）Complex research on the allelopathic effect of macrophytes on cyanobacteria and the effect of microplastics on macrophytes, cyanobacteria, and macrophytes allelopathy on cyanobacteria

研究代表者

セナヴィラタナ　ジャヤサンカ（Senaviratna, Jayasanka）

埼玉大学・理工学研究科・助教

研究者番号：７０８１２７９１

交付決定額（研究期間全体）：（直接経費）　　3,600,000円

研究成果の概要（和文）：この研究は、水生環境におけるマイクロプラスチック(MP)の影響を明確に確認した。水生生態系におけるプラスチック汚染は、植物や藍藻の成長と生理機能に影響を及ぼす可能性がある。MPは種間の相互作用に影響を及ぼす。反応は種によって異なり、MPに対する水生生物の長期的な適応を区別するには、長期暴露研究が必要である。MPは植物に吸収されなかったが、吸着は植物と藍藻に影響を与えた。ナノプラスチックは組織に吸収され影響を及ぼした。電子顕微鏡検査により、ナノプラスチックの吸収が確認されることを確認した。したがって、淡水系のMPとナノプラスチックは、深刻な結果をもたらす汚染物質として考慮する必要がある。

研究成果の学術的意義や社会的意義
This research confirmed the impact of microplastics and nanoplastics on freshwater species. Freshwater systems are closely connected to human habitats compared to ocean ecosystems. People who consume freshwater plants and animals can gain an understanding of the gravity of the issue.

研究成果の概要（英文）：The research has confirmed the impact of microplastics on the aquatic environment. Plastic pollution in water ecosystems can disrupt the growth and physiology of both plants and cyanobacteria. Notably, microplastics influence species interactions, with responses varying among different species. Extensive exposure studies are necessary to understand the long-term adaptation of aquatic species to microplastics. While microplastics were not directly absorbed into plants, their adsorption still affected plant and cyanobacterial physiology. In contrast, nanoplastics were found to be absorbed into tissues, exerting a significant impact. Electron microscopy provided evidence of nanoplastics absorption. Therefore, both micro and nanoplastics in freshwater systems should be regarded as pollutants with profound consequences.

研究分野：研究分野

キーワード：マイクロプラスチック　水生植物　藍藻　シアノバクテリア　ナノプラスチック

１．研究開始当初の背景

Plastic pollution has become a global issue faced by nearly all countries. Plastics released into the environment degrade into small particles due to UV rays, physical force, and biodegradation. Moreover, microplastics (MPs) are intentionally added to consumer products such as cosmetics, shower gels, and skin scrubbers, as well as industrial products like powder coatings and emulsion paints. The increased occurrence of cyanobacteria in freshwater systems is also a global issue driven by eutrophication and global warming. In natural environments, macrophytes and cyanobacteria maintain a balance, but pollution can compromise this balance, often leading to the dominance of cyanobacteria. This study aimed to understand the impact of microplastics on freshwater ecosystems, particularly focusing on their effects on freshwater macrophytes and cyanobacteria, as well as the interactions between them. The influences were measured in terms of morphological, physiological, and photochemical responses.

２．研究の目的

This research aimed to investigate the effects of microplastics on cyanobacteria, macrophytes, and their interactions.

(1) The study examined whether the responses of individual species differed from those of species under allelopathic interactions, thereby testing the deviation of responses.

(2) Considering the emerging concern regarding nanoplastics and their potential for cellular-level contamination, the research objective was expanded to include nanoplastics to distinguish their effects.

(3) Furthermore, the study aimed to determine the relationship between microplastic concentrations and the morphological, physiological, and photochemical parameters of both species.

３．研究の方法

(1) Cyanobacterial species *Microcystis aeruginosa* were exposed to different microplastic concentrations (0 mg/L, 0.05 mg/L, 0.25 mg/L, 1.25 mg/L, and 6 mg/L) for 7 days, under controlled conditions. The microplastic adsorption, growth, pigmentation, oxidative stress, and antioxidant responses were quantified. The different co-relations were checked.

(2) *Egeria densa* was exposed to different microplastic concentrations (0 mg/L, 0.05 mg/L, 0.25 mg/L, 1.25 mg/L, and 6 mg/L) for 7 days, under controlled conditions. The microplastic adsorption, growth, pigmentation, oxidative stress, and antioxidant responses were quantified. The different co-relations were checked.

(3) *Microcystis aeruginosa- Egeria densa/Myriophyllum sp. "Roraima"* interaction under different microplastic concentrations (0 mg/L, 0.05 mg/L, 0.25 mg/L, 1.25 mg/L, and 6 mg/L) for 7 days, under controlled conditions. The growth, pigmentation, oxidative stress, and antioxidant responses were quantified. The different co-relations were checked.

(4) *Microcystis aeruginosa* were exposed to different nano-plastic concentrations (0 mg/L, 0.05 mg/L, 0.25 mg/L, 1.25 mg/L, and 6 mg/L) for 7 days, under controlled conditions. The microplastic adsorption and absorption, growth, pigmentation, oxidative stress, and antioxidant responses were quantified. The different co-relations were checked.

(5) *Myriophyllum sp. "Roraima"* exposed to different nanoplastics concentrations (0 mg/L, 0.05 mg/L, 0.25 mg/L, 1.25 mg/L, and 6 mg/L) for 7 days, under controlled conditions. The microplastic adsorption and absorption, growth, pigmentation, oxidative stress, and antioxidant responses were quantified. The different co-relations were checked.

４．研究成果

The research outcomes confirmed the impact of microplastics on freshwater species. Moreover, when species interact, their response may diverge from that of a single species. Microplastic exposure led to the adsorption of plastic particles by roots, with adsorption levels correlating to particle concentration. Additionally, it was observed that microplastic exposure increased oxidative stress in plants. Interestingly, the growth of *E. densa* was relatively unaffected. However, the overall antioxidant levels decreased in *E. densa*. Conversely, *M. roraima* exhibited increased growth rates with rising microplastic concentrations, though antioxidants decreased and oxidative stress increased at higher concentrations. The presence of microplastics reduces the *E. densa* and *M. roraima* allopathy toward the *M. aeruginosa* at high concentrations.

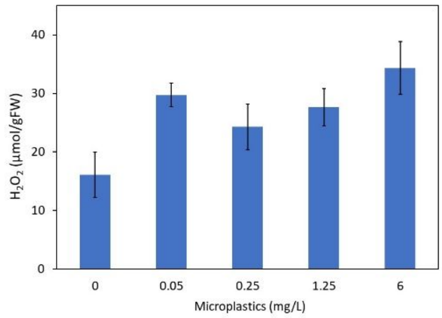

Figure 1. Oxidative stress of *E. densa*

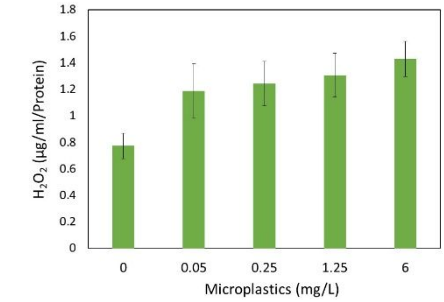

Figure 2. Oxidative stress of *M. aeruginosa*

Nanoplastics infiltrated the vascular system, significantly affecting growth and pigmentation. However, below-water parts experienced decreased oxidative stress and antioxidants. Microplastic exposure resulted in reduced optical density with increasing concentrations, accompanied by increased oxidative stress and decreased overall antioxidant levels.

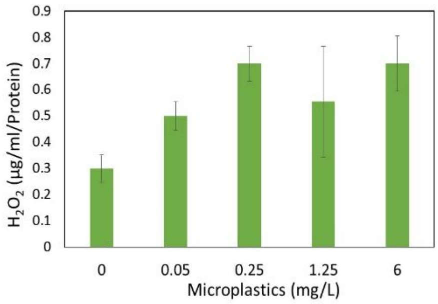

Figure 3. Oxidative stress of *M. aeruginosa* co-cultivated with *E. densa*

When two species were co-cultivated, the responses deviated. The oxidative stress and growth rates have deviated from the monocultures and the responses were also changed with the microplastic concentration. The antioxidants and pigmentations also deviated from the monocultures. The nano-plastics co-culture experiments were still ongoing and expected to compare the outcome with the microplastic experiments.

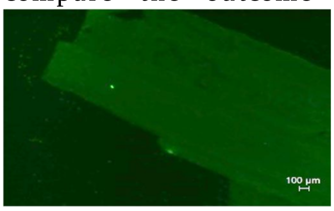

Figure 4. Fluorescence microscope image of nanoplastics in *M. roraima* stem

The regression and relationships between parameters were checked; however, still a strong relationship couldn’t be distinguished between parameters. This may have resulted due to the broad microplastic concentration difference in the present study. Therefore, further studies will be conducted.

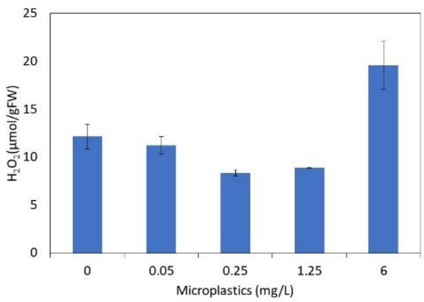

Figure 5. Oxidative stress of *M. roraima* co-cultivated with *M. aeruginosa*

Furthermore, we tested *Phormidium ambiguum* for the same microplastic concentrations and found that the odor compounds 2-MIB and Geosmin concentrations were increased with the increasing microplastic concentrations.

The findings have already been published in three high-impact journal articles, demonstrating the significance and relevance of the study. Furthermore, two additional manuscripts are currently in preparation.

５．主な発表論文等

〔雑誌論文〕　計3件（うち査読付論文　3件／うち国際共著　3件／うちオープンアクセス　0件）

１．著者名 Senavirathna Mudalige Don Hiranya Jayasanka、Zhaozhi Liu、Fujino Takeshi	４．巻 29
２．論文標題 Short-duration exposure of 3-μm polystyrene microplastics affected morphology and physiology of watermilfoil (sp. roraima)	５．発行年 2022年
３．雑誌名 Environmental Science and Pollution Research	６．最初と最後の頁 34475～34485
掲載論文のDOI（デジタルオブジェクト識別子） 10.1007/s11356-022-18642-z	査読の有無 有
オープンアクセス オープンアクセスではない、又はオープンアクセスが困難	国際共著 該当する

１．著者名 Senavirathna Mudalige Don Hiranya Jayasanka、Zhaozhi Liu、Fujino Takeshi	４．巻 233
２．論文標題 Root Adsorption of Microplastic Particles Affects the Submerged Freshwater Macrophyte Egeria densa	５．発行年 2022年
３．雑誌名 Water, Air, and Soil Pollution	６．最初と最後の頁 80
掲載論文のDOI（デジタルオブジェクト識別子） 10.1007/s11270-022-05556-2	査読の有無 有
オープンアクセス オープンアクセスではない、又はオープンアクセスが困難	国際共著 該当する

１．著者名 Senavirathna Mudalige Don Hiranya Jayasanka、Zhaozhi Liu、Fujino Takeshi	４．巻 222
２．論文標題 Growth and physiological responses of Myriophyllum sp. “Roraima” growing in co-cultivation with Microcystis aeruginosa under the influence of microplastics,	５．発行年 2024年
３．雑誌名 Environmental and Experimental Botany	６．最初と最後の頁 Article 105745
掲載論文のDOI（デジタルオブジェクト識別子） 10.1016/j.envexpbot.2024.105745	査読の有無 有
オープンアクセス オープンアクセスではない、又はオープンアクセスが困難	国際共著 該当する

〔学会発表〕　計1件（うち招待講演　0件／うち国際学会　1件）

１．発表者名 Senavirathna MDH Jayasanka, Liu Zhaozhi, Bahaguri Aihemaiti, Hiroaki Takano
２．発表標題 Responses of freshwater macrophytes and cyanobacteria to microplastic exposure
３．学会等名 UNESCO - EU H2020 LimnoPlast conference（国際学会）
４．発表年 2023年

〔図書〕　計0件

〔産業財産権〕

〔その他〕

－

6．研究組織

	氏名 （ローマ字氏名） （研究者番号）	所属研究機関・部局・職 （機関番号）	備考

7．科研費を使用して開催した国際研究集会

〔国際研究集会〕　計0件

8．本研究に関連して実施した国際共同研究の実施状況

共同研究相手国	相手方研究機関