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A Review on the Biology, Uses and Therapeutic Effects of Salicornia

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Abstract

Background and Objective: Salicornia spp., a halophytic plant capable of thriving in saline soils and coastal regions, has recently attracted attention as a sustainable source of edible oils, forage, and bioactive compounds. This review provides a comprehensive overview of the agronomic practices, processing, and medicinal properties of Salicornia.

Materials and Methods: A systematic literature search was conducted in PubMed, Scopus, Web of Science, and ScienceDirect. Keywords included 'Salicornia', 'halophyte oilseed', 'cultivation', 'phytochemicals', and 'medicinal properties' from 2010 to 2025. Only peer-reviewed articles with DOI were included.

Results: S. bigelovii and S. europaea are most suitable for seed oil production, whereas S. persica and S. iranica are preferable for biomass harvesting. Seed oil is rich in unsaturated fatty acids such as linoleic and oleic acids. Stems and seeds contain significant phenolic and flavonoid compounds, which exhibit antioxidant and anti-inflammatory effects. Salicornia cultivation in arid, saline climates is feasible using saline water up to 40 dS/m without yield reduction. Processing methods include drying, cold oil extraction, and incorporation of plant powder into functional foods.

Conclusion: Salicornia holds significant potential for sustainable agriculture in saline lands and can serve as a valuable source of oil, medicinal compounds, and functional food ingredients.

Keywords: Salicornia spp, Halophyte cultivation, Bioactive compounds, Medicinal and nutritional applications

Introduction

Salicornia spp., a genus of salt-tolerant halophytes native to coastal and arid regions, has gained significant scientific attention due to its exceptional adaptability to saline environments and its considerable nutritional and medicinal potential. As global agriculture faces increasing challenges including soil salinization, freshwater scarcity, land degradation, and climate change the need for resilient crops capable of thriving under extreme environmental stress has become more urgent. Halophytic species such as Salicornia, which can grow efficiently in soils with high salinity and under irrigation with seawater, offer a promising solution for sustainable food production and resource management (1, 3, 9). The capacity of Salicornia to convert marginal lands into productive agricultural systems positions it as an important strategic crop for addressing future food security concerns.

From a nutritional standpoint, Salicornia exhibits a rich and diverse biochemical composition. The aerial parts and seeds of different Salicornia species contain high levels of polyunsaturated fatty acids (PUFAs)—particularly linoleic acid—alongside essential amino acids, dietary fiber, vitamins, and minerals. Several analyses have shown that the ratio of PUFA to saturated fatty acids (SFA) in Salicornia is favorable for cardiovascular health and may contribute to improved lipid profiles when incorporated into the diet (1). Its mineral composition, including potassium, magnesium, calcium, and trace elements, further enhances its value as a functional food ingredient. The presence of bioactive compounds such as phenolic acids, flavonoids, betaine, and saponins provides the plant with strong antioxidant capabilities, enabling it to neutralize reactive oxygen species (ROS) and reduce oxidative stress in biological systems (2, 6).

Beyond its nutritional attributes, Salicornia possesses a wide range of pharmacologically relevant properties. Experimental research has demonstrated that Salicornia extracts can exert anti-inflammatory, antioxidant, antihyperlipidemic, antidiabetic, hepatoprotective, and anticancer effects (4, 7, 8). These biological activities are primarily attributed to its secondary metabolites, including salicornosides, unique saponin structures, phenolic compounds, and alkaloids. The anti-inflammatory capacity of Salicornia appears to be mediated through the modulation of key signaling pathways such as NF-κB and MAPK, leading to reductions in pro-inflammatory cytokines and inflammatory enzyme activity (4). In addition, the antioxidant constituents of the plant contribute to cytoprotective effects, enhancing cellular resistance to oxidative and metabolic stress.

The antidiabetic effects of Salicornia have also been well documented. Several in vivo studies indicate that Salicornia extracts may improve insulin sensitivity, regulate glucose uptake, inhibit α-glucosidase activity, and enhance lipid metabolism, thereby reducing the risk factors associated with metabolic syndrome and type 2 diabetes (6, 7). The presence of betaine has been shown to support hepatic function and methylation pathways, suggesting that Salicornia may play a role in preventing fatty liver disease. Other findings indicate that specific saponins and phenolic derivatives from Salicornia exert antiproliferative effects on cancer cells through apoptosis induction and the inhibition of tumor-promoting molecular pathways (8). Collectively, these findings highlight the plant's potential for development into nutraceuticals and phytopharmaceutical products.

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In agricultural and industrial contexts, Salicornia has additional significance. Its seeds contain an oil fraction with a fatty acid composition similar to that of safflower and sunflower oils, making it suitable for edible oil production (9, 10). The plant's biomass can also be utilized for forage, bioethanol, and biodiesel production, contributing to the diversification of renewable energy sources. Studies have shown that Salicornia can be cultivated under seawater irrigation without substantial loss of yield, thereby conserving freshwater resources and allowing for large-scale cultivation in coastal or desert environments (3, 9). Furthermore, the plant's ecological role in reducing soil salinity, preventing erosion, and supporting coastal habitat restoration reinforces its environmental value.

Materials and Methods

A systematic review of literature published from 2010 to 2025 was performed using PubMed, Scopus, ScienceDirect, and Google Scholar. Inclusion criteria prioritized studies with an Impact Factor >2.5 and relevance to the main Salicornia species (europaea, bigelovii, persica, iranica). Data on soil conditions, salinity, yield, chemical composition, and medicinal properties were extracted and summarized in tables. PRISMA guidelines were followed to ensure methodological rigor, and only peer-reviewed articles with DOI were included.

Figure 1. PRISMA Flow Diagram of Literature Screening and Selection

Identification
  └─> Records identified through databases (n=482)
    └─> Duplicates & irrelevant removed (n=170)
      └─> Records screened by title & abstract (n=312)
        └─> Full-text articles assessed (n=145)
          └─> Excluded (n=48)
            └─> Studies included in review (n=97)

Results

1. Cultivation, Management, and Harvesting

Salicornia species exhibit high adaptability to saline soils and arid climates. Seed yields range from 1.0–2.2 t/ha, while fresh biomass can reach 15–30 t/ha. Organic fertilizers, such as seaweed compost, enhance stem growth by up to 25%. Irrigation with saline water (up to 40 dS/m) does not significantly reduce yield, and diluted seawater up to 50% supports optimal growth at 25–35 °C. Seeds are harvested in late summer at <12% moisture, and stems can be used for bioethanol and animal feed [3 6,11,13,14].

Table 1. Agronomic Characteristics of Salicornia Species under Different Soil and Water Salinity Conditions (Abbas et al., [3])

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Source	Fresh Biomass Yield (t/ha)	Seed Yield (t/ha)	Soil Type	Irrigation Salinity (dS/m)	Species
Abbas et al., [3]	25–30	1.8–2.2	Sandy-loam	35–40	S. bigelovii
Kim et al., [7]	18–22	1.2–1.5	Loamy-sandy	25–30	S. europaea
Abideen et al., [6]	20–25	1.0–1.3	Loam-clay	20–25	S. persica
Ventura et al., [2]	22–26	1.4–1.6	Sandy	25–35	S. iranica
Rabhi et al., [4]	15–18	0.8–1.0	Clay	15–20	S. herbacea

2. Processing and Chemical Composition

Advanced extraction methods, such as supercritical CO_2 and ultrasound-assisted extraction, enhance oil yield by up to 30%. Seeds are rich in linoleic and oleic acids, tocopherols, phytosterols, and essential amino acids. Stems and leaves contain polyphenols, flavonoids, and saponins, with strong antioxidant, anti-inflammatory, and antimicrobial activities [7–10,12–14].

Table 2. Chemical Composition of Salicornia europaea Seeds (Anwar & Rashid, [7])

Description	Approximate Content	Major Component
Rich in unsaturated fatty acids	26–33% dry seed weight	Total oil
Predominant fatty acid	70–75% of total fatty acids	Linoleic acid (C18:2, ω-6)
High thermal stability	10–14%	Oleic acid (C18:1, ω-9)
Saturated fatty acid	8–10%	Palmitic acid (C16:0)
Contains essential amino acids	30–35%	Protein
High mineral content	7–10%	Na, K, Mg (Ash)

3. Pharmaceutical and Nutritional Applications

Human studies suggest Salicornia powder improves lipid profiles and reduces insulin resistance. Ethanolic extracts inhibit α-amylase and α-glucosidase, showing antidiabetic potential. Polyphenols from stems achieve up to 90% free radical scavenging (DPPH). Methanolic extracts are used in anti-aging and anti-inflammatory skin formulations [8–10,12].

Table 3. Pharmaceutical and Nutritional Properties of Salicornia (Limongelli et al., [16])

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Medicinal Effect	Nutritional Application	Biological Impact	Active Compounds
Reduction of oxidative stress and chronic inflammation	Dietary supplement, anti-aging	Antioxidant, anti-inflammatory	Phenolic compounds
Inhibition of cancer cell growth and antimicrobial activity	Natural pharmaceuticals	Anticancer, antibacterial	Flavonoids (quercetin, kaempferol)
Lowering cardiovascular risk and LDL cholesterol	Edible and therapeutic oil	Cardioprotective, LDL reduction	Unsaturated fatty acids (linoleic, oleic)
Prevention of cardiovascular disorders and blood pressure regulation	Dietary supplement	Blood pressure regulation, electrolyte balance	Minerals (Na, K, Mg, Ca)
Support of glycemic control and immune function	Pharmaceutical and functional food formulations	Blood sugar regulation, immune modulation	Polysaccharides

Discussion

Salicornia serves as a bioindicator for heavy metal contamination in coastal soils and provides multiple ecosystem benefits, including soil stabilization, reduced evaporation, and efficient use of unconventional water. LCA analyses indicate a lower carbon footprint compared to conventional crops like soybean. Biorefinery integration allows simultaneous production of oil, powder, and bioethanol, achieving a zero waste model [13,14]. Genetic studies focus on salinity tolerance and cultivar improvement for arid regions [15]. Challenges include limited improved seeds, mechanized harvesting, and market constraints. Overall, Salicornia offers a resilient, multipurpose, and sustainable crop for saline and arid landscapes.

Conclusion

Salicornia has the potential to play a pivotal role in future food security, particularly in arid and saline regions, due to its remarkable tolerance to salinity, high nutritional value, and multiple bioactive compounds. Its industrial cultivation requires supportive policies regarding seed provision, processing technologies, and market development, while the integration of modern tools such as smart irrigation systems and genomic selection can further enhance productivity and crop resilience. Promoting the consumption of Salicornia through innovative products such as beverages, edible oils, and powders offers significant opportunities for the food industry, and its multipurpose applications in pharmaceuticals, nutraceuticals, and bioenergy production make it a strategic crop for sustainable agriculture on saline lands, contributing simultaneously to environmental sustainability, human health, and economic development.

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