



Sustainable management of mulberry root rot using marine algal bioactive compounds

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Abstract

Seaweeds are the good source of essential nutrients, excellent eco-friendly organic manure and alternative source for inorganic chemical fertilizer for sustaining the crop yield. It is an excellent source of bioactive components with reported antimicrobial activity. The *in vitro* evaluation of seaweed extract against mulberry root rot has been carried out through poison food technique, agar well diffusion, and disc diffusion assays. After proper inoculation and evaluation indicated that the seaweed extract @ 10000 ppm was found to be best with 71.1 per cent mycelial inhibition and COC @ 1000 ppm was found to be 92.6 per cent mycelial inhibition. From the results of *in vitro* evaluation, *in planta* evaluation has been carried out using mulberry seedlings with 3 to 4 leaf stage. The pathogen has been pre-inoculated in each seedling and symptoms observed after 24 hours of inoculation. After two days the best treatment has been inoculated through soil drenching and foliar application. It has been found that SE @ 10000 ppm has shown results with disease reduction. Even though the per cent mycelial inhibition was lower than copper oxy chloride, higher concentration may be effective against the disease incidence and safe to the environment.

Keywords: Mulberry root rot, *Macrophomina phaseolina*, seaweed extract, PFT, AWDA, DDA

Introduction

Mulberry (*Morus* spp.) plant is a perennial fast growing woody plant, which is widely cultivated in many tropical and subtropical areas. The leaves of the mulberry are economically important as they are the only source of feed for the monophagous silkworm (*Bombyx mori* L.) After China, India is one of the leading producers of mulberry with a total acreage of around 2,39,926 hectares. The tropical climate of South India is highly favorable for mulberry cultivation where the crop is harvested at every 70 days (Gnanesh *et al.*, 2021 ^[12]). Mulberry production is limited by several diseases as the perennial nature of the mulberry provides scope for long-term survival and multiplication of soil-borne pathogens (Sharma *et al.*, 2003 ^[35]). Among the soil-borne diseases, root rot is epidemic in nature and a major limiting factor in the cultivation of mulberry. Root rot disease causes 30% mortality of plants with a 14% decrease in leaf yield, besides deteriorating the leaf quality (Chowdary, 2006 ^[7]; Rajeswari and Angappan, 2018) ^[31].

In mulberry, different kinds of root rot have been reported, such as black root rot, dry root rot, charcoal root rot, violet root rot, white root rot, *Armillaria* root rot, *Rhizopus* rot, and bacterial root rot (Gnanesh *et al.*, 2021) ^[12]. Molecular phylogeny, identification and pathogenicity of *Rhizopus oryzae* associated with root rot of mulberry in India. (Radhakrishnan *et al.*, 1995; Sharma *et al.*, 2003; Yoshida *et al.*, 2001) ^[35]. Among them, black root rot (BRR) caused by *Lasiodiplodia theobromae* (syn. *Botryodiplodia theobromae*), dry root rot (*Fusarium solani* and *F. oxysporum*), and charcoal root rot (*Macrophomina phaseolina*) are frequently reported in India (Pinto *et al.*, 2018).

Lasiodiplodia species are harmful fungal pathogens and have been associated with nearly 500 plant hosts causing various degrees of crop losses. It causes root rot disease in mulberry that affects all parts of the plant and it spreads rapidly affecting a large number of plants in a short period leading to the abandonment of mulberry gardens (Pappachan *et al.*, 2020). The fungus prefers 25 – 30°C for good growth and survives on all types of substrates. After pruning, the pathogens enter the host through the cut ends of the stem. Once, the plant becomes vulnerable to infection, the fungus dominates inside the roots by multiplying the hyphae rapidly in the cortical tissues and extending up to the pith region. It enters the xylem vessels and causes the death of the plants (Sharma *et al.*, 2003) ^[35].

Diseased plants appeared stunted with dark-colored stems and chlorotic leaves, gradually the leaves get wilted and defoliated prematurely. The fine feeder roots and the main root system of these infected plants will damage severely with typical symptoms like discoloration of root xylem followed by the decay of root cortex. Also, the bark of the roots becomes fragile and smelled emanating a foul odour. Gradually as the damaged roots could not firmly hold the plant in the soil they can be easily uprooted (Sowmya *et al.*, 2018; Xie *et al.*, 2014).

The macroscopic marine algae are known as “Seaweeds”. They are used as human food, cattle feed, a chemical fertiliser substitute, and a source of various fine chemicals. Aside from that, it is used to make a variety of agricultural goods like agar and alginate (Khan *et al.*, 2009) ^[21]. Since they contain several growth regulators such as, Cytokinins (Durand *et al.*, 2003), Auxins (Sahoo *et al.*, 2000), Gibberellins (Strik *et al.*, 1997 and Staden *et al.*, 1997) and various macro and micronutrients needed for plant growth

and development, seaweed extracts are marketed as liquid fertilisers and bio-stimulants. It aids in the production of beneficial soil microorganisms (Khan *et al.*, 2009) ^[21], develops tolerance against environmental stress (Zhang *et al.*, 2003), increases nutrient uptake from soil (Turan *et al.*, 2004 and Kose *et al.*, 2004) and enhances antioxidant properties (Verkleij *et al.*, 1992).

These seaweeds consist of 80 - 90% moisture. The dry seaweed extracts contain 50% carbohydrates, protein 10 - 47% with high proportions of essential amino acids, 1-3% lipids and 7-38% minerals. The essential nutrients contain in seaweeds are nitrogen, potassium, phosphorous, calcium, magnesium, sulphur, iron, sodium, zinc, and copper. The seaweed having three major types of species such as Phaeophyceae, Rhodophyta and Chlorophyta.

Around 700 species of marine algae are present and approximately 60 of them being commercially important in both the intertidal and deep-water regions of the Indian coast. Tamil Nadu, Gujarat, Maharashtra, Goa, Lakshadweep, Andhra Pradesh, and Karnataka states are major seaweed extracts producers. Seaweed good source of essential nutrients, excellent eco-friendly organic manure and alternative source for inorganic chemical fertilizer for sustaining the crop yield. It is an excellent source of bioactive components with reported antimicrobial activity.

Materials and methods

1. Collection of seaweeds

The seaweeds are collected from the coastal region of Manamalkudi, Pudukkottai, Tamil Nadu. The seaweeds are washed to remove their undesired particles and other sea debris and they have been kept for shade drying for minimum 5-6 days. After complete drying the seaweeds are grinded and made into coarse powders. 8g of powdered seaweeds has been taken with 200 ml of distilled water and mixed thoroughly in conical flask. The mixture is kept in water bath for 2 hours at 80°C. The seaweed extract has been obtained and by filtering using whatmann filter paper and stored in the amber bottle and kept in refrigerator for further use.

2. Collection and isolation of the samples

Severely affected mulberry plants show stunted growth with marginal chlorosis, vascular discoloration, and necrosis of leaf with black fungal mycelia on the root epidermis has been collected and isolated. The collected the diseased samples with healthy portions were cut into small pieces and wash the bits in 1 % sodium hypo chlorite for 60 seconds and 3 times sterile water was subsequently. The bits were transferred into petri dishes containing PDA medium and place it under room temperature. After seven days of inoculation the pathogen completes its full growth in a petri dish of 9 cm. The microscopic observations were made for the pathogen identification.

3. *In vitro* evaluation of seaweed extract against mulberry root rot

In vitro evaluation of seaweed extract against mulberry root rot has been carried out by using the design CRD with seven treatments and three replications. *In vitro* evaluation carried out by two assays viz poisoned food technique, agar well diffusion assay, and disc diffusion assay.

In poisoned food technique (Table 1.), double stranded potato dextrose agar medium has been used for pathogen

inoculation. To avoid bacterial contamination the seaweed extract has to be filtered in 0.2mm bacterial proof filter. The filtered extract is now pipetted out according to the given concentrations and mixed well in the medium before pouring into the petri plates. After solidification of the medium the pathogen has to be inoculated into the petri plates and kept in under room temperature.

In agar well diffusion assay (Table 2.), double stranded potato dextrose agar medium has been used for pathogen inoculation. To avoid bacterial contamination the seaweed extract has to be filtered in 0.2mm bacterial proof filter. The filtered extract is now pipetted out according to the given concentrations. After solidification of the medium, four wells have been made by using corn borer, and the filtered extract at different concentrations has been poured into each disc. Then the pathogen has been inoculated into each plate and kept in under room temperature.

In disc diffusion assay (Table 3.), double stranded potato dextrose agar medium has been used for pathogen inoculation. To avoid bacterial contamination the seaweed extract has to be filtered in 0.2mm bacterial proof filter. The filtered extract is now pipetted out according to the given concentrations. After solidification of the medium, four bits of filter paper which has been immersed at different concentrations of seaweed extract has been kept into each petri dish. Then the pathogen has been inoculated into each petri dish and kept it under room temperature.

4. *In planta* evaluation of seaweed extract against mulberry root rot

The best concentration of seaweed obtained from the *in vitro* studies has been selected and used for the *in-planta* evaluation and the percent disease index have to be calculated. The design used is CRD with six treatments and four replications. The variety used is V1. For *In planta* evaluation, 24 semi wood mulberry cuttings have been collected and planted in the polybags containing red sand, FYM, and native soil which has been irrigated continuously for the growth of the plant.

5. Pathogen inoculation in plants

For pathogen inoculation PD broth has been prepared and autoclaved. The mycelial disc of the pathogen has been inoculated for the conidial production (1×10^6 / ml). The conidial count has been confirmed by using haemocytometer and inoculated into each plant. After three days, the symptoms have been identified and treatments were applied (Table 4.). The best concentration obtained from *in vitro* evaluation as 1000 ppm.

Results and discussion

1. Collection of phaeophycean seaweed

The seaweeds were identified as marine brown algae (Class. Phaeophyceae) based on the appearance of olive yellow to deep brown in colour due to the presence of fucoxanthin. A short main axis, alternatively organised primary cylindrical branches with branchlets, around 30-40 cm in height, and vesicles that were spherical, pointed, stalked, and ovate about 3-4mm wide, and it grows on rocks and has a discoid holdfast observed and confirmed as *Sargassum tennerimum* (J. Agardh) (Fig. 1.). Based on the taxonomical position, it was coming under the kingdom Chromista, Order Fucales and family Sargassaceae.



Fig 1: *Sargassum tennerimum*

2. Identification of Pathogen

Based on the cultural characters such as greyish black mycelium under *in vitro*, morphological characters such as septate

mycelium with flame shaped conidia the pathogen has been confirmed as *Macrophomina phaseolina* (Fig. 2.). The pathogenicity has been proven by adopting Koch's postulates.



Fig 2: Symptoms, cultural, microscopical and pathogenicity of *M. phaseolina*

3. *In vitro* evaluation of seaweed extract against mulberry root rot

From the poison food technique, after seven days of inoculation, the standard check at the concentration of 1000

ppm inhibited maximum of 59.25 % of mycelial growth followed by the SE @ 10000 ppm exhibited 41.6 % of mycelial inhibition. There is no mycelial inhibition observed from the treatment T₁(Table 1.).

Table 1: Per cent inhibition of mycelium under poisoned food technique

Treatment	Treatment details	Radial growth of mycelium (in cm)	Percentage of mycelial inhibition
T1	SE @ 500 ppm	9	0(0.000) ^d
T2	SE @ 1000 ppm	8.75	2.8(2.77) ^d
T3	SE @ 2500 ppm	7.3	18.85(18.88) ^c
T4	SE @ 5000 ppm	5.76	35.8(35.92) ^b
T5	SE @ 10000 ppm	5.25	41.6(41.66) ^b
T6	COC @ 1000 ppm	3.66	59.2(59.25) ^a
T7	Control	9	0(0.00) ^d
		CD (0.05)	1.43
		SE (mean)	2.12

*Mean of three replications, Observations were taken after 7 days of inoculation

Figures with same letter do not have significant difference according to one- way ANOVA at $P=0.05$

From the agar well diffusion assay, after seven days of inoculation, the standard check at the concentration of 1000 ppm inhibited maximum of 88.8 % of mycelial growth

followed by the SE @ 10000 ppm exhibited 62.2 % of mycelial inhibition. There is no mycelial inhibition observed from the treatment T₁(Table 2.).

Table 2: Per cent inhibition of mycelium under agar well diffusion assay

Treatment	Treatment details	Radial growth of mycelium (in cm)	Percentage of mycelial inhibition
T1	SE @ 500 ppm	9	0(0.000) ^d
T2	SE @ 1000 ppm	8.73	1.85(2.96) ^d
T3	SE @ 2500 ppm	6.46	28.1(28.14) ^c
T4	SE @ 5000 ppm	3.3	63.3(63.33) ^b
T5	SE @ 10000 ppm	2.6	62.19(62.21) ^b
T6	COC @ 1000 ppm	1	88.8(88.54) ^a
T7	Control	9	0(0.00) ^d
		CD (0.05)	2.4
		SE (mean)	3.12

*Mean of three replications, Observations were taken after 7 days of inoculation

Figures with same letter do not have significant difference according to one- way ANOVA at $P=0.05$

From the disc diffusion assay, after seven days of inoculation, the standard check at the concentration of 1000 ppm inhibited maximum of 92.6 % of mycelial growth

followed by the SE @ 10000 ppm exhibited 71.1 % of mycelial inhibition. There is no mycelial inhibition observed from the treatment T₁(Table 3.).

Table 3: Per cent inhibition of mycelium under disc diffusion assay

Treatment	Treatment details	Radial growth of mycelium (in cm)	Percentage of mycelial inhibition
T1	SE @ 500 ppm	9	0(0.000) ^d
T2	SE @ 1000 ppm	7.6	15.55(15.55) ^e
T3	SE @ 2500 ppm	6.41	28.7 (28.7) ^d
T4	SE @ 5000 ppm	4	55.5 (55.55) ^c
T5	SE @ 10000 ppm	3.4	71.1 (67.03) ^b
T6	COC @ 1000 ppm	0.66	92.6 (92.58) ^a
T7	Control	9	0 (0.00) ^d
		CD (0.05)	2.31
		SE (mean)	1.95

*Mean of three replications, Observations were taken after 7 days of inoculation

Figures with same letter do not have significant difference according to one- way ANOVA at $P=0.05$

4. *In planta* evaluation of seaweed extract against mulberry root rot

In treatment 5, the symptoms have been observed as severe and rated disease score as 9, and healthy plants produces no

symptoms (T₆). The combined application methods of seaweed extract exhibit maximum of pathogen control and produces few lesions which is on par with the standard check. (Table 5.).

Table 5: Evaluation of lesion size after the treatment of seaweed extract

Treatment	Treatment details	Disease scoring
T1	SE (Soil Drenching)	5-6 (Moderate)
T2	SE (Foliar Application)	6-8 (Many lesions)
T3	SE (Soil Drenching + Foliar Application)	1-3 (few lesions)
T4	COC (Soil Drenching)	1-3 (few lesions)
T5	Pathogen alone	9 – Severe infection
T6	Healthy control	1 - No infection

The antimicrobial property of the seaweed against *Macrophomina phaseolina* which causes mulberry root rot. Mulberry (*Morus* spp.) exhibits the potential of mycelia I inhibition through the *in vitro* analysis (Fig. 3,4,5). The wide host range and high persistence of *M. phaseolina* in soil as microsclerotia make disease control challenging. The pathogen *M. phaseolina* affects the fibrovascular system of the roots and basal internodes of its host, impeding the transport of water and nutrients to the upper parts of the plant. As a result, progressive wilting, premature dying, loss of vigour, and reduced yield are characteristic symptoms of *M. phaseolina* infection rot, stem rot, charcoal rot, basal stem rot, and root rot. Seaweeds are the good source of essential nutrients, excellent eco-friendly organic manure and alternative source for inorganic chemical fertilizer for sustaining the crop yield. It is an excellent source of bioactive components with reported antimicrobial activity. Several scientific studies *in vitro* revealed the antimicrobial potential of seaweeds. Application of dried powder forms of *S. tenerrimum*, *S. wightii*, *S. swartzii* as a soil amendment in *Helianthus annuus*, effectively decreasing the disease incidence of root rot caused by *Macrophomina phaseolina* and *F. solani* in plants (Ara *et al*, 1996)^[5].

In comparison with ethanol, ethyl acetate, and water extracts (Thinakumar and Sivakumar, 2013)^[36] *S. wightii* and *S. lilicifolium* extracts in petroleum ether, benzene, and chloroform caused the most significant decrease in *P. aphanidermatum* mycelial growth. In *Cajanus cajan*, Ambika and Sujatha (2014)^[3] reported that *Sargassum myricocystem* demonstrated significant antifungal activity against *Fusarium oxysporum* f. sp. *udum* by employing the poisoned food method with the mycelial inhibition ranges at various intervals.

Hernández-Herrera *et al.* (2014)^[14] reported green algae extracts (*Ulva lactuca* and *Caulerpa sertularioides*), and brown algae extracts (*Padina gymnospora* and *Sargassum liebmannii*) provided protection against the necrotrophic fungus *Alternaria solani* in tomato plants (*Solanum lycopersicum*) through soil drenching and foliar application. The application of extract derived from brown sea algae (*Sargassum fusiforme*) and its ability to induce resistance in tomato plants significantly reduced the severity of late blight, grey mold, and powdery mildew in tomatoes (Sbailhat *et al*, 2015).

A lower concentration of 15 (%) *Turbinaria conoides* extract effectively inhibits the mycelial growth of *Fusarium oxysporum* fungi, and the GC-MS analysis shows the presence of several antimicrobial compounds may be inducing the antifungal activity (Selvaraju and Vijayakumar, 2016)^[34].

The inhibitory activity of aqueous and organic extracts of *Sargassum vulgare* from Tunisian coastal areas against the potato leak-causing agent, *P. aphanidermatum*, was tested *in vitro* and *in vivo*, resulting in suppressing the disease severity. The activity was modified by the types of extracts examined, sample locations, and concentrations used (Ammar *et al*, 2017).

The application of the commercial extract ((Algamar®) *A. nodosum* at 0.4 mL L⁻¹ had the most significantly decreased the incidence and severity of brown rot in the infected plum fruits and exhibited a similar control effect as the fungicide iprodione (Viencz *et al*, 2020)^[37].

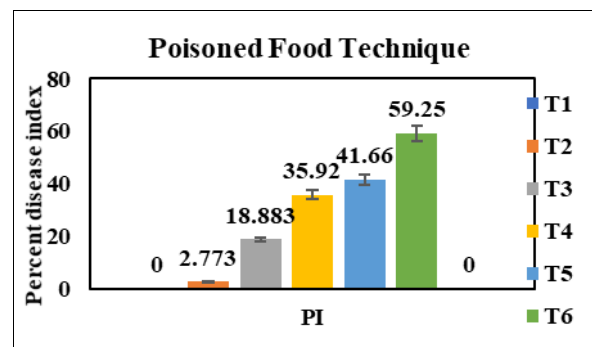


Fig 3: Per cent of mycelial inhibition of poisoned food technique

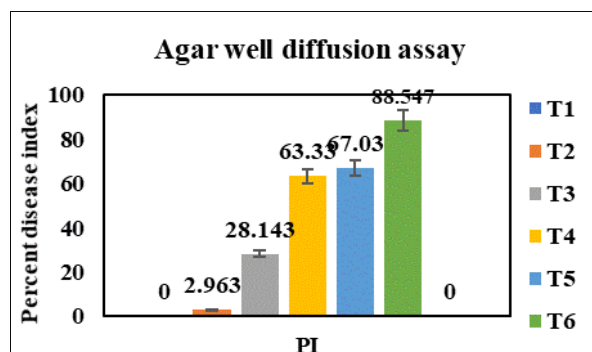


Fig 4: Per cent of mycelial inhibition of Agar Well Diffusion Assay

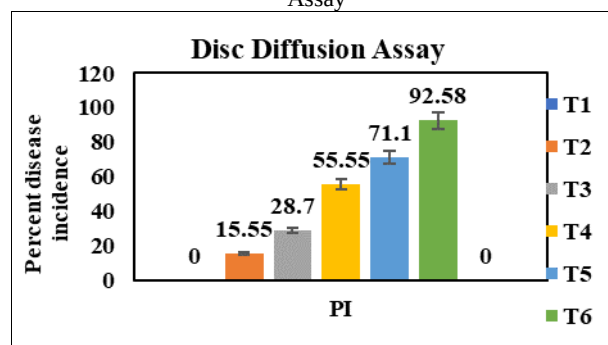


Fig 5: Per cent of mycelial inhibition of Disc Diffusion Assay

References

- Agardh JG. Species genera et ordines algarum, seu descriptiones succinctae specierum, generum et ordinum, quibus algarum regnum constituitur. Volumen Primum. Algas fucoideas complectens. Lundae [Lund]: C.W.K. Gleerup, 1848: [1]–363.
- Almomani F, Alhawatem M, Hameed K. Detection, identification and morphological characteristic of *Macrophomina phaseolina*: the charcoal rot disease pathogens isolated from infected plants in Northern Jordan. Archives of Phytopathology and Plant Protection, 2013;46:1005–1014.
- Ambika S, Sujatha K. Comparative studies on brown, red, and green algae seaweed extracts for their antifungal activity against *Fusarium oxysporum* f. sp. *udum* in Pigeon pea var. CO (Rg) 7 (*Cajanus cajan*). Journal of Biopesticides, 2014;7(2):167–17.
- Ammar N, Jabnoun-Khiareddine H, Mejdoub-Trabelsi B, Nefzi A, Mahjoub MA, Daami-Remadi M. Pythium leak control in potato using aqueous and organic extracts from the brown alga *Sargassum vulgare* (C. Agardh, 1820). Postharvest Biology and Technology, 2017;130:81–93.

5. Ara J, Ehteshamul-Haque S, Sultana V, Qasim R, Ghaffar A. Effect of *Sargassum* seaweed and microbial antagonists in the control of root rot disease of sunflower. *Pakistan Journal of Botany*,1996;28:219–224.
6. Bakshi BK, Reddy Ram MA, Puri YN, Singh S. Survey of the disease of important FRIC, Dehradun, India. 1972:93–98.
7. Chowdary NB. Studies on root rot disease of mulberry (*Morus* spp.) and its management with special reference to the antagonistic microbes. Ph.D. thesis. The University of Mysore, Mysore, India,2006.
8. Dhingra OB, Sinclair JB. Biology and pathology of *Macrophomina phaseolina*. Universidade Federal de Viscosa, Brazil,1978:12(166).
9. Dhingra OD, Sinclair JB. Variation among isolates of *Macrophomina phaseoli* (*Rhizoctonia bataticola*) from different regions. *Phytopathology*,1973;76:200–20.
10. Dulanlebit YH, Hernani H. Overview of extraction methods for extracting seaweed and its applications. *Journal of Penelitian Pendidikan IPA*,2023;9(2):817–824.
11. Genetic diversity and effect of temperature and pH on the growth of *Macrophomina phaseolina* isolates from sunflower fields in Hungary.
12. Gnanesh BN, Tejaswi A, Arunakumar GS, Supriya M, Manojkumar HB, Tewary P. Molecular phylogeny, identification and pathogenicity of *Rhizopus oryzae* associated with root rot of mulberry in India. *Journal of Applied Microbiology*,2021;131:360–374.
13. Guiry MD, Guiry GM. AlgaeBase. World-wide electronic publication, National University of Ireland, Galway (taxonomic information republished from AlgaeBase with permission of MD Guiry). *Sargassum tenerrimum* J. Agardh, 1848,2023.
14. Hernández-Herrera RM, Virgen-Calleros G, Ruiz-López M, Zañudo-Hernández J, Délano-Frier JP, Sánchez-Hernández C. Extracts from green and brown seaweeds protect tomato (*Solanum lycopersicum*) against the necrotrophic fungus *Alternaria solani*. *Journal of Applied Phycology*,2014;26:1607–1614.
15. Jamali S. First report of charcoal rot caused by *Macrophomina phaseolina* on *Kalanchoe blossfeldiana* in Iran. *Indian Phytopathology*,2021;74(4):1167–1168.
16. January GG, Naidoo RK, Kirby-McCullough B, Bauer R. Assessing methodologies for fucoidan extraction from South African brown algae. *Algal Research*,2019;40:101517.
17. Jayaraj J. Microbial Antagonists: Their Role in Biological Control of Plant Diseases. Today & Tomorrow's Printers and Publishers, New Delhi, India,2018:770–777.
18. Jayaraman J, Ali N. Sustainable Crop Disease Management Using Natural Products. CABI, Wallingford, UK,2015.
19. Jha B, Reddy CRK, Thakur MC, Rao MU. Seaweeds of India: the diversity and distribution of seaweeds of Gujarat coast. 3.
20. Kadam SU, Tiwari BK, O'Donnell CP. Application of novel extraction technologies for bioactives from marine algae. *Journal of Agricultural and Food Chemistry*,2013;61(20):4667–4675.
21. Khan W, Rayirath UP, Subramanian S, Jithesh MN, Rayorath P, Hodges DM, Critchley AT, Craigie JS, Norrie J, Prithiviraj B. Seaweed extracts as biostimulants of plant growth and development. *Journal of Plant Growth Regulation*,2009;45:112–134.
22. Lakhra L, Ahir RR, Choudhary M, Choudhary S. Isolation, purification, identification and pathogenicity of *Macrophomina phaseolina* (Tassi) Goid caused dry root rot of chickpea. *Journal of Pharmacognosy and Phytochemistry*,2018;7(3):3314–3317.
23. Littler MM, Littler DS. Smithsonian Institution, Washington, DC, USA. Book series,2011.
24. Littler MM, Littler DS. Heteromorphic life history strategies in the brown alga *Scytosiphon lomentaria* (Lyngb.). *Journal of Phycology*,1983;19(4):425–431.
25. Marquez N, Giachero ML, Declerck S, Ducasse DA. *Macrophomina phaseolina*: general characteristics of pathogenicity and methods of control. *Frontiers in Plant Science*,2021;12:6343.
26. Marquez N, Giachero ML, Declerck S, Ducasse DA. *Macrophomina phaseolina*: general characteristics of pathogenicity and methods of control. *Frontiers in Plant Science*,2021;12:634397.
27. Meyer WA, Sinclair JB, Khare MN. Biology of *Macrophomina phaseolina* in soil studies with selective media. *Phytopathology*,1973;63:613–620.
28. Mihail JD. *Macrophomina*. Methods for Research on Soilborne Phytopathogenic Fungi. American Phytopathological Society,1992:134–136.
29. Nene YL, Thapliyal PN. Fungicides in Plant Disease Control. Oxford & IBH, New Delhi,1993:691.
30. Noorjahan A, Aiyamperumal B, Anantharaman P. Characterization and biochemical properties of brown seaweed *Sargassum tenerrimum* (J. Agardh). *International Journal of Pharmacy and Biological Sciences*,2019;9(2):350–357.
31. Rajeswari P, Angappan K. Prevalence of mulberry root rot disease in Tamil Nadu. *International Journal of Chemical Studies*,2018;6:1573–1575.
32. Rao CSP. A contribution to the morphology and life-history of *Sargassum tenerrimum*. *Journal of Ag. Proceedings/Indian Academy of Sciences*,1946;23(1):39–51.
33. Remya RR, Rajasree SR. Biodiversity, distribution and utilization of brown algae in Tamil Nadu coastline. *Journal of Advanced Research in Geo Sciences & Remote Sensing*,2015;2(3):44–46.
34. Selvaraju P, Vijayakumar A. Evaluation of antifungal activity of seaweed extract (*Turbinaria conoides*) against *Fusarium oxysporum*. *Journal of Applied and Natural Science*,2016;8(1):60–62.
35. Sharma DD, Naik VN, Chowdary NB, Mala VR. Soil borne diseases of mulberry and their management. *International Journal of Industrial Entomology*,2003;7:93–106.
36. Thinakaran T, Sivakumar K. Antifungal activity of certain seaweeds from Puthumadam coast. *International Journal of Research and Review in Pharmacy and Applied Sciences*,2013;3(3):341–350.
37. Viencz T, Oliari ICR, Ayub RA, Faria CMDR, Botelho RV. Postharvest quality and brown rot incidence in plums treated with *Ascophyllum nodosum* extract. *Semina: Ciências Agrárias*,2020;41(3):753–766.
38. Vijayan K, Nair CV, Chatterjee SN. Diversification of mulberry (*Morus indica* var. S36), a vegetatively

- propagated tree species. Caspian Journal of Environmental Sciences,2009:7(1):23–30.
39. Wassie T, Niu K, Xie C, Wang H, Xin W. Extraction techniques, biological activities and health benefits of marine algae *Enteromorpha prolifera* polysaccharide. Frontiers in Nutrition,2021:8:747928.
 40. Waterman PG, Mole S. Analysis of Phenolic Plant Metabolites. Blackwell Scientific, Oxford,1994.
 41. Yoon HS, Andersen RA, Boo SM, Bhattacharya D. Stramenopiles. Encyclopedia of Microbiology,2009:721–731.