

Harnessing the Power of Seaweed: Augmentation in Agriculture

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Abstract

Seaweed, a valuable agricultural resource found in coastal and marine environments, has a rich history of use for various purposes. The practice of using seaweed as fertilizer dates back to ancient times, with the Romans and cultures in France, Britain, Japan, and China, all employing it. Even today, many countries continue to utilize seaweed and beach cast for agricultural and horticultural purposes. This traditional method has been shown to enhance crop productivity by supplying crucial nutrients like nitrogen, potassium, phosphorus, and essential trace minerals necessary for plant growth. These nutrients are released gradually, ensuring steady and balanced nourishment for plants, thereby improving soil fertility and overall crop health. Moreover, seaweed contains beneficial compounds such as cytokinins and auxins, which serve as natural growth regulators, fostering root development, enhancing nutrient absorption, and bolstering overall plant vigour. Additionally, seaweed helps plants withstand various stresses, both biotic and abiotic. Research indicates that integrating seaweed into agricultural practices can lead to higher crop yields, improved quality, and sustained soil health. Extracts derived from seaweed serve as valuable nutrient supplements in organic and natural farming methods.

Introduction

India boasts an extensive coastline stretching 8,100 km and an exclusive economic zone covering 2.17 million km², which endows it with abundant and varied seaweed resources. Along this coastline, diverse coastal ecosystems facilitate the thriving growth of various seaweed species, carrying significant economic importance. Specifically, Tamil Nadu, a south eastern state in India, possesses a coastline spanning 1076 km, encompassing 13 coastal districts and boasting 15 major ports and harbours. Seaweeds have been traditionally utilized for

economic purposes such as food, feed, phycocolloids, and agro-based products, with their potential further explored in modern applications like bio-fuel, nutraceuticals, medicine, personal care, and food additives, as extensively researched in recent studies (Hafting *et al.*, 2015; Kim *et al.*, 2017).

Multifunctional Role of Seaweed's in Agriculture

The historical use of seaweed in agriculture is well-documented, spanning many centuries and serving crucial roles in two primary aspects (Panda *et al.*, 2023).

Natural Nutrient Source: Seaweed has been employed as a natural fertilizer by coastal communities for thousands of years. Due to limited access to animal manure in the past, seaweed became a vital source of essential nutrients for crops. Historical records indicate its utilization in European agriculture as early as the 14th century, with specific seaweed varieties like *Fucus* prized for their nutrient-rich composition. The 19th and early 20th centuries witnessed a thriving seaweed collection industry dedicated to meeting agricultural demands.

Soil Amelioration: In addition to providing nutrients, seaweed significantly contributes to improving soil health. Its complex biochemical composition acts as a natural soil conditioner. Application of seaweed has been shown to enhance soil structure, facilitating optimal aeration and drainage. Moreover, it improves soil moisture retention, a crucial factor for plant growth, particularly in regions with arid climates

Types of Seaweed

In agricultural practices, specific species within the diverse taxonomic group of seaweeds are strategically utilized across three major phyla. Along the Tamil Nadu coastal regions, *Gracilaria* species such as *G. edulis*, *G. foliifera*, *G. verrucosa*, and *G. salicornia* are dominant and commercially harvested.

Brown Seaweeds (*Phaeophyceae*): These seaweeds are widely utilized in agriculture due to their abundant alginates. Alginates, complex carbohydrates, act as natural soil conditioners, enhancing soil structure and water retention. Additionally, brown seaweeds serve as valuable sources of essential plant nutrients like nitrogen, phosphorus, and potassium. Notable examples within this group include kelp (*Laminaria* spp.), *Ascophyllum nodosum*, and *Ecklonia* spp.

Red Seaweeds (*Rhodophyta*): Another significant group with substantial agricultural applications, red seaweeds are prized for their carrageenan content. Carrageenan, a versatile gelling agent, finds use in various agricultural products, including fertilizers. Similar to brown seaweeds, red varieties also provide essential plant nutrients such as nitrogen, phosphorus, and potassium. Commonly employed red seaweeds include species of *Gracilaria*, *Gelidium*, and *Euचेuma*.

Green Seaweeds (*Chlorophyta*): Although not as extensively utilized as brown and red varieties, green seaweeds still offer valuable nutrients for plant growth. They are notable sources of nitrogen, a vital element for healthy plant development. Some commonly used green seaweeds in agriculture include *Ulva* spp. and *Enteromorpha* spp.

Role of Seaweed in agriculture

Seaweed is emerging as a pivotal contributor to the shift towards sustainable agricultural practices. Once considered primarily as marine biomass, seaweed extracts are now acknowledged for their significant role in enhancing soil health and fostering plant growth. With a diverse array of macro and micronutrients, seaweed serves as a natural biofertilizer, directly enriching soil fertility and promoting vigorous plant development. Beyond mere nutrient provision, seaweed's intricate composition offers additional benefits such as improving soil structure and enhancing water retention, acting as a natural soil conditioner. Recent studies delve further into the potential of seaweed extracts as plant biostimulants. These extracts may enhance plant stress tolerance, potentially reducing the need for chemical interventions in pest and disease management (Yuvaraj and Gayathiri, 2017).

Nutritional supply for Plants through Seaweed Application

The agricultural advantages of seaweed go beyond its direct nutrient content, offering a range of indirect benefits that enhance plant nutrition and resource utilization efficiency:

Sustained Nutrient Release: Unlike quick-release synthetic fertilizers, seaweed serves as a natural, slow-release reservoir of essential macro and micronutrients. As it decomposes gradually in the soil, it continuously and steadily supplies vital elements like nitrogen, phosphorus, and potassium throughout the growing season. This sustained release minimizes the risk of nutrient leaching, a significant environmental concern associated with synthetic fertilizers, ensuring a consistent nutrient supply for optimal plant growth.

Enhanced Nutrient Acquisition: Seaweed extracts contain specific compounds, such as humic acids, that act as chelators in the soil environment. These organic molecules enhance the solubility and bioavailability of existing nutrients, making them more accessible for plant uptake. This improved accessibility enables plants to efficiently utilize available resources, potentially reducing nutrient deficiencies and optimizing their nutritional status.

Stimulation of Beneficial Microbes: Seaweed application can have a significant impact on the soil microbiome, fostering the growth of beneficial microorganisms like mycorrhizae. These symbiotic fungi form vital partnerships with plant roots, increasing the surface area for nutrient and water absorption.

This expansion of the plant's "feeding network" allows it to access a broader range of resources from the surrounding soil, leading to enhanced overall plant nutrition.

Types of Seaweed amendments

Seaweed-based amendments have emerged as valuable assets in sustainable and productive agriculture, presenting a range of forms, each tailored to offer specific advantages in promoting plant health and soil quality (Torres et al., 2019). Understanding these distinctions enables a targeted approach to meet precise plant requirements.

Sustained Nutrient Release and Soil Enhancement

Seaweed Meal: This finely-ground, dried seaweed serves as a slow-release fertilizer, gradually decomposing in the soil to release essential macro and micronutrients such as nitrogen, phosphorus, and potassium over an extended period. Additionally, seaweed meal acts as a natural soil conditioner due to its high organic matter content, enhancing water retention and fostering optimal soil moisture levels.

Kelp Meal: Extracted from kelp, a brown seaweed abundant in alginates, kelp meal provides targeted benefits for soil structure. Alginates function as natural soil conditioners, improving aeration, drainage, and moisture retention simultaneously. This creates a well-balanced environment conducive to root development and efficient nutrient absorption by plants.

Seaweed Compost: This distinctive amendment combines the advantages of seaweed with traditional compost. Seaweed offers a slow-release nutrient source, while compost supports a flourishing population of beneficial soil microbes. These microbes enhance nutrient availability to plants and contribute to overall soil health.

Nutrient Delivery and Foliar Feeding

Liquid Seaweed Extract: This highly concentrated liquid is derived from soaking seaweed in water. Unlike slower-release alternatives, liquid seaweed extract presents an immediately available nutrient source for prompt uptake by plants. When applied directly onto leaves through foliar feeding, it circumvents the soil and delivers a rapid infusion of essential minerals and micronutrients. Studies indicate that this approach may also enhance plant resilience to stress.

Seaweed Granules: These compacted forms of seaweed meal offer a convenient and controlled means of nutrient supplementation. Seaweed granules gradually break down in the soil, supplying sustained nourishment to plants over an extended period, in contrast to liquid seaweed extract. They provide a user-friendly option for gradual nutrient release, eliminating the mess often associated with loose seaweed meal.



Application methods

Soil Application: Seaweed amendments can be mixed into the soil prior to planting or applied as a top dressing during the growing season.

Foliar Application: Seaweed liquid extract can be directly sprayed onto the leaves of plants.

Mechanism of action

Seaweed extracts are gaining rapid acclaim among scientists for their capacity to foster plant growth and vitality. These intricate biological additives operate through various mechanisms, presenting a natural and sustainable avenue for agricultural improvement.

Enhanced Nutrient Provision: Seaweed extracts serve as an immediate source of crucial macro and micronutrients, such as nitrogen, phosphorus, and potassium. This direct nutrient supply supplements existing soil resources, fostering optimal plant development.

Biofertilization and Biostimulation: Beyond basic nutrients, seaweed extracts offer a unique blend of biofertilizing and biostimulating properties. Biofertilizers aid nutrient absorption and utilization within plants, while biostimulants trigger physiological processes that enhance growth and stress resistance. This combined effect cultivates a robust and resilient plant community (Bhattacharyya et al., 2015).

Hormonal Influence: Seaweed extracts contain abundant naturally occurring plant growth hormones and hormone-like compounds, such as cytokinins and auxins. These substances play a pivotal role in



stimulating cell division and elongation, fostering stronger root systems and increased shoot growth.

Alleviating Environmental Stress: Seaweed extracts can bolster plants' resilience against various environmental stressors. Antioxidants present in seaweed help neutralize harmful free radicals, while research suggests potential for enhanced defense mechanisms against pests and diseases. This augmented stress tolerance results in healthier and more productive plants.

Root Development Support: Application of seaweed extracts stimulates root growth, facilitating more efficient water and nutrient uptake. This translates to sturdier plants with enhanced overall health and resistance.

Soil Health Promotion: In addition to their direct impact on plants, seaweed extracts indirectly contribute to soil health. They can enhance soil structure, improve water retention, and stimulate the proliferation of beneficial soil microbes. This fosters a more conducive and nurturing environment for optimal plant growth.

Conclusions

The incorporation of seaweed represents a promising strategy for boosting crop yields, improving plant health, and fostering soil fertility and sustainability. Through ongoing research and development, seaweed-derived products hold the promise of becoming key contributors to sustainable agricultural practices.

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