



RESEARCH ARTICLE

Bio stimulatory and antifungal effects of seaweed extracts against root rot and stem rot diseases of groundnut

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Abstract

Groundnut (*Arachis hypogaea* L.), a major oilseeds crop, is severely constrained by soil-borne diseases such as root rot caused by *Macrophomina phaseolina* and stem rot caused by *Sclerotium rolfsii*, leading to significant yield losses. Seaweeds are rich sources of biologically active metabolites with documented antifungal and plant growth-promoting properties. The present study evaluated the antifungal efficacy of different seaweed extracts against major groundnut root and stem rot pathogens under *in vitro* and field conditions. Three seaweed extracts *Gracilaria edulis*, *Sargassum myricocystum* and *Kappaphycus alvarezii* were tested at 3, 5 and 10 % concentrations against *M. phaseolina* and *S. rolfsii* using *in vitro* assays, followed by field evaluation at the most effective concentration. *In vitro* results revealed that *G. edulis* at 10 % concentration significantly inhibited *M. phaseolina*, recording the least mycelial growth (1.0 cm), followed by *S. myricocystum* (3.7 cm) and *K. alvarezii* (5.5 cm), compared to 9.0 cm in the control. Against *S. rolfsii*, *G. edulis* and *S. myricocystum* at 10 % concentration completely suppressed mycelial growth (0.0 cm), while *K. alvarezii* recorded 5.0 cm growth. Field evaluation demonstrated that *S. myricocystum* at 10 % was the most effective, achieving 76.03 % and 71.70 % reduction in root rot and stem rot incidence, respectively, with the highest pod yield (2230 kg ha⁻¹), followed by *G. edulis* and *K. alvarezii*. These findings highlight the potential of seaweed extracts as eco-friendly alternatives for managing soil-borne diseases in groundnut.

Keywords: *Arachis hypogaea*; antifungal activity; *Macrophomina phaseolina*; seaweed extracts; *Sclerotium rolfsii*; soil-borne diseases

Introduction

Groundnut (*Arachis hypogaea* L.) is a major legume crop widely cultivated across tropical and subtropical regions of the world. It is recognised as one of the most important oilseeds crops due to its high nutritional and economic value. Groundnut kernels contain approximately 48 % edible oil, 26 % protein, 20 % carbohydrates and 3 % dietary fibre and are rich sources of essential minerals and vitamins, including calcium, thiamine and niacin (1). Beyond its nutritional importance, groundnut plays a vital role in sustainable agriculture through its symbiotic association with nitrogen-fixing bacteria. This symbiosis enables biological nitrogen fixation, contributing an estimated 80–160 kg N ha⁻¹ per growing season, thereby improving soil fertility and reducing the need for synthetic nitrogen fertilisers. Consequently, groundnut cultivation not only supports food and nutritional security but also enhances soil health and sustainability in agro ecosystems (2).

Crop yield is severely constrained by both biotic and abiotic factors that adversely affect plant growth and development (3). Among biotic stresses, insect pests and plant diseases are major contributors to yield reduction. Soil-borne fungal diseases such as dry root rot and stem rot cause substantial yield losses and pose serious challenges to sustainable crop production (4).

Seaweed extracts are widely used as foliar sprays in a range of agricultural crops, including pulses, cereals and horticultural species, due to their growth-promoting and protective effects (5). These extracts are rich in bioactive constituents such as vitamins, amino acids, cytokinins, abscisic acid, indole-3-acetic acid (IAA) and indole-3-butyric acid that enhance plant growth and physiological performance (6). Previous studies have demonstrated the inhibitory effects of seaweed extracts on the mycelial growth of soil-borne pathogens, including *Rhizoctonia solani*, *Fusarium solani* and *Macrophomina phaseolina*. While macroalgal extracts significantly reduced the radial growth of *R. solani* and *F. solani*, their effect on *M. phaseolina* was comparatively limited (7). In addition to their antifungal potential, seaweed extracts are known to enhance plant tolerance to environmental stresses, improve nutrient uptake from the soil (8) and stimulate antioxidant activity, thereby contributing to improved crop health and productivity (9).

At present, effective preventive and control measures remain inadequate to ensure sustainable protection against soil-borne diseases across diverse crops. Conventional management strategies, including the use of resistant cultivars, crop rotation and soil solarisation, often provide inconsistent control, as soil-borne pathogens can persist under adverse soil conditions and infect a

wide range of host species (10). Although chemical and biological control methods are widely employed, their effectiveness is frequently constrained by practical, environmental and regulatory limitations (11). Moreover, the prolonged and indiscriminate use of chemical pesticides has led to serious environmental contamination and the emergence of pesticide-resistant pathogen populations (12). Therefore, there is an urgent need to identify sustainable and eco-friendly alternatives for effective disease management. In this context, seaweed extracts represent a promising approach, as their suppressive activity has been demonstrated against a broad spectrum of soil-borne plant pathogens. Root rot caused by *M. phaseolina* is a major soil-borne disease causing significant economic losses in groundnut and other crops. Symptoms appear initially on young plants as water-soaked lesions on the hypocotyl near the soil surface, which enlarge, turn dark brown and girdle the stem, leading to wilting and plant death, particularly under hot and dry conditions. Stem rot caused by *Sclerotium rolfsii* is another destructive disease with a wide host range and high soil persistence. Infection occurs mainly at the collar region, where stems or branches in contact with soil begin to yellow and wilt (13). The disease progresses rapidly with extensive tissue decay accompanied by white mycelial growth and sclerotia formation. Both diseases pose serious challenges to sustainable crop production, especially under warm and humid agro climatic conditions. The present investigation was undertaken to evaluate the efficacy of seaweed extracts in managing fungal pathogens, with particular emphasis on soil-borne diseases such as root rot and stem rot in groundnut.

Materials and Methods

Collection of diseased samples and isolation of pathogens

Root rot and stem rot infected groundnut plant samples were collected from the C Block of Agricultural College and Research Institute, Madurai, Madurai (approx. 9.9252° N, 78.1198° E) during the kharif season. A total of 5 infected plants showing typical disease symptoms were randomly sampled and brought to the laboratory for isolation and further studies. The infected plant tissues were thoroughly washed under running tap water and subsequently rinsed with sterile distilled water to remove adhering soil particles. Surface sterilisation was carried out by immersing the tissues in 1.0 % sodium hypochlorite solution for 1–2 min, followed by three successive washes with sterile distilled water. The sterilised tissue segments were aseptically placed on potato dextrose agar (PDA) medium in Petri plates and incubated at 28 °C for 7 days to facilitate fungal growth and pathogen isolation.

Collection of seaweed and extraction

Three seaweed species, namely *Sargassum myricocystum*, *Gracilaria edulis* and *Kappaphycus alvarezii*, were obtained from the Department of Plant Pathology, Agricultural College and Research Institute, Madurai. The collected seaweed samples were washed thoroughly to remove debris and dried in a hot air oven at 50 °C for 48 hr. The dried samples were ground into a fine powder and 20 g of each powdered sample was transferred into a 250 mL conical flask. Subsequently, 100 mL of hexane was added and the mixture was subjected to solvent extraction for 24 hr at room temperature (27 ± 2 °C) under continuous agitation (150 rpm) using an orbital shaker. The extracts were then filtered and concentrated using a rotary evaporator under reduced pressure to obtain crude seaweed extracts, which were stored at 27 ± 2 °C until further use.

In vitro screening of seaweed extracts against *Macrophomina phaseolina* and *Sclerotium rolfsii* (Poisoned food technique)

The antifungal activity of seaweed extracts against *M. phaseolina* and *S. rolfsii* was evaluated using the poisoned food technique. Required concentrations of seaweed extracts (3, 5 and 10 %) were prepared by incorporating the extracts into molten PDA medium before solidification. The amended media were poured into sterile Petri plates and allowed to solidify. A mycelial disc (5 mm diameter) from a 7-day-old culture of each pathogen was aseptically placed at the centre of the plates. Plates without seaweed extract served as the control. All treatments were incubated at room temperature and mycelial growth was recorded when the control plates reached full growth. The percentage inhibition of mycelial growth was calculated in comparison with the control.

$$\text{Percent inhibition of mycelial growth} = \frac{C - T}{C} \times 100$$

Where, C - Mycelial growth of the pathogen in control, T - Mycelial growth of the pathogen in treatment

Antifungal activity was evaluated using the poisoned-food technique. Briefly, carbendazim (0.1 g) was incorporated into 100 mL of molten and cooled PDA to obtain a 0.1 % fungicide-amended medium, which served as the chemical check. Similarly, the prepared seaweed extracts were incorporated into molten PDA to obtain final concentrations of 3 %, 5 % and 10 % (v/v). The amended media were thoroughly mixed, poured into sterile Petri plates and allowed to solidify under aseptic conditions before inoculation. Upon solidification, a 5.0 mm mycelial disc taken from the actively growing margin of a 7-day-old culture of *M. phaseolina* and *S. rolfsii* was aseptically placed at the centre of each plate. Petri plates containing PDA with the pathogen alone served as the control and mycelial growth was recorded for each treatment.

Effect of 10 % seaweed extracts on the management of root rot and stem rot diseases in groundnut under field conditions

A field experiment was conducted during 2024 in the groundnut field located in the 'C' Block of the Agricultural College and Research Institute (AC & RI), Madurai. The experiment was conducted in a randomized block design (RBD) with a plot size of 2.5 × 1.5 m. The study consisted of 4 treatments, including an untreated control and each treatment was replicated 6 times. Seaweed extracts were diluted with the required amount of water to obtain the desired concentrations and applied as foliar sprays at a spray volume of 500 L ha⁻¹ using a hand-operated sprayer to ensure uniform coverage. Two foliar applications were made at 30 and 45 days after sowing (DAS) of the crop. Disease symptoms of root rot and stem rot were recorded at the time of application and observations on disease reduction, disease severity and pod yield were taken one week after spraying.

Statistical analysis

The experimental data were subjected to statistical analysis using the WASP 2.0 statistical package. The data were analysed following a RBD, considering the number of treatments and replications and the critical difference (CD) at the 5 % level of significance ($p = 0.05$) was calculated to compare treatment means.

Results

In vitro evaluation of seaweed extracts against *Macrophomina phaseolina* in groundnut (Poisoned food technique)

The present findings evaluate the antifungal efficacy of different seaweed extracts at 3 concentrations against *M. phaseolina* in groundnut using the poisoned food technique (Fig. 1). The results, presented in Table 1, demonstrated a significant reduction in mycelial growth across all treatments compared to the control. The seaweed extracts significantly inhibited the mycelial growth of the pathogen in a concentration-dependent manner. Among the treatments, *G. edulis* exhibited maximum inhibition with 38.89 %, 60.00 % and 88.89 % inhibited at 3 %, 5 % and 10 % concentrations, respectively, recording the lowest colony diameter (1.0 cm) at 10 %.

Table 1. Effect of different seaweed extracts against root rot disease caused by *Macrophomina phaseolina* in groundnut (Poisoned food technique)

Sl.No.	Treatments	Diameter of mycelial growth (cm)			Per cent inhibition over control
		3 %	5 %	10 %	
T1	<i>Sargassum myricocystum</i>	9.0	8.1	3.7	58.90
T2	<i>Gracilaria edulis</i>	5.5	3.6	1.0	88.90
T3	<i>Kappaphycus alvarezii</i>	8.1	7.5	5.5	38.90
T4	Control	9.0	9.0	9.0	-
	CD ($p = 0.05$ %)	-	-	0.789	-

a. *Sargassum myricocystum*



3 %

5 %

10 %



Control

b. *Gracilaria edulis*



3 %

5 %

10 %



Control

c. *Kappaphycus alvarezii*



3 %

5 %

10 %



Control

Fig. 1. In vitro evaluation of seaweed extracts against *Sclerotium rolfsii*. (a) *Sargassum myricocystum*; (b) *Gracilaria edulis*; (c) *Kappaphycus alvarezii*.

Sargassum myricocystum showed 0.00 %, 10.00 % and 58.89 % inhibition, whereas *K. alvarezii* recorded 10.00 %, 16.67 % and 38.89 % inhibition at 3 %, 5 % and 10 % concentrations, respectively.

In-vitro evaluation of seaweed extracts against *Sclerotium rolfsii* in groundnut (Poisoned food technique)

An *in vitro* study was conducted to assess the efficacy of different seaweed extracts at 3 concentrations against *S. rolfsii* in groundnut using the poisoned food technique (Fig. 1). The results, presented in Table 2, demonstrated a marked inhibitory effect of the extracts on pathogen growth. All the tested seaweed extracts significantly inhibited the mycelial growth of *S. rolfsii* compared to the untreated control. At 10 % concentration, both *S. myricocystum* and *G. edulis* completely inhibited the mycelial growth of the pathogen, recording 100 % inhibition. In contrast, *K. alvarezii* showed comparatively lower

Table 2. Effect of different seaweed extracts against stem rot disease caused by *Sclerotium rofsii* in groundnut (Poisoned food technique)

Sl.No.	Treatments	Diameter of mycelial growth (cm)*			Per cent inhibition over control
		3 %	5 %	10 %	
T1	<i>Sargassum myricocystum</i>	7.7	3.5	0.0	100.00
T2	<i>Gracilaria edulis</i>	9.0	5.5	0.0	100.00
T3	<i>Kappaphycus alvarezii</i>	9.0	6.6	5.0	44.44
T4	Control	9.0	9.0	9.0	-
	CD ($p = 0.05$ %)	0.54	0.67	0.93	-

inhibition (44.44 %) at the same concentration. At lower concentrations (3 % and 5 %), the inhibition effect was comparatively reduced, indicating a concentration-dependent response. These findings highlight the potent antifungal activity of *G. edulis* and *S. myricocystum* against *S. rofsii* under *in vitro* conditions.

Evaluation of seaweed extracts for the management of root rot and stem rot diseases in groundnut under field conditions

The experiment was conducted under field conditions for the efficacy of seaweed extracts at effective concentration (10 %) against *M. phaseolina* and *S. rofsii* in groundnut (Table 3; Fig. 2). Under field conditions, among the 3 seaweed extracts tested at 10 %

**Fig. 2.** Effect of seaweed extracts against root rot and stem rot diseases of groundnut.

concentration, *S. myricocystum* recorded the highest level of control of root rot and stem rot diseases compared to the other extracts. *Sargassum myricocystum* recorded 76.03 % and 71.70 % reduction in root rot and stem rot incidence, respectively over the control, along with the highest yield of 2230 kg ha⁻¹. This was followed by *G. edulis* and *K. alvarezii*, which recorded pod yield of 2132 kg ha⁻¹ and 1896 kg ha⁻¹, respectively.

Discussion

Environmentally friendly strategies for sustainable agriculture are increasingly being explored to enhance both the quality and productivity of food crops. In this context, seaweeds have emerged as promising bio-stimulants and bio-elicitors, capable of promoting plant growth, improving nutrient uptake and enhancing tolerance to various biotic and abiotic stresses. Their multifunctional role makes

them an effective and eco-friendly tool for sustainable crop management and yield improvement. Seaweed-derived compounds such as carrageenans, laminarins, fucans, ulvans and galactans have been recognised as potent bio-elicitors, playing a key role in activating and enhancing plant defence mechanisms against various biotic and abiotic stresses (14). Based on these findings, our study focused on utilising seaweed extracts to suppress soil-borne pathogens in groundnut.

The present investigation demonstrated that among the seaweed species tested, *G. edulis* exhibited the strongest inhibitory effect against *M. phaseolina*, recording the lowest mycelial growth (1.0 cm), followed by *S. myricocystum* (3.7 cm) and *K. alvarezii* (5.5 cm), compared to the control. This result aligns with previous reports indicating that seaweed extracts possess significant antifungal activity against soil-borne pathogens, although specific efficacy may vary with species and concentration. For example, *Sargassum* spp. extracts have been shown to inhibit the growth of several phytopathogens including *M. phaseolina* under *in vitro* conditions, highlighting their potential as biological control agents (15). Recent studies also emphasise that seaweed-derived bioactive compounds can induce plant defence responses and improve resistance against fungal infections by activating systemic defence pathways and enhancing phytohormonal balance (16). Together, these findings support the use of seaweed extracts, particularly those from *G. edulis* and *Sargassum* species, as promising eco-friendly alternatives to conventional fungicides for managing soil-borne diseases in groundnut.

In the present study, *G. edulis* and *S. myricocystum* completely inhibited the mycelial growth of *S. rofsii*, recording 0.0cm, whereas *K. alvarezii* permitted limited growth (5.0cm) compared to the control (9.0cm). These results are consistent with earlier reports demonstrating the antifungal potential of seaweed extracts against soil-borne pathogens. For example, significant inhibition of *S. rofsii* mycelial growth by methanolic extracts of *Sargassum wightii* and other macroalgae, highlighting the broad antifungal activity of brown seaweed extracts *in vitro* (17). Furthermore, recent studies have shown that seaweed extracts not only directly suppress pathogen growth but also enhance plant defence responses through induction of systemic resistance pathways, mediated by phytohormone signalling and defence enzyme activation (18). Similar extracts of several seaweeds exhibited inhibitory effects against *S. rofsii* (19). Application of seaweed extracts has been reported to induce resistance in tomato against

Table 3. Effect of seaweed extracts against root rot and stem rot diseases of groundnut in field condition

Treatments	Root rot		Stem rot		Yield (kg ha ⁻¹)
	*Per cent disease incidence	Per cent reduction over control	*Per cent disease incidence	Per cent reduction over control	
<i>Sargassum myricocystum</i> (10 %)	5.23	76.03	4.98	71.70	2230
<i>Gracilaria edulis</i> (10 %)	6.85	68.60	5.10	71.02	2132
<i>Kappaphycus alvarezii</i> (10 %)	8.12	62.78	6.74	61.70	1896
Untreated control	21.82	-	17.6	-	1346
CD ($p = 0.05$ %)	0.997	-	0.912	-	12.96

S. rolfsii, supporting their role as both direct antifungal agents and resistance inducers (20). Collectively, these findings suggest that seaweed-based formulations, especially from *G. edulis* and *Sargassum* spp., represent promising eco-friendly alternatives to chemical fungicides in the management of stem rot and other soil-borne diseases in groundnut and other crops.

The field study demonstrated that *S. myricocystum* was the most effective in managing root rot and stem rot in groundnut, achieving 76.03 % and 71.70 % disease reduction, respectively, with a corresponding pod yield of 2230kg ha^{-1} . This was followed by *G. edulis* and *K. alvarezii*, which recorded yields of 2132kg ha^{-1} and 1896kg ha^{-1} , respectively. These results indicate that seaweed extracts can significantly suppress soil-borne pathogens and enhance crop productivity. Similar findings have been reported in other crops, where seaweed extracts effectively mitigated stem rot and improved growth parameters. *Sargassum* extracts modulate physio-molecular responses in *Sesamum indicum* L., enhancing growth and tolerance to *Macrophomina* infection (21). Likewise, seaweed extracts significantly reduced *S. rolfsii* infection in sugar beet under both *in vitro* and *in vivo* conditions, confirming their broad-spectrum antifungal and growth-promoting potential. Collectively, these findings highlight the efficacy of seaweed extracts, particularly *S. myricocystum*, as eco-friendly alternatives for sustainable management of root and stem rot diseases in groundnut.

Conclusion

In this study, *Sargassum myricocystum* demonstrated superior efficacy in inhibiting the growth of *Macrophomina phaseolina* and *Sclerotium rolfsii* under *in vitro* conditions and achieved over 70 % disease reduction with higher pod yield in field trials compared to other seaweed treatments and the control. These findings highlight its potential as an effective, eco-friendly alternative for managing root rot and stem rot in groundnut. Future research should focus on the mass production of *S. myricocystum* extracts and their application in groundnut fields affected by these pathogens. The development of commercial formulations may support wider adoption and additional studies are required to evaluate its effectiveness against other diseases of groundnut and across different crop species.

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Authors' contributions

MP¹ drafted the manuscript. MP² reviewed the manuscript. MK and RN reviewed and corrected the manuscript. CK provided corrections. AM contributed to manuscript writing. RKR performed the statistical analysis and manuscript formatting and corrections. PS and YC assisted in manuscript formatting and SM contributed to formatting and corrections. All authors read and approved the final manuscript [MP¹- Mareeswari Petchimuthu and MP²- Mahalakshmi Palani].

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interests to declare.

Ethical issues: None

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