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HALOPHYTE BIOACTIVE COMPOUNDS: A REVIEW OF THEIR CHEMICAL COMPOSITION AND BIOLOGICAL ACTIVITIES

Nicoleta Olimpia CIOARĂ (ANDREI)[1,2], Amalia Carmen MITELUȚ[2]

[1]National Institute of Research and Development for Biological Sciences, 060031, 296 Splaiul Independentei, District 6, Bucharest, Romania
[2]University of Agronomic Sciences and Veterinary Medicine of Bucharest, 59 Marasti Blvd, District 1, Bucharest, Romania

Corresponding author email: nicol_andrei@yahoo.com

Abstract

Halophyte plants, which thrive in saline environments (non-competitive agriculture areas), have garnered significant attention in recent years due to their potential as a rich source of bioactive compounds. These plants have evolved unique mechanisms to tolerate high salt concentrations, and in the process, they have accumulated a diverse array of secondary metabolites that are chemically and economically significant. Researchers have identified a wide range of bioactive compounds from halophytes, including phenolic compounds, terpenoids, alkaloids, and polysaccharides, each with their own distinct biological activities. These specialized metabolites often serve as osmoprotectants, antioxidants, and signalling molecules in the plants, conferring their characteristic resilience to high-salinity environments. This review synthesizes and examines the academic literature on secondary metabolites generated by halophyte plants.

Key words: *bioactive compounds, biological activities, halophytes, saline environments, secondary metabolites.*

INTRODUCTION

Natural products derived from secondary metabolites of plants play a crucial role in human and animal health, serving as primary sources of medicinal compounds (Qasim et al., 2017). These compounds are widely accepted due to their diversity, accessibility, sustainability, efficacy, and safety (Medini & Ksouri, 2018). Since ancient times, the study of plant-based bioactive compounds has been an essential part of drug discovery and development, enabling scientific validation of traditional remedies and the formulation of modern pharmaceuticals (Dangol, 2008; Kussmann et al., 2023).

Halophytes are plants adapted to saline conditions, and more than 2,500 genera of halophytes have been identified worldwide (Latruffe, 2010; Hameed et al., 2024). Many of these salt-tolerant species have potential as cash crops, with uses including livestock fodder, edible plants, medicinal resources, sources of chemical compounds, ornamental plants, and biofuel production (Sharma et al., 2016).

Saline environments, such as marine and hypersaline habitats, are widely distributed around the world. They include sea waters, saline lakes, solar salterns, or hypersaline soils (Vengosh, 2003: Torres et al., 2019). Primary salinity occurs naturally in soils and waters. Examples of naturally occurring saline areas include salt lakes, salt pans, salt marshes and salt flats. Secondary salinity is salting that results from human activities, usually land development and agriculture (Hassani et al., 2021). Water Mixing and Enclosed Seas: Limited freshwater mixing increases salinity. Examples: Black Sea, Caspian Sea, Red Sea, and Persian Gulf have high salinity (Beck et al., 2024).

Halophytes have been documented since the early 18th century, with their morphological and anatomical adaptations being closely linked to soil salinity and moisture levels (Toth et al., 2008; Panagos, 2022). Aquatic systems can be classified according their salinity as fresh (< 1 g L^{-1}), hyposaline (1-10 g L^{-1}), saline (10-100 g L^{-1}) and hypersaline (> 100 g L^{-1}) (Davis et al., 2003; Herbert et al., 2015). Although there is a lively discussion on a definition as exhaustive as possible, halophytes, in the broadest sense of the term, should be considered as all plant species occurring on a salty soil, recognized "macroscopically" by certain characters (xeromorphic aspects, flowering saline, salt dust), but also by some indicator species of soils saline (Flowers & Colmer, 2008; Flowers & Muscolo, 2015; Santos et al., 2016).

Notable examples of edible halophytes and salt-tolerant species include: Marine fennel (*Crithmum maritimum* L.) (Lemoine et al., 2024)*;* Mediterranean saltwort (*Soda inermis* Fourr.) (Agudelo et al., 2021)*;* Glassworts (*Salicornia* spp.) (Nájar et al., 2023); Seablite (*Suaeda maritima*) (Alfheeaid et al., 2022). Several halophyte species are already utilized as food, forage, oilseed crops, and medicinal plants (Barreira et al., 2017). The significant diversity of saline habitats in Romania provides an optimal framework for investigating the chemical diversity and biological activities of halophytes (Ben Hsouna et al., 2022). The best-known species of halophytes in the maritime area of the Danube Delta, and not only, are: *Salicornia europaea, Suaeda maritima, Limonium gmelinii, Halimione Verrucifera*, *Festuca arundinacea, Portulaca oleracea, Gypsophila elegans, Ipomoea* (Grigore, 2008; Gavra, 2015).

Environmental factors, particularly those related to high salinity, arid climates, and nutrient scarcity, have highlighted the importance of halophytic plants in medicinal and agricultural sciences (Rozentsvet et al., 2021). The concept of halo-biotechnology the use of halophytes for agriculture and ecological restoration has emerged as a viable strategy for rehabilitating saline lands and establishing sustainable production systems (Musimba, 2012; Lombardi et al., 2023; Loconsole et al., 2019). Given the increasing pressure on freshwater resources, cultivating halophytes could provide an alternative agricultural model, but its success depends on economic viability, environmental sustainability, and the development of effective agronomic practices (Buhmann & Jutta, 2013; Saleem et al., 2021).

These plants have evolved unique adaptive mechanisms to survive under extreme conditions, producing a higher concentration of secondary metabolites such as phenolics, flavonoids, alkaloids, and saponins (Hulkko et al., 2022; Hulkko et al., 2023) These compounds contribute to the plants' defense mechanisms against oxidative stress, microbial infections, and herbivory while also offering significant nutritional and medicinal benefits (Todorović et al., 2022).

Certain halophytic plants from other areas, including *Lycium shawii, Anabasis articulata, Zilla spinosa,* and *Rumex vesicari*us, have demonstrated remarkable adaptability to these harsh conditions. Their ability to thrive in saline environments is attributed to specialized physiological and biochemical responses, such as the production of enzymatic and non-enzymatic antioxidants to counteract oxidative stress. These edible halophytes exhibit a nutritional profile suitable for human consumption. They contain high levels of protein (5.20-13.2 g per 100 g dry weight) and are rich in n-3 polyunsaturated fatty acids (omega-3 fatty acids), particularly α-linolenic acid, which accounts for about 19.3-25.9% of the total fatty acids. Furthermore, the concentrations of toxic metals in these plants are low, remaining below the limits established by the European Commission for food safety. These plants are traditionally used in various medicinal and nutritional applications (Ivanova et al., 2009). For instance, *Lycium shawii* has been historically employed for infection control, *Rumex vesicarius* as a diuretic and treatment for gastrointestinal disorders, *Anabasis articulata* for diabetes management, and *Zilla spinosa* for urinary and gallbladder ailments.

Globally, soil and water salinization pose significant threats to agricultural productivity, affecting nearly 1 billion hectares of land. Halophytes, defined as plants capable of completing their life cycle in high-salinity conditions, have evolved various tolerance mechanisms, distinguishing them from glycophytes, which lack such resilience. Adaptations to saline environments involve morphological, physiological, and biochemical modifications that allow halophytes to manage osmotic stress, ion toxicity, and nutrient imbalances (Hameed et al., 2010). These adaptations include salt secretion, succulence, ion sequestration, and specialized transport mechanisms (Ashraf et al., 2010).

This work reviews recent findings on halophytes under saline conditions, highlighting their ecological and agricultural potential, as well as the challenges and considerations necessary for their large-scale application.

MATERIALS AND METHODS

The searches for this review were conducted in the databases Scopus, Web of Science, SciFinder and Google Scholar. Articles published from the year 1995 till present were used for the review with some inclusion and exclusion criteria. The search terms included (for example) “hypolipidemic and hepatoprotective screening of halophytes species”, “hypolipidemic and hepatoprotective analysis of halophytes species”, “halophytes species with hypolipidemic and hepatoprotective activity”, and “hypolipidemic and hepatoprotective activity of bioactive compounds from halophytes species”. Major references from some of the articles were also searched for additional information.

Based on the number of articles accessed, some inclusion and exclusion criteria were applied, so as to include the most relevant articles in this review. Publications that extensively examined the efficacy of the bioactive compounds of halophytes species were included (Zakirova et al., 2024; Piatti et al., 2021; Purushothaman et al., 2024). I have kept mostly references from recent years, because halophytes have not been scientifically investigated and analyzed for too long time.

CHARACTERISTICS OF HALOPHYTIC PLANTS

Increasing salinization has severe consequences for land, water, vegetation, wildlife, and agricultural productivity, particularly in arid and semi-arid regions where high evapotranspiration rates intensify environmental stress (Shahid et al., 2020). Unlike conventional crops, halophytes salt-tolerant plants found in coastal, wetland, and desert environments have evolved sophisticated adaptive mechanisms at the whole-plant, cellular, and molecular levels, enabling them to thrive under high salinity (Ghanem et al., 2021). Representing approximately 1% of the world's flora, these species offer a promising solution for utilizing the estimated one billion hectares of salt-affected land worldwide.

To be widely adopted, saline agriculture must ensure sufficient crop yields and profitability while preventing further environmental degradation (Karkanis et al., 2022). Halophyte domestication holds potential for producing food, forage, oilseeds, pharmaceuticals, and ornamental plants. Additionally, certain halophytes could contribute to soil desalination, enhancing the productivity of marginal lands. However, the effective implementation of this approach requires comprehensive research on the salt tolerance thresholds of candidate species throughout their life cycle.

Although, their common xeromorphic characteristics must be universally acknowledged, as they underpin their ability to thrive in saline environments. So, many halophytes are also consumed for their organoleptic (sensory) qualities and medicinal properties (Barreira et al., 2017). To date, over 7,000 plant species worldwide have been documented as edible (Shikov et al., 2017). However, only a very small fraction of these edible species are strict halophytes.

1. Taxonomic and Phylogenetic Considerations

Halophytes belong to diverse plant families, with representatives across multiple taxonomic groups. Notable families that include halophytic species are: *Acanthaceae, Aizoaceae, Amaranthaceae, Apiaceae, Asteraceae, Brassicaceae, Caryophyllaceae, Combretaceae, Convolvulaceae, Euphorbiaceae, Fabaceae, Frankeniaceae, Fumariaceae, Juncaceae, Lamiaceae, Malvaceae, Plantaginaceae, Plumbaginaceae, Primulaceae, Rhizophoraceae, Salvadoraceae, Salicornia*, *Tamaricaceae,* and *Zygophyllaceae* (Shahid et al., 2020).

Phylogenetic studies have revealed that halophytism has evolved multiple times across plant lineages, with distinct strategies emerging in different ecological niches. Understanding these evolutionary pathways may aid in identifying genetic determinants of salt tolerance and developing salt-resistant crops (Cárdenas-Pérez et al., 2021).

2. Adaptation Mechanisms of Halophytes

Halophytes, particularly those from the *Chenopodiaceae* family, exhibit diverse strategies for coping with salinity, such as accumulating or secreting salts. Their ability to grow optimally in saline conditions makes them valuable for ecological and agricultural

applications. Studying their elemental composition and phylogenetic relationships provides insights into their adaptive mechanisms and potential uses (Ashraf et al., (2010).
Aspects and problems related to the adaptive mechanisms of halophytes will be analysed in a future paper.

3. Compounds and secondary metabolites
Halophytes possess adaptive mechanisms that enable them to retain and absorb water, protect cellular structures from oxidative stress induced by reactive oxygen species, and maintain ion homeostasis in saline environments. These adaptations involve the biosynthesis of various bioactive compounds with significant biological properties, including antioxidant, antimicrobial, anti-inflammatory, and antitumoral activities. Consequently, halophytes have potential applications in disease prevention, particularly in reducing the risks of cancer, chronic inflammation, and cardiovascular disorders when incorporated into the human diet (Fakhri et al., 2021).
Moreover, these bioactive compounds contribute to the enhanced nutraceutical value of halophytic grasses, as their concentration and diversity are typically higher than those found in non-salt-tolerant crop species (Kraouia et al., 2023). Certain specialized metabolites are exclusive to halophytes, offering promising applications in the agri-food, pharmaceutical, and cosmetic industries (Correia et al., 2022). These unique properties underscore the importance of halophytes as valuable resources for both human health and industrial applications.
The complexity of halophyte adaptation is reflected in their biochemical composition. These plants synthesize a wide array of secondary metabolites with significant ecological and pharmacological relevance (Rodrigues et al., 2018). Some of the most common secondary metabolites in halophytes include:
 Phenolic compounds and flavonoids. Flavonoids are classified as flavone or isoflavones based on the position of the benzoid ring. Phenolic compounds have been widely reviewed and reported to have beneficial effects on human health such as anticancer, antimicrobial, and antimutagenic properties. Phenolic acids such as vanillic, caffeic, ferulic and protocatechuic can be present in some halophytes (Lopes et al., 2021; Lopes et al., 2023; Srivarathan et al., 2023)
 Saponins and alkaloids. Play protective roles against herbivores and pathogens, while also exhibiting medicinal properties (Medini & Ksouri (2018).
 Triterpenes and sterols. Provide structural integrity to cell membranes and enhance stress tolerance.
 Osmoprotectants. Such as betaines and proline, which help maintain cellular function under salt stress conditions.
Halophyte secondary metabolism is particularly significant from a pharmaceutical perspective, as many of these bioactive compounds have demonstrated antimicrobial, anti-inflammatory, hepatoprotective, and antidiabetic properties.

4. Ecological and Agricultural Significance
Halophytes hold great potential for ecological restoration and sustainable agriculture. Their ability to thrive in saline environments makes them candidates for:
 Soil remediation. Certain species, such as *Salsola* and *Salicornia*, can absorb and sequester salts, improving soil quality in degraded coastal and inland regions (Castagna et al., 2022).
 Alternative crops. Some halophytes can be cultivated as food or fodder crops in saline soils where conventional crops fail to grow (Kraouia et al., 2023).
 Medicinal applications. Due to their bioactive compounds, these plants are of interest for drug discovery and development (Fangjie et al., 2024).
Halophytic plants represent a unique ecological group characterized by their specialized adaptations to saline environments (Clavel-Coibrié et al., 2021). Their physiological mechanisms, phytochemical diversity, and ecological roles make them valuable for scientific research, conservation, and agricultural innovation (Alhaddad et al., 2021). Continued exploration of halophyte biology will enhance our understanding of plant stress tolerance and open new avenues for sustainable resource utilization in saline-prone ecosystems.
It is concluded that halophytes may become important sources of natural products for the treatment of various ailments and for

supplementing the human diet with necessary non-nutrients and minerals. However, extensive studies are needed to deepen the knowledge of their biological potential in vivo, so that they can be introduced to the pharmaceutical and food industries.

PHYTOCHEMICAL DIVERSITY OF HALOPHYTES

Studies have identified a diverse array of bioactive compounds in halophytes, including alkanes, alkenes, fatty acids, acylglycerols, cinnamic acids, benzoic acids, short-chain carboxylic acids, carbohydrates, amino acids, alcohols, aldehydes, ketones, terpenoids, tocopherols, flavonoids, polyphenols, alkaloids, stilbenoids, and their derivatives, along with various other specialized metabolites (Kim et al., 2021; Lopes et al., 2021; Lopes et al., 2023; Srivarathan et al., 2023).
These compounds contribute to the functional and pharmacological properties of halophytes (Srivarathan et al., 2023), further reinforcing their potential applications in medicinal, nutritional, and industrial domains (Roberto et al., 2021).
Bioactive compounds of Halophytes (Rahmanie et al., 2022; Markovskaya et al., 2024):

- hydrocarbons;
- organic acids, acylglycerols and derivatives;
- strong-smelling isoprenoids;
- polyphenols;
- hydrocarbon chains with c6-c2-c6 structure; derivatives of stilbene;
- other compounds.

BIOLOGICAL ACTIVITIES OF HALOPHYTES

Plant adaptation and phytoremediation (Ashraf et al., 2010), exhibits the highest diversity. To emphasize, various halophyte species have been used in folklore medicine and increasing number of modern chemical and pharmacological reports have revealed that halophyte plants have many beneficial effects, including nutraceutical value, anti-diabetic and anti-obesity activities, anti-oxidant (Saleh et al., 2021) neuroprotective (Khaled et al., 2024), anti-Alzheimer, anti-ulcer (Jaiswal et al., 2024), anticarcinogenic activity (Custodio et al., 2022)., anti-viral/antifungal (Fredsgaard et al., 2023), antibacterial (Al-Judaibi, 2020), anti-hypertensive, hypolipidemic and hepatoprotective (Souid, 2020), hypoglycemic, anti-inflammatory effects (Karker et al., 2023) spasmolytic and antidiarrheal activities (Chen Hsiao-Ting et al., 2023)
Moreover, halophytic plants represent a potential reservoir of edible and highly nutritious species, which is particularly relevant in the present context. Over the past decade, the global population has continued to grow, while the availability of arable land has steadily declined due to increasing soil salinity (Todorović et al., 2022). It is estimated that approximately 1,000 million hectares of land are affected by this phenomenon, accounting for 20% of the world's cultivated areas. Soil salinity is widely recognized as a significant threat to global food security and agricultural sustainability. However, certain highly salt-tolerant species within the Poaceae family offer a promising solution, as they can withstand seawater-level salt concentrations while also exhibiting substantial nutraceutical potential. Notably, some of these species have already been deemed suitable for livestock consumption, as exemplified by *Beckmannia syzigachne* (Steud.) (Faustino et al., 2019).

FUTURE CHALLENGES ON THE RESEARCH

Furthermore, halophytic plants represent a valuable reservoir of highly nutritious and edible plant species, an essential consideration given the increasing global population and the continuous decline in arable land due to soil salinization. Currently, an estimated 1000 million hectares of land, accounting for approximately 20% of the world's cultivated area, are affected by salinity. This presents a major challenge to global food security and agricultural sustainability. However, certain salt-tolerant species offer a promising solution, as they are capable of surviving in seawater-level salinity while also exhibiting high nutraceutical potential (Alfheeaid et al., 2022). Some of these species, such as *Beckmannia syzigachne* (Steud.), are already recognized as valuable fodder crops for livestock, further emphasizing the potential role of halophytes in future agricultural systems aimed at addressing food security challenges.

In addition, halophytic plants could be a reservoir of edible and highly nutritional plants which is vital today, since in the past decade, the world population has increased continuously while a constant reduction of arable lands is observed due to increased soil salinity (Jia et al., 2011). It is estimated that 1000 million hectares of land are affected by this issue, which corresponds to 20% of the world-cultivated area (Kafi & Khan, 2008). Soil salinity is considered a serious threat to global food security and sustainability; however, a glimmer of hope lies on the existence of some truly salt-tolerant plants from *Poaceae*, which can survive in seawater salt concentrations and simultaneously have high nutraceutical potential. For instance, some of these species have already been considered edible for cattle, which is the case of *Beckmannia syzigachne* (Steud.), *Cenchrus ciliaris* L., *Echinochloa colona* (L.) Link (Dangol, 2008). *Echinochloa crus-galli* (L.), *Dactyloctenium aegyptium* (L.) Willd. (Dedrilkumar & Binu, 2016), *Imperata cylindrica* (L.) Raeusch. (Subramaniam & Sivasubramanian, 2015), *Leymus arenarius* (L.) Hochst. (Svanberg & Egisson, 2012), *Phragmites australis* (Cav.) Trin. ex Steud. (Agudelo et al., 2021) and *Zizania aquatica* L. (Zhang et al., 2014).

RESULTS AND DISCUSSIONS

Halophytes possess adaptive mechanisms that enable them to retain and absorb water, protect cellular structures from oxidative stress induced by reactive oxygen species, and maintain ion homeostasis in saline environments.

These adaptations involve the biosynthesis of various bioactive compounds with significant biological properties, including antioxidant, antimicrobial, anti-inflammatory, and antitumoral activities (Nasernakhaei, 2021; Renna & Gonnella, 2021; Limongelli et al., 2022; Li et al., 2024). Consequently, halophytes have potential applications in disease prevention, particularly in reducing the risks of cancer, chronic inflammation, and cardiovascular disorders when incorporated into the human diet.

Review of the bioactive compounds in halophytes reveals an impressive chemical diversity, demonstrating the importance of these plants in traditional medicine and modern pharmaceutical research (Nazish et al., 2020). Halophytes contain compounds such as flavonoids, saponins, phenolic compounds and fatty acids, each with specific biological activities ranging from antioxidant and anti-inflammatory effects to antimicrobial and antidiabetic properties (Gourguillon et al., 2016; Gheraissa et al., 2024).

For example, *Salicornia herbacea*, analyzed in detail by Rhee & Park (2009) contains phenolic acids such as tungtungmadic acid (*quinic acid*) and flavonoids such as quercetin 3-O-glucoside and isorhamnetin 3-O-glucoside. These substances have been found to have potent antioxidant and anti-inflammatory properties, justifying the traditional use of the plant in the treatment of conditions such as diabetes and atherosclerosis (Arya Sunder Singh et al., 2019). On the other hand, *Polygonum maritimum* L. (sea knotgrass/knotweed), another halophyte of pharmaceutical interest (Rodrigues et al., 2018), has been studied for its effects on salt stress and secondary metabolite content (Oliveira et al., 2023). Studies on this plant have shown that salinity levels significantly influence its chemical composition, affecting antioxidant and anti-inflammatory activities (Rodrigues et al., 2018). This underlines the importance of environmental factors in the biosynthesis of bioactive compounds and thus in the therapeutic potential of halophytic plants

Chemically, halophytes produce a broad range of secondary metabolites of economic significance (Katel et al., 2023). Several of these compounds are unique to halophytic species or exist in higher concentrations compared to glycophytes. For their optimal exploitation, precise plant cultivation conditions, as well as efficient extraction, fractionation, and isolation processes, must be established. While individual bioactive compounds can be specifically identified and controlled, crude extracts containing a mixture of these compounds may exhibit synergistic effects, enhancing their functional potential. Additionally, the concentration and composition of secondary metabolites vary significantly among different

plant organs and across developmental stages (Kim et al., 2021).
The secondary metabolites derived from halophytes have potential applications in diverse fields, including pharmacognosy, functional foods, Halophytes possess adaptive mechanisms that enable them to retain and absorb water, protect cellular structures from oxidative stress induced by reactive oxygen species (ROS), and maintain ion homeostasis in saline environments, and industrial applications. While many of these applications remain in the research and development phase, certain halophyte-derived products have already reached commercial markets. Notable examples include species such as *Salicornia spp.* and *Crithmum maritimum*, which contain valuable compounds utilized in various industries (Melo et al., 2024). These attributes highlight the economic potential of halophytes and underscore their relevance for sustainable industrial and pharmaceutical applications (Ozturk et al., 2023).

CONCLUSIONS

Halophytes represent a specialized group of plants capable of thriving in saline environments where glycophytes fail to survive. These plants have evolved specific physiological and biochemical adaptations that enable them to endure high salt concentrations in diverse habitats, including seawater, salt marshes, and salt deserts. Nearly all halophytes are angiosperms, with dicotyledonous species often exhibiting growth stimulation in response to moderate salinity, while monocotyledonous species generally do not display this trait.
Given that a substantial portion of global water resources is saline, the agricultural importance of halophytes is increasingly recognized, particularly in the context of food security and sustainable land use. Halophytes have undergone significant evolutionary adaptations, allowing them to tolerate high salinity levels due to specialized traits developed over time. These plants exhibit a broad range of halotolerance, making them valuable models for studying salt tolerance mechanisms. Although halophytes constitute only about 2% of terrestrial plant species, they are represented across nearly half of all higher plant families, demonstrating remarkable diversity in their life forms.
In saline environments halophytes must address two primary challenges: tolerating high soil salinity and absorbing water from a medium with low water potential (Ivanishev, 2021). To overcome these challenges, halophytes employ a variety of mechanisms, including the regulation of osmotic balance and ion transport. The increasing global prevalence of soil salinization, driven by factors such as excessive irrigation, industrial waste disposal, and groundwater contamination, poses a significant challenge to agricultural sustainability. Current estimates suggest that approximately 400 million hectares of land are affected by salinity, necessitating the development of salt-resistant crops to ensure food security. Genetic approaches aimed at enhancing salt tolerance in crops have shown promising results, with research focusing on the identification of key stress-tolerance genes and regulatory promoters. Given the rapid growth of the global population and the declining availability of arable land, the study of halophytes has become increasingly relevant. These plants hold potential applications in agriculture, animal fodder production, and medicinal research. Furthermore, halophytes are emerging as a viable alternative for biofuel production, providing a sustainable source of energy while mitigating the negative impacts of fossil fuel consumption (Sudhanshu & Ramachandran, 2021). By leveraging their genetic traits, researchers aim to develop transgenic crops with enhanced salt tolerance, paving the way for innovative agricultural solutions in saline-affected regions (Dagar & Gupta, 2024).
This review synthesizes existing knowledge on halophytes, integrating information from various research studies to provide a comprehensive understanding of their classification, chemical diversity and biological activities of their, and ecological significance.
This work aims to present a holistic overview, offering insights into their potential applications in sustainable agriculture and biotechnology, and more (Grigore et al., 2025).
The continued study of halophytes is imperative for addressing global challenges related to salinity, food security, and environmental conservation.

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REFERENCES

Agudelo A, Carvajal M., Martinez-Ballesta M.D.C. (2021). Halophytes of the Mediterranean Basin-Underutilized species with the potential to be nutritious crops in the scenario of the climate change, Foods, 10 p. 119, 10.3390/foods10010119

Akinniyi, G., Lee, J., Kim, H., Lee, J.-G., & Yang, I. (2022). A Medicinal Halophyte *Ipomoea pes-caprae* (Linn.) R. Br.: A Review of Its Botany, Traditional Uses, Phytochemistry, and Bioactivity. *Marine Drugs*, *20*(5), 329. https://doi.org/10.3390/md20050329

Alfheeaid, H. A., Raheem, D., Ahmed, F., Alhodieb, F. S., Alsharari, Z. D., Alhaji, J. H., BinMowyna, M. N., Saraiva, A., & Raposo, A. (2022). *Salicornia bigelovii*, *S. brachiata* and *S. herbacea*: Their Nutritional Characteristics and an Evaluation of Their Potential as Salt Substitutes. *Foods*, *11*(21), 3402. https://doi.org/10.3390/foods11213402

Alhaddad, F.A., ALrajhei, K.N.H., Abu-Dieyeh, M.H. (2021). Biodiversity and Possible Utilization of Halophytes in Qatar. In: Grigore, MN. (eds) Handbook of Halophytes. Springer, Cham. https://doi.org/10.1007/978-3-030-57635-6_109

Al-Judaibi, A.A. (2020). *Tamarix arabica* and *Salvadora persica* as antibacterial agents. AIMS Microbiol 6(2):121–143. https://doi.org/10.3934/microbiol.2020008

Arya Sunder Singh, Devi Sarita, Ram Kirpa, Kumar Sunil, Kumar Naveen, Mann Anita, Kumar Ashwani, Chand Gurdev (2019). Halophytes: The Plants of Therapeutic Medicine Ecophysiology, Abiotic Stress Responses and Utilization of Halophytes, ISBN: 978-981-13-3761-1

Ashraf, M. et al. (eds.) (2010). Plant Adaptation and Phytoremediation, Springer Science+Business Media B.V., DOI: https://doi.org/10.1007/978-90-481-9370-7_1

Barreira L., Resek E., M.J. Rodrigues, M.I. Rocha, H. Pereira, N. Bandarra, M.M. da Silva, J. Varela, L. Custódio (2017). Halophytes: gourmet food with nutritional health benefits? J. Food. Comp. Anal., 59 pp. 35-42, https://doi.org/10.1016/j.jfca.2017.02.003

Beck, M., Van Bunnen, P., Bodart, S., Münch, A. et al. (2024). Research for AGRI Committee – Rural Areas - Levels of support and impact on competitiveness of farms, European Parliament, Policy Department for Structural and Cohesion Policies, Brussels https://www.europarl.europa.eu/RegData/etudes/STUD/2024/747270/IPOL_STU(2024)747270_EN.pdf

Ben Hsouna, A., Michalak, M., Kukula-Koch, W., Ben Saad, R., ben Romdhane, W., Zeljković, S. Ć., & Mnif, W. (2022). Evaluation of Halophyte Biopotential as an Unused Natural Resource: The Case of *Lobularia maritima*. *Biomolecules*, *12*(11), 1583. https://doi.org/10.3390/biom12111583

Buhmann Anne and Jutta Papenbrock (2013). An economic point of view of secondary compounds in halophytes, *Functional Plant Biology* 40(9) 952-967 https://doi.org/10.1071/FP12342

Cárdenas-Pérez, S., Piernik, A., Chanona-Pérez, J. J., Grigore, M. N., & Perea-Flores, M. J. (2021). An overview of the emerging trends of the Salicornia L. genus as a sustainable crop. Environmental and Experimental Botany, 191, 104606. https://doi.org/10.1016/j.envexpbot.2021.104606

Castagna, A., Mariottini, G., Gabriele, M., Longo, V., Souid, A., Dauvergne, X., ... & Ranieri, A. (2022). Nutritional Composition and Bioactivity of *Salicornia europaea* L. Plants Grown in Monoculture or Intercropped with Tomato Plants in Salt-Affected Soils. Horticulturae, 8(9), 828. https://doi.org/10.3390/horticulturae8090828

Chen Hsiao-Ting, Chuang Chi-Wen, Cheng Ju-Chien, Yeh Yung-Ju, Chang Tsung-Hsien, Shi Yu-Ting, Chao Chih-Hua (2023). Terpenoids with anti-influenza activity from the leaves of Euphorbia leucocephala, *Natural Product Research* 37:6, 936–943.

Clavel-Coibrié E., Sales J.R., da Silva A.M., M.J. Barroca, I. Sousa, A. Raymundo (2021). *Sarcocornia perennis*: a salt substitute in savory snacks, Foods, 10 p. 3110, https://doi.org/10.3390/foods1012311

Correia, A., Silva, A.M., Moreira, M., Salazar, M., Svarc-gajic, J., Brezo-Borjan, T. (2022). *Salicornia ramosissima*: A New Green Cosmetic Ingredient with Promising Skin Effects. Antioxid11, 12. [Google Scholar]

Custodio, L., Garcia-Caparros, P., Pereira, C. G., & Castelo-Branco, P. (2022). Halophyte Plants as Potential Sources of Anticancer Agents: A Comprehensive Review. *Pharmaceutics*, *14*(11), 2406. https://doi.org/10.3390/pharmaceutics14112406

Dagar, J.C., Gupta, S.R. (2024). Synthesis: Prospects of Halophytes in Saline Agriculture to Achieve Food and Livelihood Security. In: Dagar, J.C., Gupta, S.R., Kumar, A. (eds), Halophytes vis-à-vis Saline Agriculture. Springer, Singapore. https://doi.org/10.1007/978-981-97-3157-2_20

Dangol, D. R. (2008). Traditional uses of plants of commonland habitats in Western Chitwan, Nepal. *Journal of the Institute of Agriculture and Animal Science*, *29*, 71.

Dedrilkumar, S., & Binu, M. (2016). Wild edible plants used by Meitei community of Eastern Himalayas, India. *Int. J. Agric. Sci*, *8*, 2699-2702.

Fakhri, S., Tomas, M., Capanoglu, E., Hussain, Y., Abbaszadeh, F., Lu, B., Khan, H. (2021). Antioxidant and anticancer potentials of edible flowers: where do we stand? *Critical Reviews in Food Science and*

Nutrition, *62*(31), 8589–8645. https://doi.org/10.1080/10408398.2021.1931022

Fangjie Li, Wenli Xie, Xianrui Ding, Kuo Xu & Xianjun Fu. (2024). Phytochemical and pharmacological properties of the genus Tamarix: a comprehensive review. *Archives of Pharmacal Research,* 47:5, 410–441.

Faustino, M. V., Faustino, M. A. F., & Pinto, D. C. G. A. (2019). Halophytic Grasses, a New Source of Nutraceuticals? A Review on Their Secondary Metabolites and Biological Activities. *International Journal of Molecular Sciences*, *20*(5), 1067. https://doi.org/10.3390/ijms20051067

Flowers, T.J. and Colmer, T.D. (2008). Salinity Tolerance in Halophytes. New Phytologist, 179, 945-963. http://dx.doi.org/10.1111/j.1469-8137.2008.02531.x

Flowers, T.J. and Muscolo, A. (2015) Halophytes in a Changing World. AoB Plants, 7, 1–5. https://doi.org/10.1093/aobpla/plv020

Fredsgaard, M.; Kaniki, S.E.K.; Antonopoulou, I.; Chaturvedi, T.; Thomsen, M.H. (2023), Phenolic compounds in Salicornia spp. and their potential therapeutic effects on H1N1, HBV, HCV, and HIV: A review. *Mol. 28*, 5312. [Google Scholar]

Gavra, C. (2015). Study regarding the halophilous vegetation of the Crişurilor Plain (North Western Romania). *Analele Universității din Oradea, Fascicula: Ecotoxicologie, Zootehnie şi Tehnologii de Industrie Alimentară, XIV*/A, 339–349.

Ghanem A.F.M., Mohamed E., Kasem A.M.M.A., El-Ghamery A.A. (2021). Differential salt tolerance strategies in three halophytes from the same ecological habitat: augmentation of antioxidant enzymes and compounds, *Plants,* 10 1100, https://doi.org/10.3390/plants10061100

Gheraissa, N., Chemsa, A. E., Cherrada, N., Benamor, B., Erol, E., Elsharkawy, E. R., … Atoki, A. V. (2024). Exploring the phytochemical and biological properties of *Salsola foetida*: a promising wild plant from Southeastern Algeria. *International Journal of Food Properties*, *27*(1), 584–601. https://doi.org/10.1080/10942912.2024.2339248

Gourguillon L, Cattuzzato L, Lavaud C, Lobstein (2016). Biological properties and phytochemical analysis of the halophyte *Armeria maritima* Willd. (Plumbaginaceae), *A Planta Med*, 82(S 01): S1-S381; DOI: https://doi.org/10.1055/s-0036-1596467

Grigore, M., Arora, J., Joshi, A. (2025). *Sustainable Utilisation and Bioengineering of Halophytes*, Ed. Springer, ISBN: 978-981-97-9818-6

Grigore, M.N. (2008). *Halofitotaxonomia. Lista plantelor de sărătură din România*. Iaşi: Ed. Pim.

Hameed, A., Hussain, S., Rasheed, A., Ahmed, M. Z., & Abbas, S. (2024). Exploring the Potentials of Halophytes in Addressing Climate Change-Related Issues: A Synthesis of Their Biological, Environmental, and Socioeconomic Aspects. *World*, *5*(1), 36–57. https://doi.org/10.3390/world5010003

Hameed, M., Ashraf, M., Ahmad, M. S. A., & Naz, N. (2010). Structural and functional adaptations in plants for salinity tolerance. *Plant adaptation and phytoremediation*, 151–170.

Hassani, A., Azapagic, A. & Shokri (2021). N. Global predictions of primary soil salinization under changing climate in the 21st century. *Nat Commun* 12, 6663. https://doi.org/10.1038/s41467-021-26907-3

Herbert, E. R., P. Boon, A. J. Burgin, S. C. Neubauer, R. B. Franklin, M. Ardón, K. N. Hopfensperger, L. P. M. Lamers, and P. Gell. (2015). A global perspective on wetland salinization: ecological consequences of a growing threat to freshwater wetlands. *Ecosphere* *6*(10):206. http://dx.doi.org/10.1890/ES14-00534.1

Hulkko L.S.S., R.M. Rocha, R. Trentin, M. Fredsgaard, T. Chaturvedi, L. Custódio, M.H. Thomsen (2023). Bioactive extracts from *Salicornia ramosissima* J. Woods biorefinery as a source of ingredients for high-value industries, *Plants*, 12 p. 1251, 10.3390/plants12061251

Hulkko L.S.S., T. Chaturvedi, M.H. Thomsen (2022). Extraction and quantification of chlorophylls, carotenoids, phenolic compounds, and vitamins from halophyte biomasses, Applied Sci, 12 p. 840, https://doi.org/10.3390/app12020840

Ivanishev, V.V. (2021). New research directions in enhancing plant salt tolerance, *Izv. Tul. Gos. Univ.,* vol. 2, 48.

Ivanova A, Nechev J, Tsvetkova I, Stefanov K, Popov S. (2009). Chemical composition of the halophyte plant Stachys maritima Gouan from the Bulgarian Black Sea coast. *Nat Prod Res. 23*(5):448–54, https://doi.org/10.1080/14786410802048027

Jaiswal A.K., Yasheshwar Salar, Shamim Yadav, Mansi Aggarwal, Shalini, Ekbbal, R., Gaurav (2024). Multitargeted therapeutic exploration of Tamarix gallica flowers for anti-ulcer activity and associated complications. *Journal of Ayurveda and Integrative Medicine, 15*(4), 100947

Jia, J., Cui, X., Wu, J., Wang, J., & Wang, G. (2011). Physiological and biochemical responses of halophyte Kalidium foliatum to salt stress. *African Journal of Biotechnology*, *10*(55), 11468–11476.

Kafi, M., & Khan, M. A. (Eds.). (2008). *Crop and forage production using saline waters*. Daya Books.

Karkanis, A., Polyzos, N., Kompocholi, M., Petropoulos, S.A. (2022). Rock Samphire, a Candidate Crop for Saline Agriculture: Cropping Practices, Chemical Composition and Health Effects. *J. Appl. Sci. 12*, 737. [Google Scholar]

Karker, M., Oueslati, S., Falleh, H., Msaada, K., Legault, J., Abdelly, C., Ksouri, R. (2023). Phytochemical investigation, antioxidant, anti-inflammatory and cytotoxic activities of Tunisian medicinal *Tamarix africana Poir*. *International Journal of Environmental Health Research*, *34*(5), 2366–2377. https://doi.org/10.1080/09603123.2023.2249424

Katel, S., Yadav, S. P. S., Oli, S., Adhikari, R., & Shreeya, S. (2023). Exploring the potential of Salicornia: A halophyte's impact on Agriculture, the Environment, and the Economy. *Peruvian Journal of Agronomy*, *7*(3), 220–238. https://doi.org/10.21704/pja.v7i3.1991

Khaled, M., Ouache, R., Pale, P., & Harkat, H. (2024). Phytochemical Profiles and Biological Activities of *Frankenia* Species: A Review. *Molecules*, *29*(5), 980. https://doi.org/10.3390/molecules29050980

Kim, E.Y. Lee, P.F. Hillman, J. Ko, I. Yang, S.J. Nam, (2021). Chemical structure and biological activities of secondary metabolites from *Salicornia europaea* L. Molecules https://doi.org/10.3390/molecules 26082252

Kim, S., Lee, E.-Y., Hillman, P. F., Ko, J., Yang, I., & Nam, S.-J. (2021). Chemical Structure and Biological Activities of Secondary Metabolites from *Salicornia europaea* L. *Molecules*, *26*(8), 2252. https://doi.org/10.3390/molecules26082252

Kraouia, M., Nartea, A., Maoloni, A., Osimani, A., Garofalo, C., Fanesi, B., Ismaiel, L., Aquilanti, L., & Pacetti, D. (2023). Sea Fennel (*Crithmum maritimum* L.) as an Emerging Crop for the Manufacturing of Innovative Foods and Nutraceuticals. *Molecules*, *28*(12), 4741. https://doi.org/10.3390/molecules28124741

Kussmann, M., Cunha, D.H.A., Berciano, S. (2023). Bioactive compounds for human and planetary health. Front. *Nutr. 10*, 1193848. [Google Scholar]

Latruffe, L. (2010). Competitiveness, Productivity and Efficiency in the Agricultural and Agri-Food Sectors, OECD Food, Agriculture and Fisheries Working Papers, No. 30, OECD Publishing. http://dx.doi.org/10.1787/5km91nkdt6d6-en

Lemoine, C., Rodrigues, M. J., Dauvergne, X., Cérantola, S., Custódio, L., & Magné, C. (2024). A Characterization of Biological Activities and Bioactive Phenolics from the Non-Volatile Fraction of the Edible and Medicinal Halophyte Sea Fennel (*Crithmum maritimum* L.). *Foods*, *13*(9), 1294. https://doi.org/10.3390/foods13091294.

Li, F., Xie, W., Ding, X. (2024). Phytochemical and pharmacological properties of the genus *Tamarix*: a comprehensive review. *Arch. Pharm. Res.* 47, 410–441 https://doi.org/10.1007/s12272-024-01498-x

Limongelli F., Crupi P., Clodoveo M.L, Corbo F, Muraglia M. (2022). Overview of the polyphenols in *Salicornia*: from recovery to health-promoting effect, Molecules, 27 p. 7954, 10.3390/molecules27227954

Loconsole D, Cristiano G., B. De Lucia (2019). Glassworts: from wild salt marsh species to sustainable edible crops. *Agriculture, 9* p. 14, 10.3390/agriculture9010014

Lombardi, T., Ventura, I., & Bertacchi, A. (2023). Floristic Inventory of Ethnobotanically Important Halophytes of North-Western Mediterranean Coastal Brackish Areas, Tuscany, Italy. *Agronomy*, *13*(3), 615. https://doi.org/10.3390/agronomy13030615

Lopes M. , Roque M.J. , C. Cavaleiro, F. Ramos (2021). Nutrient value of *Salicornia ramosissima*-A green extraction process for mineral analysis, J. Food Comp. Anal., 104 Article 104135, 10.1016/j.jfca.2021.104135

Lopes M. , Silva A.S. , Séndon R., L. Barbosa-Pereira, C. Cavaleiro, F. Ramos (2023). Towards the sustainable exploitation of salt-tolerant plants: nutritional characterisation, phenolics composition, and potential contaminants analysis of *Salicornia ramosissima* and *Sarcocornia perennis alpine, Molecules, 28*. 2726, 10.3390/molecules28062726

Lopes M., Sanches-Silva A., Castilho M., Cavaleiro C., F. Ramos (2023). Halophytes as source of bioactive phenolic compounds and their potential applications, Crit. Rev. Food. Sc. Nutr., 63 pp. 1078–1101, 10.1080/10408398.2021.1959295

Lopes, M., Sanches-Silva, A., Castilho, M., Cavaleiro, C., & Ramos, F. (2021). Halophytes as source of bioactive phenolic compounds and their potential applications. *Critical Reviews in Food Science and Nutrition*, *63*(8), 1078–1101. https://doi.org/10.1080/10408398.2021.1959295

Markovskaya, E.F., Gulyaeva, E.N. & Galibina, N.A. (2024). Carbohydrate Status of Halophytes in the Littoral of the White Sea. *Russ J. Plant Physiol* 71, 170 https://doi.org/10.1134/S1021443724607596

Medini, F., Ksouri, R. (2018). Antimicrobial Capacities of the Medicinal Halophyte Plants. In: Mérillon, JM., Riviere, C. (eds), Natural Antimicrobial Agents. Sustainable Development and Biodiversity, vol 19. Springer, Cham. https://doi.org/10.1007/978-3-319-67045-4_11

Melo, C. F. D., Souza, A. F., Macedo Bezerra Filho, C., Andrade, R. F. D. S., Lima, M. A. B., Franco, L. O., Fernandes, J. G., & Campos-Takaki, G. M. (2024). Chemical Characterization and Biotechnological Potential of Bioactive Compounds in Salicornia neei Lag., Preprints. https://doi.org/10.20944/preprints202406.1265.v1

Musimba, N. K., Ndathi, A. J., Nyangito, M. M., & Mitaru, B. N. (2012). Farmers' preference and nutritive value of selected indigenous plant feed materials for cattle in drylands of south-eastern Kenya.

Nájar AM, Romero-Bernal M, Del Río C, Montaner J. A., (2023). Review on Polyphenols in *Salicornia ramosissima* with Special Emphasis on Their Beneficial Effects on Brain Ischemia. *Nutrients*;15(3):793. doi: https://doi.org/10.3390/nu15030793.

Nasernakhaei F, Zahraei M. (2021), *Halocnemum strobilaceum* (Pall.) M.Bieb.: a review of its botany, phytochemistry, pharmacology and ethnobotany. J. Med. *Plants, 20*(80):1–12 URL: http://jmp.ir/article-1-3201-en.html

Nazish, M., Zafar, M., Ahmad, M., Sultana, S. (2020). Halophyte Diversity in Pakistan. In: Grigore, MN. (eds) Handbook of Halophytes. Springer, Cham. https://doi.org/10.1007/978-3-030-17854-3_101-1

Oliveira, D., Dias, M. I., Barros, L., Custódio, L., & Oliveira, R. (2023). Antigenotoxic properties of the halophyte *Polygonum maritimum* L. highlight its potential to mitigate oxidative stress-related damage. *Scientific reports*, *13*(1), 3727. https://doi.org/10.1038/s41598-022-20402-5

Ozturk, M., Altay, V., Nazish, M., Ahmad, M., Zafar, M. (2023). Ethnic Aspects of Halophytes and Importance in the Economy. In: Halophyte Plant Diversity and

Public Health. Springer, Cham. https://doi.org/10.1007/978-3-031-21944-3_4

Panagos, P., Van Liedekerke, M., Borrelli, P., Köninger, J., Ballabio, C., Orgiazzi, A., Lugato, E., Liakos, L., Hervas, J., Jones, A. Montanarella, L. (2022). European Soil Data Centre 2.0: Soil data and knowledge in support of the EU policies, European Journal of Soil Science, 73(6), e13315. DOI: https://doi.org/10.1111/ejss.13315

Piatti, D., Angeloni, S., Caprioli, G., Maggi, F., Ricciutelli, M., Arnoldi, L., Sagratini, G. (2021). Sea Fennel (*Crithmum maritimum* L.) A Promising Biosaline Crop. Extraction, Purification and Chemical Characterization of Polar Extracts. Biol. Life Sci. Forum., 11, 61. [Google Scholar]

Purushothaman R, Vishnuram G, Ramanathan T. (2024). Fractionation and identification of bioactive compounds from a salt marsh plant *Sesuvium portulacastrum* (L.) and its antioxidant activity. *Nat Prod Res.* Apr 10:1-4. doi:https://doi.org/10.1080/14786419.2024.2338812

Qasim M., Abideen, Z., Adnan, M. Y., Gulzar, S., Gul, B., Rasheed, M., Khan, M. A. (2017). Antioxidant properties, phenolic composition, bioactive compounds and nutritive value of medicinal halophytes commonly used as herbal teas, *South African Journal of Botany*, vol. 110, no. Complete, pp. 240–250

Rahmani, R., Arbi, K.E., Aydi, S.S. et al. (2022). Biochemical composition and biological activities of *Salicornia europaea* L. from southern Tunisia. *Food Measure* 16, 4833–4846. https://doi.org/10.1007/s11694-022-01574-0

Renna, M., Gonnella, M. (2021). Ethnobotany, Nutritional Traits, and Healthy Properties of Some Halophytes Used as Greens in the Mediterranean Basin. In: Grigore, MN. (eds), Handbook of Halophytes. Springer, Cham. https://doi.org/10.1007/978-3-030-57635-6_100

Rhee, M.H., & Park, H.J. (2009). Salicornia herbaceae: botanical, chemical and pharmacological review of halophyte marsh plant. *Journal of Medicinal Plants Research, 3*, 548-555.

Roberto, P.V., Surget, G., Lann, K.L., Mira, S., Tarasco, M., Guerard, F. (2021). Antioxidant, Mineralogenic and Osteogenic Activities of Spartina alterniflora and Salicornia fragilis Extracts Rich in Polyphenols. Sec F. Chem., 8. [Google Scholar]

Rodrigues Maria João, Matkowski Adam, Ślusarczyk Sylwester, Magné Christian, Poleze Thatyana, Catarina Pereira, Luísa Custódio, (2018). Sea knotgrass (*Polygonum maritimum* L.) as a potential source of innovative industrial products for skincare applications, Industrial Crops and Products, Volume 128, Pages 391-398, ISSN 0926-6690, https://doi.org/10.1016/j.indcrop.2018.11.038.

Rozentsvet, O.A., Nesterov, V.N., Kosobryukhov, A.A., Bogdanova, E.S., and Rozenberg, G.S. (2021). Physiological and biochemical determinants of halophyte adaptive strategies, *Russ. J. Ecol.*, vol. 52, p. 27. https://doi.org/10.1134/S1067413621010124

Saleem, H., Khurshid, U., Sarfraz, M., Tousif, M.I., Alamri, A., Anwar, S., Alamri, A., Ahmad, I., Abdallah, H.H., Mahomoodally, F.M., Ahemad, N. (2021). A comprehensive phytochemical, biological, toxicological and molecular docking evaluation of Suaeda fruticosa (L.) Forssk.: An edible halophyte medicinal plant. Food Chem Toxicol. 154:112348. doi: https://doi.org/10.1016/j.fct.2021.112348

Saleh, I.A., Usman, K., Abu-Dieyeh, M.H. (2021). Halophytes as Important Sources of Antioxidants and Anti-Cholinesterase Compounds. In: Grigore, MN. (eds) Handbook of Halophytes. Springer, Cham. https://doi.org/10.1007/978-3-030-57635-6_79

Santos, J., Al-Azzawi, M., Aronson, J.A., and Flowers, T.J., (2016), eHALOPH: A database of salt-tolerant plants: Helping put halophytes to work, *Plant Cell Physiol.,* vol. 57, p. e10. https://doi.org/10.1093/pcp/pcv155

Shahid, M.A., Sarkhosh, A., Khan, N., Balal, R.M., Ali, S., Rossi, L., Gomez, C., Mattson, N., Nasim, W., and García-Sánchez F. (2020). Insights into physiological and biochemical impacts of salt stress on plant growth and development, *Agronomy,* vol. 10, p. 938. https://doi.org/10.3390/agronomy10070938

Sharma Rita, Wungrampha Silas, Singh Vinay, Pareek Ashwani, Sharma Manoj K. (2016). Halophytes As Bioenergy Crops, Frontiers in Plant Science 7, https://www.frontiersin.org/journals/plant-science/articles/10.3389/fpls.2016.01372

Souid, A., Della Croce, C.M., Pozzo, L., Ciardi, M., Giorgetti, L., Gervasi, P.G., Abdelly, C., Magné, C., Ben Hamed, K., Longo, V. (2020). Antioxidant Properties and Hepatoprotective Effect of the Edible Halophyte *Crithmum maritimum* L. against Carbon Tetrachloride-Induced Liver Injury in Rats. Eur. Food Res. Technol. 246, 1393–1403. [Google Scholar]

Srivarathan, S., Addepalli, R., Adiamo, O. Q., Kodagoda, G. K., Phan, A. D. T., Wright, O. R. L., Sultanbawa, Y., Osborne, S., & Netzel, M. E. (2023). Edible Halophytes with Functional Properties: In Vitro Protein Digestibility and Bioaccessibility and Intestinal Absorption of Minerals and Trace Elements from Australian Indigenous Halophytes. *Molecules*, *28*(10), 4004. https://doi.org/10.3390/molecules28104004

Subramaniam, S., Sivasubramanian, A. (2015). Tradition to therapeutics: Sacrificial medicinal grasses *Desmostachya bipinnata* and *Imperata cylindrica* of India. *Boletín Latinoamericano y del Caribe de Plantas Medicinales y Aromáticas*, *14*(3), 156-170.

Sudhanshu S. Behera & Ramachandran, S. (2021). Potential uses of halophytes for biofuel production: opportunities and challenges, Sustainable Biofuels, Page: 425–448, DOI10.1016/b978-0-12-820297-5.00015-3

Svanberg, I., & Egisson, S. (2012). Edible wild plant use in the Faroe Islands and Iceland. *Acta Societatis Botanicorum Poloniae*, *81*(4).

Todorović, M., Zlatić, N., Bojović, B., and Kanjevac, M., (2022) Biological properties of selected *Amaranthaceae* halophytic species: A review, *Braz. J. Pharm. Sci.,* vol. 58, e21229 https://doi.org/10.1590/s2175-97902022e21229

Torres, M., Dessaux, Y., & Llamas, I. (2019). Saline Environments as a Source of Potential Quorum Sensing Disruptors to Control Bacterial Infections: A Review. *Marine drugs*, *17*(3), 191. https://doi.org/10.3390/md17030191

Toth G, Adhikari K, Varallyay Gy, Toth T, Bodis K, Stolbovoy V. (2008). Updated map of salt affected soils in the European Union. in: Toth, G., Montanarella, L. and Rusco, E. (eds.) Threats to Soil Quality in Europe EUR 23438 EN, Office for Official Publications of the European Communities; Luxembourg, p 65-77

Vengosh A. (2003). Salinization and Saline Environments, *Treatise on Geochemistry*, 9-9, pp. 1-35. DOI10.1016/b0-08-043751-6/09051-4

Zakirova, R.P., Khidyrova, N.K. & Gusakova, S.D. (2024). Lipids, Lipophilic Components of Halophytes of the Flora of Uzbekistan and Their Biological Activity. *Russ J Plant Physiol* 71, 129 https://doi.org/10.1134/S102144372460689X

Zhang, Y., Xu, H., Chen, H., Wang, F., & Huai, H. (2014). Diversity of wetland plants used traditionally in China: a literature review. *Journal of Ethnobiology and Ethnomedicine*, *10*, 1-19.