# Chapter 4
# Ethnic Aspects of Halophytes and Importance in the Economy

## 4.1 Ethnic Aspects

Halophytes include plant species that are adapted to live especially in saline soils. About 955 million hectors of land are salt-affected worldwide and the Southwestern Asian deserts constitute the most part of this land. Nearly 30% of the semi-arid irrigated areas of Asia are facing salinization. Afghanistan, Bahrain, Iran, Iraq, Jordan, Kuwait, Lebanon, Oman, Pakistan, Palestine, Qatar, Saudi Arabia, and Yemen are mostly arid countries having large sandy and gravel deserts. Some parts of Asia are below sea level due to continental rifting, like the Dead Sea which lies between Jordan and Israel. Anatolian Peninsula is located between the Mediterranean and the Black Sea, while Arabian Peninsula is located between the Persian Gulf and the Red Sea. Gravel and sandy plains cover the Arabian Peninsula in the Southwest. Rubal Khali is also located here, which is included among the world's large sand deserts. Iran's central plateau has large saline areas. Zagros mountainous range in Iran is an arid area, divided into the salt desert (Dasht-e-Kavir) and Dasht-e-Loot. Umma's Samim is the large salt inland plain located in the western part of Oman. Most of the plain areas in Asia receive less than 400 mm of precipitation in a year. Some regions in Southwest Asia have insufficient resources of water. The Euphrates and Tigris rivers flow through Syria, Iraq, and Turkiye and are considered critical for the agriculture in the area. Most Asian deserts have large saline areas with salt flats. The information on the accurate identification of salt-tolerant plants and their potential medicinal and non-medicinal utilization and other economic benefits is very weak and scattered in most regions of Asia. This information is necessary for the research on rangeland management, biosaline agriculture, coastal management and saline, and arid habitat restoration.

 
M. Ozturk et al., *Halophyte Plant Diversity and Public Health*,
https://doi.org/10.1007/978-3-031-21944-3_4

Saline habitats are regarded as one of the most fragile ecosystems. Many floristic, ecological, and ecophysiological studies have been carried out on these habitats by different workers. In addition to these studies, lately some initiative activities have been started emphasizing their sustainable use, management as well as importance of these sensitive habitats. In accordance with this aim agriculture, agroforestry and eco-tourism have started to come to the forefront. Although these habitats seem harsh for alternative agriculture, the possible uses and potential evaluations of halophytes, the characteristic natural plants of these habitats, allow them to provide different ecosystem services (Yensen 2006; Luković et al. 2021). Among these ecosystem services, supply, regulatory, and cultural services top the list. In supply services, halophytes are considered as an alternative potential for genetic resources of medicinal plants, food and/or vegetables, animal feed, biofuel and fuelwood, lumber, fiber, and for ornamental flowers. Regulatory services refer to the significant benefits halophytes and saline habitats provide such as climate regulation, coastal reclamation and protection, land reclamation and landscaping, carbon sequestration, biodiversity preservation, honey production, bioremediation or phytoremediation, pollination and pest control. Cultural services, on the other hand, are based on the evaluation of these ecosystems in terms of alternative potential areas these are of recreational value and have aesthetic sides as well that they provide to human beings (Dajić Stevanović et al. 2019; Luković et al. 2021; Radulovich and Umanzor 2021).

## 4.2 Economic Significance

Halophytes are of great importance for restoration of saline and degraded lands. They have a potential for biomass production for renewable energy, as cash crops, for medicinal uses, as fodder, for $CO_2$ sequestration, and in building materials. In arid and semi-arid zones, mostly vegetation is sparse due to extreme and unpredictable temperature ranges but the potential of medicinal plants in these areas has an economic and social potential. Most of these areas are unexploited because of a lack of water for agriculture. The economic potential of saline vegetation is greatly imperative as it reduces the loss caused by the water and soil salinization.

In view of their ecological abilities, halophytes thrive well on saline soils. These plants are also very important economically (Aronsen 1989; Ahmad et al. 2021). Some halophytes are consumed as food, used as medicine and feed, which reveals their great potential (Aronsen 1989; Ahmad et al. 2021). However, these natural resources are decreasing gradually, and some representative species have reached to the point of extinction, the reason being population pollution which have tremendous anthropogenic impacts. The halophytes have been neglected for a long time as natural resources (Ahmad et al. 2021). Their utilization as food, fodder and fuelwood have been reported in most regions of Asia (Rozema and Flowers 2008; Ozturk et al. 2014, 2016, 2019a). Their use as medicinal plants has been acknowledged in many research papers published in various parts of Asia together with their healing potential (Ahmad et al. 2014; Nadembega et al. 2011; Malik et al. 2021; Ozturk et al. 2021a, 2022). Ghazanfar (1995) in his book on Middle East medicinal plants has reported different beneficial uses of halophytes. She has mentioned that *Phragmites* and *Typha* species are useful for making boats, mats and thatching, sa well as the medicinal uses of halophytes by native people as a support towards their regional socioeconomic conditions. Halophytes can be cultivated as energy crops, fodder, and food crops on unused salinized lands, thereby resting them for productive purposes by planting halophytes (Boyko and Boyko 1964; Ozturk et al. 2014, 2016).

### *4.2.1 Halophytes as a Source of Medicinal Plants*

Ethnobotanical assessments of medicinal plants provide knowledge about their traditional uses, conservation, indigenous communities, and the necessity for the herbal drug development (Heinrich and Gibbons 2001; Vitalini et al. 2013; Altay et al. 2015a, b; Malik et al. 2021; Ozturk et al. 2021a, 2022). These surveys are crucial to enlighten the important plant species, mainly for developing new crude drugs (Cox 2000; Leonti et al. 2002; Ozturk et al. 2017a; Pleskanovskaya et al. 2019; Masoodi et al. 2020). Indigenous knowledge has been held by the traditional societies as a fundamental to their health and social interests (Cotton 1996; Getahun 1976; Malik et al. 2021). Moreover, the ethnomedicinal investigations support the communities in sociocultural and socioeconomic contexts, being important for the conservation of global plant heritages (Sanz-Biset et al. 2009; Younessi-Hamzekhanlu et al. 2020; Malik et al. 2021; Ozturk et al. 2021a, 2022).

Several plants with great therapeutic potential have been broadly exploited in different regions of the world. Ethnic knowledge about medicinal plants confirms their therapeutic activities against many diseases (Balunas and Kinghorn 2005; Nadembega et al. 2011; Malik et al. 2021). Several ailments have been cured by plant-based medications in arid regions (Yaseen et al. 2015). Most people in rural areas in the developing world do not have access to drugs, therefore, they use traditional herbal medicines to cure diseases (Calixto 2005; Malik et al. 2021; Ozturk et al. 2021a, 2022). Almost 4 billion humans in developing countries are consistently exploiting the therapeutic potential of plant species. The medicinally valuable plants from the wild have been utilized since ancient times by different ethnic groups in different areas of the world (Ahmad et al. 2020; Malik et al. 2021; Ozturk et al. 2021a, 2022). Several pharmacological and ethnobotanical studies have been carried out on the preference and utilization of plants by several ethnic groups globally (Jeruto et al. 2008; Walter et al. 2011; Altay and Çelik 2011; Altay and Karahan 2012; Ozturk et al. 2012; Altay et al. 2015a; Altay and Karahan 2017; Imanberdieva et al. 2018a, b; Ozturk et al. 2017b, 2017c, 2018a, b, c, d, e, f, g; Letchamo et al. 2018; Malik et al. 2021; Ozturk et al. 2021a, 2022).

The medicinal plants are still recognized as primarily health care in underdeveloped communities because of their cultural preferences while in developed countries these give an alternative for health care (Svarstad and Dhillion 2000; Malik et al. 2021). The report shows that 70–80% of the people depend on the ethnobotanical and ethno-medicinal uses of medicinal plants in the world (Muthu et al. 2006). A rough estimate is that 35,000–75,000 medicinal plants provide the basis for health care systems worldwide (Farnsworth and Soejarto 1991). Herbal pharmaceuticals play significant role in the cure of number of human ailments (Rehecho et al. 2011). The ethnobotanical studies have gained significant attention among the scientific communities concerning medicinal plants utilization (Tripathi et al. 2017). A number of ethnomedicinal surveys have been converted into conservation and health care programs (Quamar and Bera 2014). The ways of plant utilization are diverse in various communities around the globe (Abebe et al. 2003; Kassaye et al. 2006; Malik et al. 2021; Ozturk et al. 2021a, 2022).

Many drugs available on the market are synthetic analogs of isolated compounds from plants (Amjad et al. 2017). Traditional phytotherapy is still popularly practiced in many rural communities and handed down from one generation to the next in spite of the variety of clinical agents developed by the pharmaceutical industries (Abbasi et al. 2010). The extensive cultural value studies and their systematic documentation have been placed on high priority to highlight the pharmaceutical potential of plants and to explore their new properties during the past decades. The traditional studies on the plants plays important role in farming, nutraceutical and pharmaceutical industries (Cox 2000; Idrisi et al. 2010). The interactions of the number of chemical constituents in medicinal plants cause harmony and synergy in the human body and heal the body tissues progressively. The drug industries have developed medicines using isolated chemical compounds from medicinal plants which have physiological responses (Shinwari and Gilani 2003). To ascertain the therapeutic uses of plant-based drugs, it is necessary to conduct the pharmacological and pharmacognostic studies and explore their uses (Ahmad et al. 2009).

The increasing research interest in halophytes reflects their importance as valuable resources as a cash crop (Khan et al. 2009). The medicinal uses of halophytes have been recommended for the increasing population since times (Rozema and Flowers 2008). An increasing population in Asia is facing the challenges of food security and increase in growth is exacerbated by fluctuations in climate change. The high temperature, variable precipitation rates, and increase in salinity are major impacts of climate change (Flowers and Muscolo 2015). The fresh water and land of good quality are always used for the cultivation of crops and food but the real potential lies in the reclamation saline lands for cultivation of cash crop halophytes. Out of 6.5 million hectares of salt-affected land, two million hectares are moderately affected, which can be evaluated for growing “halophytes” as these areas present diverse environmental conditions and halophytes growing on such habitats points out to their ability to tolerate different salts (Song et al. 2008).

Most of the saline areas in Asia are underdeveloped and the rural communities depend on native flora and traditional therapeutics for health care. The ethnomedicinal significance of halophytes stresses the fact that the halophytes have potential as a valuable resource (Khan et al. 2009). These plants give many alternatives in various countries (Khan and Duke 2001). According to Koyro et al. (2011), these are of great ecological, industrial and agricultural value. Indigenous knowledge is decreasing day by day due to rapid land degradation, modern cultural exposure, urban development, and war effects much the rural communities, the traditional knowledge about medicinal plants survives due to its transformation from one generation to the next generation (Figueiredo et al. 1993; Kayani et al. 2015; Manandhar 1995; Tabuti et al. 2003). The domestication of salt-tolerant plant species is of great significance. The salinity has not threatened the food availability for humans. The continuous increase in population and climate change at the global level are predicting a decrease of resources in the next century which will push us towards the need for new avenues for food availability and health security.

Asian countries have a variety of climate zones and topographic regions and are endowed with a diversity of halophytic medicinal plants. The parochial knowledge and herbal utilization reflect the different natural resources present in different countries. Ahmad and Waseem (2006) have reported that older people utilize more the traditional knowledge about medicinal plant species than younger people. The cultivation and conservation of such natural resources can uplift the socioeconomic conditions of these communities in different countries (Qasim et al. 2010). In countries such as Afghanistan, Bangladesh, India, and Pakistan, the native medicinal flora is facing the depletion threat due to biotic interference, less rainfall, cutting of vegetation for fuel and fodder purposes, lower water table, high deforestation, accidental fires, and overgrazing. In some Asian countries, medicinal halophytes are declining because of over exploitation. Ashfaq et al. (2019) have reported the medicinal halophytes significance for primary health care among the rural communities.

According to Qureshi et al. (2007), 84% of population in Pakistan depends on traditional medicines for the cure of various health disorders. Previous surveys have described that about 60,000 traditional healers are involved in this practice in remote areas and utilize medicinal plants against several ailments (Rehman et al. 2017). Medicinal halophytes are used against genito-urinary disorders, pain, toothache, digestion problems, fever, and in respiratory and skin diseases (Qasim et al. 2010). Ghazanfar (1994) in her book on medicinal plants of Arabian Peninsula has reported several medicinal uses of halophytes. She mentions that *Aerva javanica, Portulaca oleracea*, and *Vernonia cinerea* are used against skin diseases and stings; *Artemesia* spp. as antihelminthic, *Salvadora persica* as tooth cleanser, *Centella asiatica* and *Apium graveolens* as diuretics, *Teucrium* spp. against digestive disorders; *Phoenix dactylifera* and *Cocos nucifera* are reported to show multiple beneficial uses, these are known plant species since ancient times.

The indigenous herbal medicines rely on the properties of local medicinal plants (Bartam 1995). The traditional Unani medicinal system is practiced popularly among the rural population of Asia (especially in Pakistan, India, and other Asian countries) (Obón et al. 2021). Unani medicinal system was adopted and documented by Muslim scholars in the magnificent period of Islamic civilization and they practiced it for many centuries in Asian countries (Khan et al. 2012). Examples of some medicinal halophytes used in this traditional medicine system are outlined below. In Iranian medicine, the leaves of *Atriplex leucoclada* are used as an emollient to treat cough and sore throat (Guerreiro 2018). In different parts of Pakistan, *Calotropis procera* in chest pain; *Cressa cretica* as expectorant; *Suaeda fruticosa* as diuretic, laxative and emetic; *Caesalpinia crista* in asthma, cough, headache and stomach upset; together with *Thespesia populnea* and some of the halophytes used in skin disorders (Rashid et al. 2000; Ksouri et al. 2012; Qasim et al. 2011). Also in Bahrain, *Cressa cretica* is used as anexpectorant; *Phragmites australis* in the treatment of rheumatism in Turkiye and Lebanon. In Lebanon, *Limbar crithmoides* is a well-known halophytes used as tonic (Priyashree et al. 2010; Rivera et al. 2012). The halophytes distributed in some countries representing east Mediterranean part of Asia, such as Turkiye, Syria, Lebanon, Palestine, and Jordan have been studied well in this connection and halophytes are mostly used in traditional folk medicine for urinary system disorders (Ozturk et al. 2014).

More than 100 medicinal halophytes are used in the treatment of various diseases in traditional Chinese medicine, and some of these are also used for commercial purposes (Kefu et al. 1995; Buhmann and Papenbrock 2013; Obón et al. 2021). Of these halophytes, *Nitraria tangutorum* leaves, fruits, and seeds are used as antiarrhythmic, antineuropathic, and antispasmodic agents to treat weaknesses in the spleen and stomach, including dyspepsia, neurasthenia, and common cold (Ksouri et al. 2012; Obón et al. 2021). The fruits of this plant have even been used in Northwest China to treat hypertension, abnormal menstrual bleeding and abdominal pain, and to support milk secretion during lactation (Ksouri et al. 2012; Obón et al. 2021).

Other oldest medical system in the world is Ayurvedic, which generally constitutes the widespread traditional health system applications in India (Ayush 2019; Obón et al. 2021). Extracts prepared from popular halophyte species belonging to the *Tamarix* genus in India are widely used in the Ayurvedic system for immunomodulatory and carminative (especially in children) purposes. The medicinal effect of these plants has been confirmed by clinical case studies as well (Buhmann and Papenbrock 2013). The extract obtained from *Salsola kali* is also used in liver complications (Kshirsagar et al. 2011).

### *4.2.2 Halophytes as a Source of Bioactive Compounds*

These plants are potential natural source which could serve as a source of various bioactive molecules and innovative drugs (Stanković et al. 2015; Dajić Stevanović et al. 2019; Luković et al. 2021). Several primary and secondary compounds in the bioactive forms such as natural vitamins, fatty acids, amino acids, flavonoids, alkaloids, terpenes, isoflavonoids, saponins, anthocyanins, and phenolic acids are found in these plants (Arya et al. 2019; Luković et al. 2021). This interesting group of plant resources can play an essential role in community health and safety (Lagos et al. 2015; Arya et al. 2019). Particularly, they may provide bioactivity compunds with potential nutraceutical features and necessary for the treatment of a disease and/or for people to lead a healthy lifestyle (Kalra 2003). These bioactive substances are generally known as functional enzymes, probiotics, proteins, saponins, phytosterols, phytic acids, peptides, isoflavones, and fibers (Stankovi et al. 2015; Jdey et al. 2017; Arya et al. 2019). The halophytes are characterized by bioactive compounds and various phytochemical profiles and often show many bioactivity properties such as antioxidant, antimicrobial, and anticancer (Stanković et al. 2015). Many researchers have reported that halophyte taxa specific to the families such as Chenopodiaceae, Fabaceae, Tamaricaceae, Amaranthaceae, Plantaginaceae, Juncaceae, Plumbaginaceae, and Acanthaceae have attracted attention as a source of bioactive compounds (Dajić Stevanović et al. 2019).

### *4.2.3 Halophytes and Nutritional Lipids*

The adequate optimal composition as well as content of lipids and other nutritive compounds in the seeds of some halophytes such as *Salicornia* species (especially *Salicornia europaea* and *Salicornia bigelovii*), *Suaeda salsa, Suaeda aralocaspica, Halocnemum strobilaceum* and *Nitraria sibirica* have revealed that these can be used as alternative oilseed sources (Geissler et al. 2013; Abideen et al. 2015; Ozturk et al. 2018g; Nanduri et al. 2019; Altay and Ozturk 2021). The seeds of species such as *Salicornia fruticosa* and *Kochia scoparia* have been reported to be the sources of fats and fat-soluble vitamins of good-quality edible oils (Geissler et al. 2013). Atia et al. (2019) and Ozturk et al. (2021b) have reported that *Portulaca oleracea*, a well-known food plant, is rich in omega-3 FA, while Nanduri et al. (2019) mention that Quinoa (*Chenopodium quinoa*), known as a promising pseudocereal, irrigated with salt water, contains high levels of unsaturated fatty acids, proteins, fiber, and minerals in terms of oleic and linoleic acids.

### *4.2.4 Halophytes as a Source of Food and Nutrition*

The conventional crops are difficult to grow in saline regions which could develop the gap between demand and supply of good quality food in saline regions. Halophytes are the potential source of nutrition, thereby securing the livelihood of people in saline areas (Ganesan et al. 2019). Despite all this information, the halophytes are considered as underutilized sources (Lieth and Hamdy 1999). They possess great significance for subsistence and can play big role in local cultural heritage. *Beta vulgaris* and *Phoenix dactylifera* are high salt-tolerant foods eaten by people in Asia. Leaf and stem of *Atriplex halimus, Portulaca oleracea, Sesuvium portulacastrum, Chenopodium album, Salicornia bigelovii, Suaeda maritima* and *Atriplex hortensis* have been and are consumed even now as vegetables and salads in many countries (Khan and Qaiser 2006; Ozturk et al. 2008, 2014, 2016, 2018g, 2021b; Altay and Ozturk 2021). *Suaeda fruticosa, Salicornia* spp., and *Halogeton* spp. are economically important halophyte taxa as the sources of high-quality edible oil

(Weber et al. 2007; Ozturk et al. 2018g; Altay and Ozturk 2021). Khan and Qaiser (2006) have provided a checklist of 410 salt-tolerant plants from Pakistan and reported significant economic uses of 274 salt-tolerant species. In Southwest Asia evaluation of halophytes as food is as follows: the Mediterranean and Arabian Gulf countries use over 10 taxa, as against the 40 taxa consumed in Afghanistan, Iran, Iraq, and Pakistan (Ozturk et al. 2019a). Halophytes' economic usage is one of the most advantageous options for saline soil and saline water economic utilization (Kokab and Ahmad 2010).

Although not widely used on a global scale, halophytes are generally used as food by local people, mainly as vegetables, salads, and pickles (Ozturk et al. 2019a, b, c, 2021a). Among these halophytes those worth mentioning are *Salicornia, Portulaca, Sesuvium, Sporobolus, Chenopodium,* and *Suaeda* genera (Ozturk et al. 2019a, 2021b; Altay and Ozturk 2021). The halophytes are at the same time most important candidates for future use both as fresh as well as processed food, due to their functional and health properties (Loconsole et al. 2019; Luković et al. 2021).

Some halophyte plants, such as date palm (especially fruits) have been domesticated and cultivated for thousands of years and are widely consumed as food. There are some halophyte taxa such as *Crithmum, Salicornia,* and *Portulaca*, which are collected from nature and consumed with great admiration in traditional cuisines, and some like *Suaeda* and/or *Arthrocnemum* are usually collected and consumed by localas in times of famine. Under all circumstances, the halophytes have started taking place as an alternative food source in gastronomic cuisine (Ríos et al. 2021).

The edible parts of *Sesuvium portulacastrum* (especially stem and leaves) are rich in minerals such as Ca, Fe, and carotene, suitable for vegetable consumption and traditionally consumed as a vegetable by local people in arid regions of India; the leaves of some *Salicornia* species, especially *Salicornia bigelovii*, are rich in omega-3 polyunsaturated fatty acids, making it advantageous to consume these plants as vegetables (Lokhande et al. 2009; Zerai et al. 2010; Bhat and Hakeem 2021).

The use of halophytes as food may be a potential commercial option for the agricultural sector, although only locally since most of the agricultural crops show low salt tolerance and these may become unnecessary in the future as the soil salinity increases with climate change. The plants from this interesting ecological group are regarded as nontraditional products, although not easily available on our dining table due to our established food preferences, their salt-tolerance may provide the potential for their use as human food in the future (Shrivastava and Kumar 2015; Bhat and Hakeem 2021; Ozturk et al. 2021b).

### *4.2.5 Halophytes as a Source of Animal Feed and Forage*

In arid and semi-arid areas, feed reserves are very important for livestock, which is one of the most important source of income for the localals who generally depend on the breeding of camels, sheep, goats and other herbivores. In these areas, halophyte plants are often preferred as natural feed reserves. The salt-tolerant characteristics of halophytes provide a potential for their use as livestock fodder in the future. Among these plants, *Atriplex* spp., *Nitraria retusa* and *Salsola* spp. are attracting much attention (Khattab 2007; El Shaer 2021). The species of genera *Salsola* and *Suaeda* generally flourish on saline habitats as well as under extreme climatic conditions, these can serve as a promising animal feed source. The species of these genera are of significant importance and many taxa can be used as animal fodder (Altay and Ozturk 2021).

A recently published study reports nearly 331 fodder halophyte taxa with distribution in Southwest Asia (Ozturk et al. 2019a). In the Arabian Gulf countries, *Haloxylon salicornicum, Convolvulus glomeratus, Blepharis ciliaris, Cleome brachycarpa, Senna italica, Tecomella undulata, Zaleya pentandra, Leptadenia pyrotechnica, Lycium shawii, Aerva javanica,* and *Aizoon canariense* are serving as a good fodder for camels, cattle, goats, and sheep as major halophyes, while *Halocnemum, Salsola, Suaeda, Sarcocornia, Haloxylon, Aeluropus,* and *Aellenia* are among the 20 taxa evaluated as animal feed in the Mediterranean part of Southwest Asia. In Afghanistan, Iran, Iraq, and Pakistan the number of halophytes used as animal feed exceeds 100 taxa (Ozturk et al. 2019a). Evaluation of necessary information on the ecological and ecophysiological status of halophytes naturally distributed in arid and semi-arid areas sheds light on the importance of the establishment of sustainable forage and livestock production in saline grassland habitats and develop appropriate management practices (Dajic Stevanovic et al. 2008; Luković et al. 2021). As an example, feeding with *Panicum turgidum* a halophyte is reported to have resulted in better meat quality in the livestock (Abideen et al. 2011). The quality of forage from halophytes varies a lot as it is affected by various factors such as palatability, feeding value, nutrient digestibility, nutrient composition, quantity of plant secondary metabolites, and voluntary animal feeding. The analysis of nutrient contents and chemical composition of the feed can be determined and the forage quality as well as suitability for cattle put forward (Duncan et al. 2000; Ahmad et al. 2021).

Biomass production and nutritional values of halophytes in arid and semi-arid areas may change from region to region, depending on the ecological conditions of the area, as well as from season to season (Le Houérou 1992; El Shaer 1997, 2021). This situation may lead to the variation in the flavor and nutritional values of existing halophytes (Le Houérou 1992; El Shaer 1997, 2021). Many studies report that many halophytic plants contain sufficient levels of crude protein and other essential nutrients to meet the nutritional requirements of animals under suitable climatic conditions (especially during the rainy seasons) (Kandil and El Shaer 1988; Arieli et al. 1989; Le Houérou 1992; Khan and Qaiser 2006; El Shaer 2010, 2021). Halophytes have potential animal feed properties due to the complementary crude proteins they contain, especially under arid conditions, as well as in times of famine. The species belonging to the genus *Atriplex* have been evaluated as an alternative feed source. Riasi et al. (2008) have emphasized that the amount of digestible "crude protein" associated with *Atriplex* may contain more crude protein than many other meadow plants. A similar study has been published by El-Hack et al. (2018). The halophytes can produce fodder for livestock, especially in the areas where livestock is very limited because of fodder shortage and is directly linked to human survival (Khan 2003, 2016). There is a preference for choosing different halophytic plant species by different animals. They prefer to consume different species of these plants. For example, *Alhagi maurorum* and *Atriplex leucoclada* are preferred by sheep and goats, while camels prefer to eat *Salicornia fruticosa* (Glenn et al. 1999; Ahmad et al. 2021).

### *4.2.6 Cash Crop Halophytes as Potential Genetic Resources*

Parallel to the global population growth, the problem of food demand is constantly increasing with a decrease in the agricultural lands. To overcome this problem, alternative/complementary plant species that can be included in existing agricultural systems are investigated. The halophytes have come to the forefront recently as edible wild plant species. These have emerged as a promising option very recently as a potential genetic resource (Ladeiro 2012; Molina et al. 2014; Corrêa et al. 2021). In fact, many uses have been proposed for these plants, including food and/or feed production as well as industrial raw materials and chemicals, for landscaping, plant breeding, and evaluation for health benefits (Koyro et al. 2011; Ventura et al. 2014; Petropoulos et al. 2018, 2019; Corrêa et al. 2021).

This special group of plants occupies a special place in ecological and ecophysiological terms. These can be used to save and rehabilitate lands that are currently uncultivated and will not generate income, as well as make important contributions to potentially sustainable farming systems, although on a small scale (Ventura and Sagi 2013; Corrêa et al. 2021). Some important abiotic factors such as salinity and drought pose great challenges to food security and sustainable agriculture (Murdiyarso 2000; Ahmad et al. 2021). On a global scale, these factors can cause a significant decrease in crop yields, as well as adversely affect food and animal populations (Ahmad et al. 2021). The fact that most of the cereals with high economic value are sensitive to salt, negatively affecting crop productivity, poses a major problem in terms of food safety (Ventura and Sagi 2013; Ahmad et al. 2021). Therefore, the high potential for survival of halophytes in saline habitats provides excellent opportunities for their cultivation as potential food and forage crops (Colmer et al. 2006; Ahmad et al. 2021). One of the potential strategies to ensure food security could be halophyte cultivation in arid and semi-arid regions (Ahmad et al. 2021). According to Koyro et al. (2013), introducing the concept of sustainable agriculture could be a good solution for future food crisis. The so-called "cash crop halophytes" can prevent the waste of limited freshwater resources and overcome the water reserves problems in crop growing. Many halophyte plant taxa possess a potential commercial value as "cash crops" (Lieth and Menzel 1999). The utilization of halophytes for industrial, ecological, or agricultural purposes is possible according to the data published today. Some halophytes are used as food even at present and some for medicinal purposes, some as forage, and oil seed crops in agronomic field trials (Li et al. 2019). Eisa et al. (2017) *Chenopodium quinoa* is accepted as an alternative cash crop worth growing in the salt-affected soils of Egypt and very promising results have been obtained in terms of quality of the produced seeds. Similarly *Aster tripolium* too is considered a potential candidate for biosaline agriculture as it shows improved salt tolerance through filtering excessive Na and Cl ions in lateral shoots as well as a positive response to elevated $CO_2$ through increasing photosynthetic rate and water use efficiency (Geissler et al. 2009). Currently, more research is needed to fine-tune all the requirements for sustainable production and rational use of halophytes as natural resources, the cultivation practices for such species are based on practices for related conventional crops (Corrêa et al. 2021).

### *4.2.7 Halophytes as a Source of Bioenergy*

These plants are of great significance as a source of bioenergy because salt tolerant crops can be given sea water which does not cause any reduction in seed yield and biomass (Ozturk et al. 2017d). Recently several halophytic plants have been identified having potential to produce large biomass on salt effected lands (Ventura et al. 2014). Xian-Zhao et al. (2012) mention about the halophytes whose use has been banned for the production of biofuel in China. *Atriplex, Saueda, Salicornia,* and *Distichlus* spp. are the halophytes that have high lignocellulose content. These can be evaluated for biofuel production as well as improve the soil quality and reduce the environmental footprint. The National Aeronautics and Space administration (NASA) have *Rhizospora mangle* and *Avicenia berminans* in green lab as a source of alternative energy (Bomani et al. 2011).

According to Ozturk et al. (2017d) and Bhat and Hakeem (2021), the use of green wealth "feedstock" for biofuel generation can only be made in practice if we can recognize better alternative plants, able to flourish in saline environs and must show least competition for conservative agricultural services. Halophytes have an incredible capacity to flourish in high saline environments. If these plants get adapted in such environments they can be an excellent option as "bioenergy" resource. Both oils extracted from the seeds and the "lignocellulosic biomass" from halophytes can be used for biofuel extraction. With the presence of high content of "lignocellulosic biomass" and their potential standing in high salt environments, halophytes are considered as an alternative and a valuable candidate for the production of biofuels.

The nonconventional plants or halophytes can produce two valuable harvests the seed oil and lignocellulosic biomass and straw to produce biofuel separately. These plants produce high oil yield, the oil containing a huge amount of long-chain fatty acids (Joshi et al. 2021). The oil yield and fatty acids composition varies in differing species. In the case of *Suaeda aralocaspica,* yield is more than 25% oil, as against *Suaeda acuminata* yield of only 14%. The *Crithmum maritimum* seeds contain up to 45% oil dominated by oleic acid, while *Salicornia brachiata* seeds contain 35% oil but it is dominated by linoleic acid. The oilseed halophyte oil production is reported to be potentially useful to produced biofuel, mainly biodiesel. The biodiesel is primarily composed of monoalkyl esters of long-chain fatty acids where their configuration provides reaction sites for the addition or cracking of the functional group to produce liquid fuel with miscellaneous features (Kinder and Rahmes 2009; Joshi et al. 2021).

The cultivation of halophytes for the production of biodiesel could be a reasonable option for sustainable use of saline lands, as these plants are well adapted to the salinity and can tolerate irrigation with saline water. *Salicornia bigelovii* is cultivated for biodiesel and oilseed production on farms in Mexico (Luković et al. 2021). *Aster tripolium* too is recognized as a potential cash crop halophyte, with higher content of triacylglycerol compounds in seeds than *Suaeda fruticosa* and *Chenopodium quinoa*. Different species of *Salicornia* are considered as potential new crops for biodiesel production, but there are some drawbacks such as a lower yield of biomass (Duarte et al. 2019; Luković et al. 2021). Many studies have enlightened the fact that the "fatty acid methyl ester" composition of oils produced from the plants growing on saline habitats is as good as the extraction of biodiesel from other plants (Abideen et al. 2012; Gul et al. 2013). Currently studies are continuing on the possible capacity under saline conditions and these has been identified to yield large amounts of precious metabolites, which possibly can be converted to produce oil as fuel (Hastilestari et al. 2013; Bhat and Hakeem 2021).

### *4.2.8 Halophytes as Landscaping and Ornamental Plants*

Ornamental plants used in gardening, landscaping and as cut flowers are products of high economic value on global scale (Altay 2012; Azadi et al. 2016; Kishi-Kaboshi et al. 2018; García-Caparrós and Lao 2018; García-Caparrós et al. 2021). Halophytes can be suggested as an environmentally and sustainable alternative choice for the restoration of urban and degraded areas (Ozturk et al. 2014; García-Caparrós et al. 2021). These plants have a high survival rate in different stressed habitats due to their ecological abilities (García-Caparrós et al. 2021). The intensity of anthropogenic activities is increasing as an increase in artificial structures such as industrial areas, urban areas, roads and buildings increases, and the idea that new healthy green areas with aesthetic qualities should be created as an urgent priority (Poortinga et al. 2011; García-Caparrós et al. 2021). Although the application of ornamental plants is considered a good alternative, especially in urban areas, it is necessary to have correct ecological information about the plant species to be planted (Ferrante et al. 2011; Farieri et al. 2016). In this sense, the evaluation of halophytes as ornamental plants can be very practical (Ferrante et al. 2011).

During the last three decades, the surface of salt marshes has got reduced because of the high anthropogenic pressures originating from agriculture and the high demand for tourist urban facilities (Litalien and Zeeb 2020). Despite all this, the implementation of local halophytes in these areas could be a promising alternative, maybe the introduction of biosaline agricultural approach with the aim of restoring biodiversity and productivity could be another environmentally sustainable choice (Daoud et al. 2016; García-Caparrós et al. 2021). The ornamentals used in the restoration of urban areas initially prefer because of their attractiveness, flower colors or fragrances. Unfortunately, the maintenance required for these plants is very costly, and irrigation with poor quality water damages both the sensitive and aesthetic values of these plants thereby not accepted as a sustainable environmental approach (Ferguson and Grattan 2005; Grahn and Stigsdotter 2010). Therefore, for urban areas restoration, use of halophytes can be considered an environmentally sustainable option (Miyamoto et al. 2001; Miyamoto and White 2002). Moreover, in the case of dry ecosystems, marginal lands, salt marshes and even urban areas the restoration of roads and roadsides is of particular importance among ecologists and government agencies (Celentano and Rousseau 2016; García-Caparrós et al. 2021).

The most common uses of ornamental plants include professional landscaping (especially in urban habitats), home gardening, and cut flowers (Altay et al. 2010a, 2010b; Osma et al. 2010; Dobres 2011; Eskin et al. 2012; Tarakçı et al. 2012; García-Caparrós et al. 2021). The native species in general are well adapted to stressed conditions. The increase in soil salinization and due to scarcity of freshwater, which is increasing day by day, take us towards the most viable solution, that is, the utilization of halophytes for landscaping (Ozturk et al. 2014). Cassaniti et al. (2013) points out that the ornamental use of halophytes is a must; they have provided an extensive list of different botanical families as well as species for their use in ornamental landscaping. Much work has been done lately on the halophytes in the east Mediterranean. Ozturk et al. (2014) have reported that *Ipomoea imperati, Salsola tetrandra*, *Halimione portulacoides, Inula crithmoides, Suaeda fruticose,* and *Arundo donax* can be used as ornamentals.

### *4.2.9 Halophytes and Climate Change Mitigation Potential*

Within the scope of the global warming scenario, it is estimated that the emergence of severe drought in many areas will cause the expansion of arid and semi-arid areas. As a result of these effects, these may cause an increase in freshwater scarcity and salinization of the existing lands. Over time, these may lead to a decrease in cultivated areas as well as the yield. This will endanger food security on a global scale (Wang et al. 2003; Imanberdieva et al. 2018b; Luković et al. 2021). Keeping this in view, the halophytes have potential to tolerate abiotic factors such as salinity and drought, can easily cope with the effects of global climate change. This situation offers a promising alternative as farming option for these plants in future. Moreover, United Nations Environment Program (UNEP) (1993) has suggested that the use of "Cash Crop Halophytes" and the ability of these plants to capture $CO_2$ could serve as a potential alternative natural resource to reduce the negative impacts on agriculture and the environment caused by global climate change (Caçador et al. 2002; Geissler et al. 2013; Luković et al. 2021). The vegetation of saline habitats is of great significance as it can prevent soil erosion, replenish sodic and saline soils which are imperative in the present global climate change scenario. In developed countries, there is a focus on policymaking and research on the crops that can grow well under limited resources. Mangroves and halophytes are looked upon as the alternative crops for the next generation because they can give sustainable yields under varying environments. *Suaeda fruticosa* is the best example of mitigation potential in changing climatic conditions because it can complete its life cycle under the salinity of 65 ds $m^{-1}$ (Wungrampha et al. 2019).

### *4.2.10 Halophytes as Carbon Sequestration Potential*

For C sequestration in arid and semi-arid regions a large-scale production of halophytes might be an attractive alternative. The reason being that salt-tolerant species can be grown on lands which is usually too saline and unfavorable for the production of most crops and trees. A high rate of productivity is being recorded from the salrt marshes and these areas are excellent sinks for C fixation. Their carbon sequestration capacity is higher than other wetland systems. They show good potential to sequester carbon continuously over thousands of years (Caçador et al. 2016).

Glenn et al. (1993, 1999) have studied halophytes as biomass crops used for the sequestration of 0.7 Gt C. The plants from this group play an important role similar to other plants in the environment by absorbing C from the air. Their ability in carbon sequestration can enrich the status of organic carbon in any infertile soil. These authors have also reported that some halophytes are proposed as promising candidates for carbon sequestration, referring to species of genera *Atriplex, Batis, Salicornia, Suaeda*, and *Sesuvium*. The studies conducted by ICAR-CSSRI research groups in India have reported many species with high potential for C sequestration such as *Populus deltoids* and *Eucalyptus tereticornis* (Chinchmalatpure et al. 2015).

### *4.2.11 Halophytes as Potential of Phytoremediation*

Halophytes have great potential for phytoremediation of heavy metals present in saline soils, the reason being their high tolerance toward heavy metals (Liang et al. 2017; Caparrós et al. 2022). Many researchers have conducted research on the halophytes as the potential for phytoremediation of heavy metals present in the soils, indicating the environmental significance of halophytes (Christofilopoulus et al. 2016; Santos et al. 2015; Caparrós et al. 2022). *Atriplex halimus* and *Tamarix africana* are well-known examples of halophytes' potential for phytoremediation (Manousaki and Kalogerakis 2009; Santos et al. 2017; Caparrós et al. 2022).

### 4.2.12 Halophytes: Potential Economic Resources as Cultural Values

The saline habitats represent a complex ecological and socioeconomic system. They create an environment for a huge number of plants and animals; also offering a multitude of services of cultural importance (Bingzhen et al. 2018). The halophyte vegetation has a potential to provide cultural services which humans try to get from other ecosystems such as recreation, tourism and aesthetic values, intellectual development, and spiritual enrichment together with social relations for specific interest groups. The cultural services of higher priority include the aesthetic value, recreation and tourism, cultural heritage, as well as social relations for specific interest groups (Everard et al. 2010) such as herbal tours for observing rare and endemic plants (botanical safari) and bird watching (Everard et al. 2010).

A large number of visitors are attracted for enjoying natural saline habitats with outstanding landscapes. The saline habitats provide many opportunities for recreational activities, through their aesthetic values. One can walk, hike, go cycling, and study nature. The ecotourism in such habitats will lead towards an increase in the number of visitors, trying to follow recreation in natural areas. The cultural ecosystem services in such areas will include the benefits to visitors and income opportunities for nature tourism service providers (Luković et al. 2021). Nature-based tourism is reflected in visits and exploration of unusual saline flora and vegetation through herbal, educational, or photo tours (Loconsole et al. 2019; Luković et al. 2021). Keeping in the mind that most of these habitats are protected areas, their utilization level is low. The services they provide are mainly regulatory and less cultural. In addition to scientific and educational activities, cultural-artistic activities (painting colonies) and touristic visits can be organized in such habitats, so as to learn more about rare plant species distributed here or to observe birds (Luković et al. 2021).

### 4.2.13 Other Potential Economic Uses of Halophytes

There are some provisioning services, which might be considered here. These refer to the halophytes as a source of fibers, use as shelter and construction material. Some salt marsh plants (particularly *Bolboschoenus maritimus, Phragmites communis, P. karka*, and *Typha latifolia*) are the sources used for construction purposes (Luković et al. 2021). The saline habit plant sources can be evaluated as biomass and used in many industrial applications. Abideen et al. (2011) have pointed out that saline habite plants are one of the most productive sources of lignocellulosic biomass. Very high amounts of cellulose are found in the xerohalophytic plants such as *Suaeda fruticosa* and *Atriplex halimus*, while *Limonium boitardii* is rich in lignin. In the halophytes lignocellulosic biomass can be considered as material for future applications in the production of good quality paper and reinforcement of polymers. The saline steppes, particularly the saline grasslands, are dominated by xerohalophytic plant taxa which can be used as renewable resources by different fiber industries as an example; *Suaeda fruticosa* could be used in the production of high-quality lightweight paper (Salem et al. 2019; Luković et al. 2021). Moreover, on the physical and chemical characteristics and composition we find good thermal and acoustic insulation, good mechanical features, low density, high specific stiffness, biodegradability, eco-friendliness, and toxicological harmlessness as the characteristics of fiber plants where halophytes can be used. A range of halophytes represent great potential for use in plastic industry (as reinforcement in polymers) as well as automotive, and packaging industries (Salem et al. 2019; Luković et al. 2021).

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