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Beyond culture, production and post-harvest practices with innovative integration of sea grapes (*Caulerpa lentillifera*): A review on its potential for mass production and adoption

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Abstract

Sea grapes, scientifically known *as Caulerpa lentillifera*, are a type of green seaweed widely consumed as a vegetable. In recent years, this seaweed has gained significant popularity in the food industry due to its palatability, nutritional benefits, and ease of cultivation. While numerous studies have been conducted on the nutritional value and other components of *C. lentillifera*, there is limited information available on its cultivation characteristics, production, and post-harvest practices hence this study focus on the review and document *C. lentillifera*, including innovative practices. Results indicated that sea grapes identified practices are potential for mass production with integration of innovative practices. The compiled data in this review emphasize the importance of careful site selection and production management, wherein the results of test planting should guide the determination of area suitability and the appropriate farming methods to be employed. Furthermore, the findings address the specific needs of farmers.

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Introduction

Sea grapes (*Caulerpa lentillifera*), commonly known as "green caviar," are an edible green seaweed extensively cultivated and consumed worldwide, particularly in Southeast Asia. Abbott IA (1991) highlighted the unique texture and rich nutritional content of *Caulerpa*, which has garnered significant attention both as a culinary delicacy and a potential source of bioactive compounds with health benefits (Bast, 2013). The cultivation of sea grapes has grown due to its economic potential, providing livelihoods for coastal communities and contributing to food security. However, successful sea grapes production requires more than just cultivation; it involves a comprehensive understanding of the ecological, managerial, and production practices necessary to sustain and enhance yield and quality.

The cultivation of sea grapes began in Japan (specifically Okinawa) and the Philippines. According to Trono and Toma (1993) and Yap (1999), the species was initially introduced accidentally into fish ponds in the Philippines. However, due to its successful growth, targeted cultivation practices were developed and refined. The ongoing cultivation and research in the Philippines have continued to evolve, with studies such as those by Trono and Largo (2019) contributing to the understanding and optimization of sea grape farming.

In addition, sea grapes are easily cultivated due to their ability to propagate through fragmentation, which requires minimal infrastructure and expertise (de Gaillande *et al.,* 2017). Cultivation methods vary by country and system. In the Philippines and Vietnam, the algae are grown using the tray method—where they are placed in perforated plastic trays or nets—or the sowing method, where they are planted directly into the sediment in tidal ponds, sometimes with shading materials like gauze (Trono and Largo, 2019). In contrast, Japan and China are increasingly using land-based raceway cultures to meet the high demand for sea grapes (de Gaillande *et al.,* 2017), although cultivation in sheltered coastal areas using nets or trays is also practiced (Tanduyan *et al.,* 2013).

The rapid growth and low habitat requirements of sea grapes make them ideal for integrated aquaculture systems, where they help mitigate nutrient-rich wastewater effluent while providing additional income from the metabolized biomass (Paul and de Nys, 2008; Largo *et al.,* 2016; Bambaranda *et al.,* 2019; Dobson *et al.,* 2020). After harvesting, the fronds are soaked in seawater tanks to heal tissue injuries before being sorted based on quality standards such as color and size.

Fronds that meet the criteria are stored in plastic containers with moisture sheets for fresh product shipment or preservation through dehydration or brine-curing (de Gaillande *et al.,* 2017; Terada *et al.,* 2018; Chaiklahan *et al.,* 2020). However, 60–70% of the biomass, which does not meet food quality standards, is often discarded, though it holds potential for other uses (Chaiklahan *et al.,* 2020).

As economic interest in sea grapes grows, there has been a noticeable increase in scientific publications on the subject. Recent reviews and book chapters have focused on various aspects, including the consumption, nutritional value, and farming practices of the genus *Caulerpa* (de Gaillande *et al.*, 2017), its biology and uses (Zubia *et al.*, 2020), and its potential in nutraceutical and pharmaceutical applications (Darmawan *et al.*, 2020). Notably, a 2019 review article by Chen *et al.* provides a comprehensive summary of research on the species *C. lentillifera*, while a 2022 review by Syakilla *et al.* discusses its nutrients, phytochemicals, and health benefits.

Despite the positive feedback on sea grapes, growers face significant challenges that threaten the productivity and sustainability of this aquaculture practice. These challenges include environmental issues such as water quality, disease, pests, and climate change, as well as technical difficulties like the reliable production of high-quality seedlings and the impact of overharvesting, which can reduce regrowth rates and long-term productivity Chamberlain, and Pickering, 1998). Additionally, inadequate post-harvest practices lead to significant losses, while economic challenges such as market fluctuations, high costs of inputs, and limited market access further complicate the industry. Social challenges, including a lack of technical expertise and knowledge among farmers, particularly in less-developed regions, exacerbate these issues.

Addressing these obstacles requires a comprehensive approach that includes improving technical knowledge, investing in research and development, enhancing market access, and fostering collaboration between stakeholders. By overcoming these challenges, the *Caulerpa* industry can continue to grow and contribute to sustainable coastal livelihoods.

This study aims to review and document fundamental practices, including culture, production, and post-harvest techniques, for potential adoption and integration of innovative methods.

Methodology

In this study, mixed method research design was used to ensure the validity and reliability of the information gathered, two complementary methods were employed: a literature review and targeted interviews coupled with observations of actual cultivation practices. The literature review provided a foundational understanding of existing research on culture management and production practices related to *Caulerpa* cultivation. The systematic literature review was conducted by using the search in two widely recognized scientific citation databases: Web of Science (WoS) and Scopus. The search followed the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines (Liberati *et al.*, 2009). The search string used is "*Caulerpa*" AND "*lentillifera*" to search within titles, keywords, and abstracts, covering the period from 2000-2024. The search was performed on June- July, 2024. Enhanced with a patent search from espacenet, google patents, lens.org, WIPO/Patenscope using same search strings "*Caulerpa*" AND "*lentillifera*".

This study established the standard methods in eligibility identification of studies for inclusion. The specific selection criteria were established like a) the study must focus primarily on sea grapes as a key topic, b) the language of the publication must be English, c) the article must be original research, not a review, and d) the study must demonstrate scientific rigor and accuracy.

The initial evaluation involved screening the titles and abstracts to determine their relevance and adherence to these criteria. If the information provided in the abstract was insufficient to confirm eligibility, the full text of the document was reviewed to ensure it met the required standards. Additionally, studies were cross-referenced for methodological soundness and relevance to contemporary sea grapes research topics, ensuring that only high-quality, pertinent research was included in the analysis.

This was followed by interviews with experts and practitioners in the locals, which offered real-world insights and practical knowledge. These interviews were further validated by direct observation and analysis of current cultivation practices in the field. By integrating these two methods, the study was able to present a well-rounded and concrete validation of the information, ensuring that the findings are both theoretically sound and practically applicable. This approach not only triangulates the data but also highlights any discrepancies between documented research and actual practices, allowing for a more accurate and comprehensive understanding.

Results and discussion

Review analysis: The results indicate that since 2000, two review articles on sea grapes (*Caulerpa lentillifera*) have been published, both appearing between 2020 and 2021. These articles focused on biomass production and biochemical composition, particularly pigments, proteins, and fatty acid content (Fig. 1). Light intensity emerged as a significant experimental parameter, with shade-adapted sea grapes achieving the highest biomass production at photosynthetically active radiation (PAR) levels of 40 to 100 µmol photons m^2/s, compared to other light intensities. However, irradiances of 100 µmol photons m^2/s or higher were found to induce physiological stress in the plants. Studies on *C. lentillifera* have frequently explored its biochemical composition, focusing on pigments, proteins, and fatty acid content and patterns.

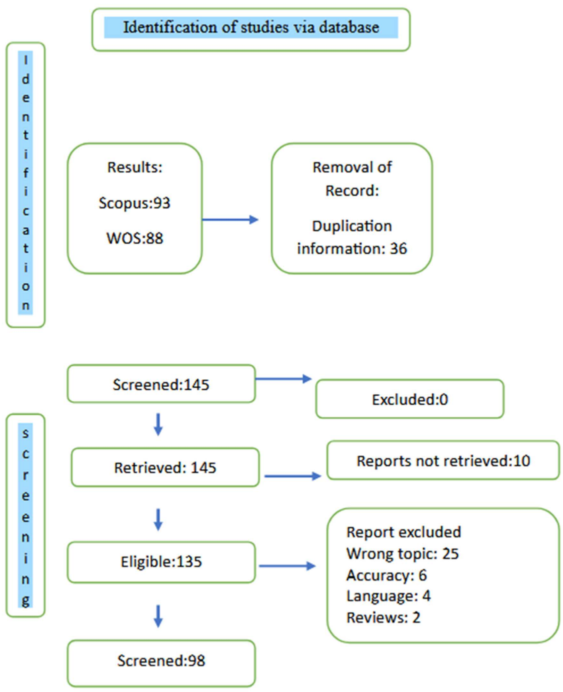

Fig. 1. Records of the studies literatures using the database

These investigations have included assessments of pigment concentrations (Guo *et al.*, 2015), protein levels (Long *et al.*, 2020b; Cai *et al.*, 2021b), and the composition and structure of fatty acids (Long *et al.*, 2020b). However, higher irradiances (≥ 100 µmol photons m^2/s) were shown to induce physiological stress, negatively impacting the growth and health of the plants (Kang *et al.*, 2020; Stuthmann *et al.*, 2020; Cai *et al.*, 2021b).

In addition, this review was used with a dual purpose: first, to conduct a scientometric analysis of existing literature to identify research trends and knowledge gaps; and second, to provide a contextual overview of sea grape aquaculture for practitioners and field researchers. From 181, yielded to 98 literatures only that focuses on the culture management, production practices to potentials for commercialization.

Culture practices of seagrapes

Researches on *Caulerpa* has extensively focused on biomass production and biochemical composition. Among of these is the interaction of light conditions—such as irradiance, photoperiod, and spectrum that contributes significant impact on the physiology of sea grapes. For example, blue light has been found to enhance the expression of phytoene desaturase (PDS) and boost antioxidant activity (Kang *et al.*, 2020; Guo *et al.*, 2015; Long *et al.*, 2020b; Cai *et al.*, 2021b; Stuthmann *et al.*, 2020) while red light promotes biomass accumulation. Based on these findings, researchers recommend using a light spectrum with 16.7% blue light and 83.3% red light, combined with a 12-hour light/dark photoperiod, for optimal indoor cultivation of sea grapes (Kang *et al.*, 2020). Although light is a key factor, most experiments have been relatively short in duration, ranging from seven (7) days to four weeks, with only one study examining exposure times of less than 72 hours (Fig. 2&3).

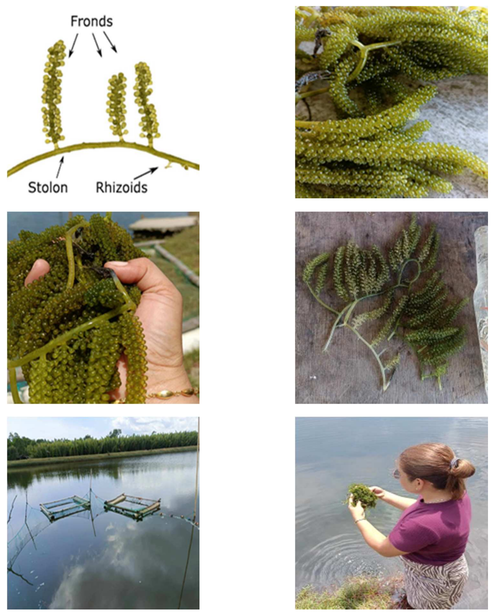

Fig. 2. The documentation of actual culture practices of sea grapes (*Caulerpa lentillifera*)

Additionally, sea grapes with UV light are known to induce oxidative stress in seaweeds, its specific effects on *C. lentillifera* have yet to be thoroughly investigated (Tanaka *et al.,* 2020; Terada *et al.,* 2021). This gap highlights the need for further research into the long-term impacts of various light conditions on sea grape cultivation.

Fig. 3. Documentation on the actual seedling preparation of sea grapes

Production practices of sea grapes

The production of sea grapes has met some environmental factors that are crucial to its cultivation. In Southeast Asia, especially in the Philippines and Vietnam, *Caulerpa* is typically grown in shallow brackish water ponds, which provide easy access to sunlight necessary for photosynthesis. Cultivation practices include either planting the algae directly into the pond sediments or suspending them in the water column using nets or perforated plastic trays. In the study of Kang *et al.* (2020) trays may be shaded to prevent excessive sunlight, which can cause physiological stress to the algae. In traditional farming practices, the algae are directly sown into the sediments of tidal ponds, a method particularly effective in regions with stable salinity and temperature conditions.

In Japan and China, land-based raceway systems are increasingly being used for *Caulerpa* cultivation. These systems allow for greater control over environmental factors such as temperature, light, and water flow, leading to more consistent production outputs. For example, in the Northwestern Pacific, temperature and light availability are key factors that restrict *C. lentillifera* cultivation to specific seasons (Terada *et al.*, 2021). In contrast, in the Philippines and other Southeast Asian regions, temperature and salinity change due to seasonal rainfall limit cultivation to the dry season (Estrada *et al.*, 2021).

Beyond culture of sea grapes (Caulerpa lentillifera)

Sea grapes application

As food for human, as indicated the red and brown algae dominate the global commercial seaweed market, with green macroalgae representing only a small fraction of production (FAO, 2020; Moreira *et al.,* 2021). However, *Caulerpa lentillifera* has the potential to compete with these commercially valuable seaweeds in terms of nutritional content, offering comparable or even superior levels of minerals, vitamins, and antioxidant properties (Cultivation). The biochemical composition (Syakilla *et al.,* 2022) of *C. lentillifera*, including its protein, lipid, carbohydrate content, and bioactive compounds.

Harvest and post-harvest handling

This is after harvesting, *Caulerpa* is soaked in tanks with seawater to heal any tissue injuries. The fronds are then sorted based on quality, with those meeting the standards being packed for fresh sale or preservation. The handling of *Caulerpa* post-harvest is delicate (Fig. 4, 5 & 6), as the algae are still alive and photosynthetically active, requiring careful management to maintain quality.

a) preparation of container

b) with harvesting tray

c) Situation during harvest

d) the harvest proper

Fig. 4. Documentation on actual harvesting practices of sea grapes

Challenges and opportunities

The cultivation of *Caulerpa* faces challenges related to environmental variability, as seen in Fig. 5, such as changes in temperature and salinity, which can impact yield and quality. Removing poor-quality seedlings (brown ones) is the first step before placing the harvested *Caulerpa* in the container. However, advances in controlled cultivation systems and a better understanding of the algae's physiological needs offer opportunities to enhance production efficiency and product quality.

Fig. 5. Unhealthy sea grapes during harvest

Fig. 6. Post-harvest practices of sea grapes

Potentials of sea grapes

The culture of *Caulerpa* in the context of the Philippines has significant implications across several domains, including economic development, environmental sustainability, food security, and coastal community livelihoods. In addition, Philippines is one of the leading producers of *Caulerpa*, particularly *Caulerpa lentillifera* (locally known as "lato" or "ar-arosip"), which is widely consumed as a salad ingredient. Expanding the cultivation of *Caulerpa* can boost local economies, especially in coastal regions where fishing and aquaculture are primary sources of income. The export potential of *Caulerpa* as a high-value marine product can also contribute to the country's economy.

Caulerpa farming can provide employment opportunities for coastal communities, particularly in rural areas where alternative livelihoods may be limited. The low capital investment required for *Caulerpa* farming makes it accessible to small-scale farmers, helping to alleviate poverty and improve living standards and *Caulerpa* is a highly nutritious food, rich in vitamins, minerals, and antioxidants. Its cultivation can contribute to food security in the Philippines by providing a readily available and affordable source of nutrition, particularly in coastal and rural communities.

Promoting *Caulerpa* as part of a healthy diet can help address malnutrition and improve public health outcomes.

The inclusion of *Caulerpa* in the country's aquaculture portfolio (SEAFDEC-AQD, 2019) helps diversify the range of marine products available in the market. This diversification can reduce dependence on more resource-intensive species and provide a buffer against market fluctuations in other aquaculture products, such as fish or shrimp. *Caulerpa*'s ability to absorb excess nutrients from the water can be harnessed to improve water quality in coastal areas, particularly in regions affected by nutrient pollution from agriculture or urban runoff.

Using *Caulerpa* in integrated aquaculture systems can help mitigate the environmental impacts of intensive aquaculture by reducing nutrient loads in the water. Cultivating *Caulerpa* in degraded coastal areas can also contribute to habitat restoration efforts. *Caulerpa* helps stabilize sediments, reduce erosion, and provide habitat for marine life, thereby enhancing the overall health and resilience of coastal ecosystems. This is especially important in the Philippines, where coastal erosion and habitat loss are significant environmental concerns. While *Caulerpa* cultivation offers many benefits, it is crucial to manage it sustainably to avoid potential ecological impacts, such as the displacement of native species or unintended consequences from large-scale monoculture. Ensuring environmentally sound cultivation practices will help preserve biodiversity and maintain the health of marine ecosystems. Developing markets for *Caulerpa*, both domestically and for export, requires attention to product quality, safety standards, and value addition. Creating value-added products, such as dried or processed *Caulerpa*, can open new markets and increase profitability for farmers.

Research and innovation

Incorporating *Caulerpa* into integrated aquaculture systems can help mitigate the environmental impacts of intensive aquaculture by reducing nutrient loads in the water. Research by Lee *et al.* (2018) indicates that *Caulerpa* can effectively absorb excess nutrients, thus improving water quality and reducing eutrophication. Cultivating *Caulerpa* in degraded coastal areas also supports habitat restoration by stabilizing sediments, reducing erosion, and providing critical habitat for marine life, thereby enhancing the overall health and resilience of coastal ecosystems. This is particularly relevant in the Philippines, where coastal erosion and habitat loss are pressing environmental concerns. While *Caulerpa* cultivation presents numerous benefits, sustainable management is essential to avoid potential ecological issues, such as the displacement of native species or the unintended consequences of large-scale monoculture. Adopting environmentally sound cultivation practices will help preserve biodiversity and maintain the health of marine ecosystems. Furthermore, developing markets for *Caulerpa*, both domestically and internationally, necessitates a focus on product quality, safety standards, and value addition, as indicated in the Fig. 5 for the post-harvest practices and a great potential for export. Research by Mendoza *et al.* (2021) highlights that creating value-added products, such as dried or processed *Caulerpa*, can open new markets and enhance profitability for farmers. Beyond culture the patent search results of sea grapes *Caulerpa lentillifera* is shown in Fig. 7.

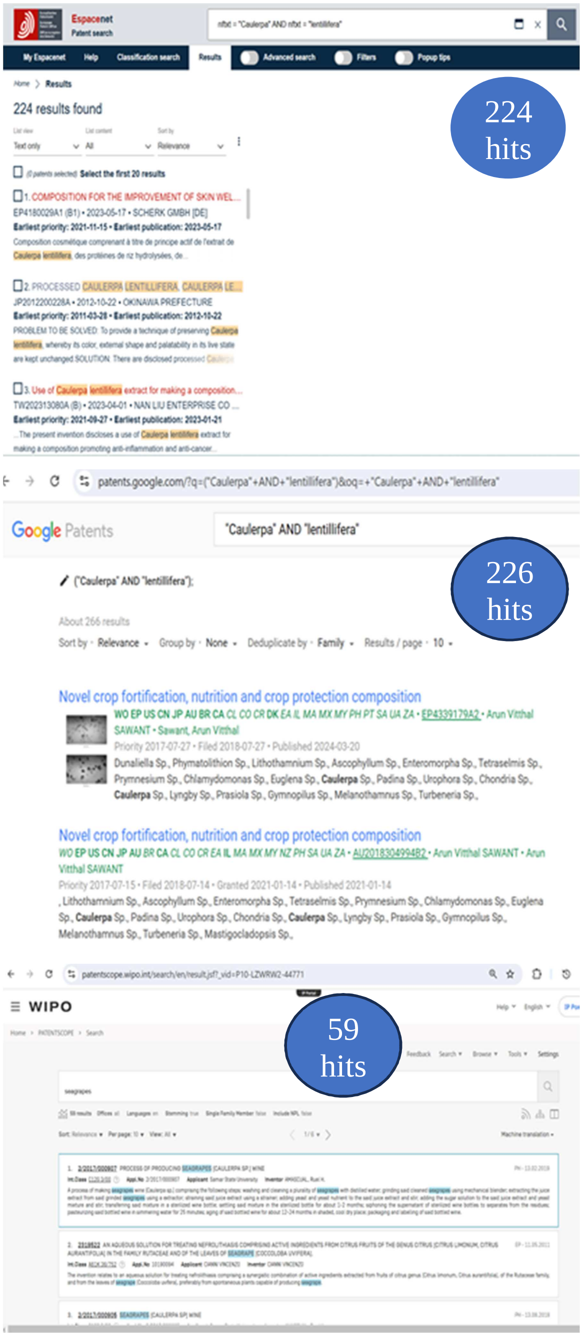

Fig. 7. Beyond culture the patent search results of Sea grapes *Caulerpa lentillifera*

Conclusion

The review and documentation of sea grapes highlight that numerous studies have detailed the fundamental cultural, production, and post-harvest practices. These studies have been validated by local seaweed growers in their actual setups. Beyond culture, the integration of potential innovations demonstrates remarkable potential for mass production and adoption by both local and international consumers.

References

Abbott IA. 1991. Polynesian uses of seaweed. In: Cox PA, Banack SA (eds), Islands, plants and Polynesians: An introduction to Polynesian ethnobotany, Dioscorides Press, Portland, Oregon, 135–145.

Balasubramaniam V, June Chelyn L, Vimala S, Mohd Fairulnizal MN, Brownlee IA, Amin I. 2020. Carotenoid composition and antioxidant potential of *Eucheuma denticulatum*, *Sargassum polycystum* and *Caulerpa lentillifera*. Heliyon **6**, e04654.

Bambaranda BVASM, Sasaki N, Chirapart A, Salin KR, Tsusaka TW. 2019a. Optimization of macroalgal density and salinity for nutrient removal by *Caulerpa lentillifera* from aquaculture effluent. Processes **7**, 303.

Bambaranda BVASM, Tsusaka TW, Chirapart A, Salin KR, Sasaki N. 2019b. Capacity of *Caulerpa lentillifera* in the removal of fish culture effluent in a recirculating aquaculture system. Processes **7**, 440.

Bast F. 2013. Agronomy and cultivation methods for edible seaweeds. International Journal of Agriculture, Food Science and Technology **4**, 661–666.

Cai Y, Li G, Zou D, Hu S, Shi X. 2021a. Rising nutrient nitrogen reverses the impact of temperature on photosynthesis and respiration of a macroalga *Caulerpa lentillifera* (Ulvophyceae, *Caulerpa*ceae). Journal of Applied Phycology **33**, 1115–1123.

Ceccherelli G, Piazzi L. 2001. Dispersal of *Caulerpa racemosa* fragments in the Mediterranean: The role of vegetative propagation. Marine Ecology Progress Series.

Chamberlain A, Pickering T. 1998. Post-harvest handling of *Caulerpa racemosa* for artisanal and export fisheries in Fiji. In: Fisheries and Marine Resources, The University of the South Pacific, Suva, 97–109.

Choi HG, Lee SG, Choi TS. 2006. Effects of temperature and irradiance on the growth of *Caulerpa lentillifera* in aquaculture. Aquaculture.

Chung IK, Kang YH, Yarish C, Kraemer GP, Lee JA. 2002. Application of seaweed cultivation to the bioremediation of nutrient-rich effluent. Algae **17**, 187–194.

De Gaillande C, Payri C, Remoissenet G, Zubia M. 2017. *Caulerpa* consumption, nutritional value and farming in the Indo-Pacific region. Journal of Applied Phycology **29**, 2249–2266.

Delgado O, Ruiz JM, Pérez-Lloréns JL. 1999. Nutrient uptake by *Caulerpa prolifera* and its implications for nutrient cycling in coastal waters. Estuarine, Coastal and Shelf Science.

Dobson GT, Duy NDQ, Paul NA, Southgate PC. 2020. Assessing potential for integrating sea grape (*Caulerpa lentillifera*) culture with sandfish (*Holothuria scabra*) and Babylon snail (*Babylonia areolata*) co-culture. Aquaculture **522**, 735153.

Estrada JL, Arboleda MDM, Dionisio-Sese ML. 2021. Current status of sea grapes (*Caulerpa* spp.) farming and wild harvesting in the Philippines. Journal of Applied Phycology **33**, 3215–3223.

FAO. 2020. The state of world fisheries and aquaculture 2020. FAO, Rome.

Guo H, Yao J, Sun Z, Duan D. 2015a. Effects of salinity and nutrients on the growth and chlorophyll fluorescence of *Caulerpa lentillifera*. Chinese Journal of Oceanology and Limnology **33**, 410–418.

Guo H, Yao J, Sun Z, Duan D. 2015b. Effect of temperature, irradiance on the growth of the green alga *Caulerpa lentillifera* (Bryopsidophyceae, Chlorophyta). Journal of Applied Phycology **27**, 879–885.

Kang LK, Huang YJ, Lim WT, Hsu PH, Hwang PA. 2020. Growth, pigment content, antioxidant activity, and phytoene desaturase gene expression in *Caulerpa lentillifera* grown under different combinations of blue and red light-emitting diodes. Journal of Applied Phycology **32**, 1971–1982.

Largo DB, Diola AG, Marababol MS. 2016. Development of an integrated multi-trophic aquaculture (IMTA) system for tropical marine species in southern Cebu, Central Philippines. Aquaculture Reports **3**, 67–76.

Phang SM, Yeoh M, Lim SH. 1996. Nutrient management in the cultivation of *Caulerpa lentillifera*. Journal of Applied Phycology.

Phang SM, Yeoh M. 1996. Post-harvest handling and storage of *Caulerpa lentillifera*. Journal of Applied Phycology.

Raju G, Venugopal A. 2013. Growth and substrate preference of *Caulerpa prolifera* in coastal aquaculture. Indian Journal of Marine Sciences.

Trono CG, Toma T. 1993. Cultivation of the green alga *Caulerpa lentillifera*. In: Ohno M, Critchley AT (eds), Seaweed Cultivation and Marine Ranching. Kanagawa International Fisheries Training Center, JICA, Yokosuka, 17–24.

Trono GC, Largo DB. 2019. The seaweed resources of the Philippines. Botanica Marina **62**, 483–498.

Williams SL, Smith JE. 2007. Impact of herbivory on *Caulerpa taxifolia* in the Mediterranean. Marine Ecology Progress Series.

Yamamoto H, Kobayashi H. 2004. Growth response of *Caulerpa brachypus* under different light regimes. Journal of Applied Phycology.

Yang Y, Liang Z, Hu Z. 2008. Bacterial diseases in *Caulerpa lentillifera*: Prevention and control strategies. Aquaculture Research.

Zubia M, Draisma SGA, Morrissey KL. 2020. Concise review of the genus *Caulerpa* J.V. Lamouroux. Journal of Applied Phycology **32**, 23–39. https://doi.org/10.1007/s10811-019-01868-9