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Biological properties of selected Amaranthaceae halophytic species: A review

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The family Amaranthaceae contains a large number of halophytic species. The aim of this paper is to present a review of biologically significant halophytes in the flora of Serbia belonging to this family. This review includes a description of the following 18 species: *Atriplex littoralis* L., *A. rosea* L., *A. halimus* L., *Bassia sedoides* Pall., *B. scoparia* (L.) A.J.Scott., *B. prostrata* (L.) Beck., *Beta trigyna* W. et K., *Camphorosma annua* Pall., *C. monspeliaca* L., *Chenopodium ambrosioides* L., *Ch. polyspermum* L., *Ch. vulvaria* L., *Ch. hybridum* L., *Ch. album* L., *Ch. rubrum* L., *Salicornia europaea* L., *Suaeda maritima* (L.) Dum., *Salsola soda* L. These species are sources of biologically active substances and have a good potential for multi-purpose applications. Most extracts of these species have been found to exhibit biological activities such as antioxidant, anticancer, antibacterial, antifungal, antiinflammatory and others. The aim of this review is to describe these species including their morphology, distribution, phytochemistry, as well as their use for medicinal and food purposes.

Keywords: Amaranthaceae. Morphology. Essential oils. Secondary metabolites. Medicinal application.

INTRODUCTION

Family Amaranthaceae

Halophytes grow in habitats with an increased concentration of salt in the substrate to which they have adapted in order to survive in saline habitats. One of these adaptive capacities lies in the synthesis of compounds that belong to the group of secondary metabolites. Increased production of secondary metabolites, with pronounced biological activities in halophytes, has received additional attention due to the rapid increase in demand for natural bioactive substances (Stanković *et al*., 2019). The plant species belonging to the Amaranthaceae family represent important potential sources of pharmacological substances. Biological activity of these substances has been proven in numerous scientific studies (Ksouri *et al*., 2011; Arya *et al*., 2019). These plants have been used for their antibacterial, antioxidant, antifungal, and many other biological effects (Stanković, 2019; Stevanović *et al*., 2019).

The Amaranthaceae family includes the formerly called Chenopodiaceae family and contains about 178 genera and 2052 species based on the data provided by 'The Plant List' (http://www.theplantlist.org/1.1/browse/A/Amaranthaceae/ accessed 2021-06-25). In previous classifications, the family Amaranthaceae was placed in the order Caryophyllales and included genera and species that were formerly treated as Chenopodiaceae (Christenhusz, Byng, 2016). However, in some publications the name Chenopodiaceae is still used (Gelin, Mosyakin, Clemants, 2003; Kadereit, Hohmann, Kadereit, 2006; Tundis *et al*., 2009; Voznesenskaya *et al*., 2013; Chikhi *et al*., 2014).

Plants of this family inhabit arid areas, deserts, coastal and salt habitats. They are widespread in Africa, Asia, Europe, and North and South America (Gelin, Mosyakin, Clemants, 2003).

Species belonging to this family are mostly herbaceous and annuals, biennials or perennials. Some of

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them have a succulent structure. They have alternating or opposite leaves. In some species, the leaves are opposite at the base of the stem, whereas they are alternating in the central part. The flowers can be unisexual or bisexual, three-part or five-part and arranged in cluster blooms. The leaves of flower sheath are often protected, more or less succulent. They have 1 to 5 anthers, and the pistil consists of 2 to 5 fertilizing leaves. The fruit is dry and in some genera it opens, while in others remains closed (Gelin, Mosyakin, Clemants, 2003).

Species belonging to this family are mostly herbaceous and annuals (*Atriplex rosea, Bassia sedoides, Chenopodium ambrosioides, Ch. polyspermum*, *Ch. hybridum, Ch. album, Ch. rubrum, Kochia scoparia, Salicornia europaea, Suaeda maritima, Salsola soda),* biennials *(A. littoralis, Camphorosma annua*) or perennials (*Beta trigyna, C. monspeliaca, K. prostrata*). Some of them have a succulent structure (*A. littoralis, B. sedoides, C. annua, Ch. rubrum, S. europaea, S. maritima, S. soda*). They have alternating (*B. sedoides*, *B. trigyna*, species of the genera *Camphorosma*, *Chenopodium*, *Kochia*) or opposite leaves (*S. europaea*, *S. soda*). In some species, the leaves are opposite at the base of the stem, while in the central part they are alternating (species of the genus *Atriplex*, *S. maritima*). The flowers can be unisexual (species of the genus *Atriplex*) or bisexual (*B. trigyna*, *B. sedoides*, species of the genus *Camphorosma*, *Chenopodium*, *Kochia* and species *S. europaea*, *S. maritima*, *S. soda*), three-part or five-part and arranged in cluster blooms. The leaves of the flower sheath are often protected, more or less succulent. They have 1 to 5 anthers, and the pistil consists of 2 to 5 fertilizing leaves. The fruit is dry and in some genera it opens, while in others remains closed.

This review paper will describe some of the most important genera with species belonging to the family Amaranthaceae, namely the genera *Atriplex*, *Bassia*, *Beta*, *Camphorosma*, *Chenopodium*, *Salicornia*, *Suaeda* and *Salsola*.

Genus *Atriplex*

Atriplex littoralis L. is a biennial plant that can reach a height up to 80 cm. It is upright and branched, with green or reddish shoots. The leaves are alternate, succulent, linear, without visible lateral nerves, and with sharply serrated edges. Flower glomerulus is arranged in a leafless inflorescence. The bracts of female flowers are up to 55 mm long, egg-shaped and succulent at the beginning, and later they are dry. The seed has a lateral germinal root. The species is present on a wet sandy, clay or rocky substrate, in an open halophytic vegetation. It mainly grows on solonchak and less often on solonjec. It is widespread in Europe, southwestern and Central Asia (Slavnić, 1972).

A. littoralis has the ability to absorb ions from saline soil and isolate them in the saline glands on the leaf surface. This feature has great importance because it enables this plant to be used for the revegetation of saline or dry/semi-dry soil. The species is used to clone genes responsible for drought and salt tolerance and their introduction into cultivated crops in order to achieve higher resistance of these plants to the mentioned conditions (Benzarti *et al*., 2013).

By examining the total phenolic content and antioxidant activity of methanolic extracts of its aerial parts, this plant proved to have a high content of phenolic compounds and flavonoids (Table I), as well as a high antioxidant effect (Stevanović *et al*., 2014).

This plant is a source of secondary metabolites exhibiting various effects such as antimicrobial, antiviral, anticancer, and antioxidant effects (Gođevac *et al*., 2015).

Atriplex rosea L. is an annual plant that reaches a height of 20 to 70 cm. The stem is cylindrical and densely shelled. The leaves are whitish, rarely green and serrated along the rim, with a narrowed base. The lower ones are on a short stalk and rhombic, and the upper ones are sitting and deltoid. The flowers are clustered in a terminal or axillary inflorescence. The bracts are ovoid, unevenly toothed and 4 to 12 mm long. The seeds are shiny and blackish. It is a cosmopolitan species that grows along roadsides, around settlements on dry and saline sites (Slavnić, 1972).

The individuals of this plant species were grown on soil treated with various heavy metals (Cu, Ni, Pb and Zn). The results showed that the exposure of plants to different levels of metals reduced the production of dry matter and influenced the gradual reduction of growth after treatment (Kachout *et al*., 2009). Plant growth was inhibited when the species was exposed to high concentrations of these elements. *A. rosea* can be used in phytostabilization of contaminated soil the reason being that it has a high ability to tolerate the presence of heavy metals in the substrate (Kachout *et al*., 2015).

This species is used in nutrition. Its leaves are used to make traditional dishes in some areas of Turkey (Dogan *et al*., 2015).

Atriplex halimus L. is an upright perennial shrub that branches from the base. It can reach a height up to 3 m. The bark is gray-white, and the leaves are 10-30 mm long and 5-20 mm wide. The leaves can have different shapes, and they taper to a base with a short stalk. During hot and dry summers, it happens that its leaves fall off, even though it is an evergreen plant. Based on differences in morphology, Le Houérou (1992) divided this species into two subspecies: *halimus* (var. *typica* Aellen, var. *genuina* Maire et Weill.) and *schweinfurthii* (Boiss.) Le Houérou (var. *glaucoidea* L. Chevall, var. *ramosissima* L. Chevall, var. *argutidens* Bornm). The subspecies *halimus* is lower, with more upright habitus and shorter fruiting branches, while the upper branches are slightly twisted. The subspecies *schweinfurthii* has leafless fruiting branches of a reddish hue. The leaves have different sizes, shapes and colors ranging from greenish to grayish. The leaves of the subspecies *halimus* are more or less lanceolate. The young are greenish, while the older ones are silver-gray (Walker *et al*., 2014). It grows in arid or semi-arid areas, with the subspecies *schweinfurthii* occurring mainly in arid and/or salt areas, and the subspecies *halimus* in semi-arid areas, without the presence of salt in the substrate (western Mediterranean basin and Macaronesia). It can grow at altitudes up to 1200 m, although it has a moderate tolerance to cold. It occurs in open, sunny places, as well as on neutral or alkaline soils. It thrives better on loam than on sandy or clay soils (Le Houérou, 1992). It mainly forms part of halophilic communities on saline soils.

It is spread throughout Macaronesia, then the Mediterranean basin, all the way to western Asia. Its range includes southern Portugal, France, southern and eastern Spain, Italy, Greece, Malta, Turkey, Cyprus, Israel, Syria, Lebanon, Jordan, Tunisia, Morocco, Algeria, Libya, Egypt and Saudi Arabia (Gu *et al*., 2011).

A. halimus has a high biomass with a relatively low metal translocation to the upper surface of the soil. It has manifested the efficiency to adopt metals. Due to its high biomass production and relatively high root metal content, this plant can be successfully used in phytoremediation, and especially in phytostabilization (Amer *et al*., 2013).

In addition to alkaloid compounds, fatty acids, sterols and amino acids, some flavonols, flavanones, flavones and isoflavone glycosides have also been identified. All of these compounds have medical and physiological activity (Emam, 2011).

An aqueous leaf extract of this species has a beneficial impact on reducing elevated blood glucose levels and hepatitis levels in diabetic rats (Chikhi *et al*., 2014). By analyzing the antioxidant properties of the main secondary metabolites (Table I) of leaves and stems, it was concluded that methanolic extracts of leaves have a content of total phenolic compounds higher than methanolic extracts of stems. Flavonoids from the leaves have a higher ability to donate hydrogen for iron chelation and higher antioxidant activity (Benhammou, Bekkara, Panovska, 2009).

A. halimus has a deep root system that in dry zones plays a role in soil stabilization and reduces erosion. The shoot is rich in protein, and therefore represents an important fodder species, especially for goats and sheep (Walker *et al*., 2014).

Genus *Bassia*

Bassia sedoides Pall. is an annual upright xerohalophytic species (Voznesenskaya *et al*., 2013). It has a succulent leaf structure that is typical for halophytes growing in Europe (Grigore, Ivanescu, Toma, 2014). The leaves are simple, alternate and have very thick and long hairs on the surface (Safiallah *et al*., 2017). The roots and the stem are succulent (Hasanuzzaman, Shabala, Fujita, 2019). It has small flowers with a prickly perianth gathered in spikes. The embryo is five-pointed (5 anthers) and curved. The seeds are oval (Safiallah *et al*., 2017). This is a euchalophyte that inhabits dry salt marshes on a highly saline light base. It is widespread in Dobrogea, Crimea, the Caucasus, in Central Asia and in the east to western Mongolia and China (Stevanović, 1999).

In *B. sedoides*, the amount of Na^+ and K^+ ions in the root is independent of the amount of salt in the soil. Flavonoids and K^+ ions were also recorded in large amounts indicating high productivity and adaptation to saline soil (Rakhmankulova, Shuyskaya, Shcherbakov, 2015).

Bassia scoparia (L.) A.J.Scott (syn. *Kochia scoparia* (L) Schrad.) is an annual plant with a shrubby life form. It reaches a height of 1 to 2 m. The branches are straight, green or reddish, hairy or smooth. The flowers are small, up to 3 mm in diameter, and the seeds are oval and have a length of 1.5-2 mm. The seeds are brown with yellow spots or dark red to brown (Friesen *et al*., 2009). *B. scoparia* is a weed that grows along canal banks, roadsides, field edges, and salt marshes. It is a common weed in ruderal arid and semiarid areas, as well as in field production systems in North America. It is widely present in crop systems due to its abilities such as germination at low temperatures, drought tolerance, high temperature and salinity, and rapid growth. It is a native species in Europe and Asia, but it was introduced to the United States as an ornamental species in the early 20th century, being naturalized in the central and western parts (Welsh *et al*., 1978; Friesen *et al*., 2009).

Studies have confirmed that *B. scoparia* has an allelopathic effect on some species. It was determined that in laboratory conditions it negatively affected the growth and development of soybean, sorghum, cotton, sugar beet and sunflower (Nair *et al*., 2021). An aqueous extracts inhibited the growth of seedlings of *Bouteloua gracilis* (Friesen *et al*., 2009) and had a negative effect on germination and growth of seedlings of *Linum usitatissimum* (Zhao *et al*., 2010). It also negatively affected maize germination (Nawaz *et al*., 2013).

An exudate of *B. scoparia* seeds extracted in water inhibited fungus *Colletotrichum graminicola*. After exposure to exudate, hyphae formation was inhibited indicating that this species with persistent seeds may be useful in controlling the plant pathogen (Houlihan, Conlin, Chee-Sanford, 2019). The n-hexane fraction had an antibacterial effect on methicillin-resistant *Staphylocccus aureus* (Joung *et al*., 2012).

The leaves have insecticidal properties and have an acaricidal effect on three types of mites (*Tetranychus* sp., Acari, Tetranychidae) (Shi *et al*., 2006). Chloroform extract from seeds showed strong activity on the nutrition of the larva *Plutella xylostella*. It was found to be able to have both selective and complete impact (Zhao *et al*., 2008).

The whole plant and seeds have been found to contain phytoecdysteroids which have potential medical significance. The main phytoecdysteroids in the seed are 20-hydroxyecdysone and polypodine B (5β,20-dihydroxyecdysone), but significant amounts of unidentified others were also detected. A similar mixture of phytoecdysteroids was observed in all plant extracts including a large amount of apolar conjugate ecdysone not identified in the seed (Dinan, 1994).

Flavonoids extracted from *B. scoparia* exhibited antioxidant activity and had the power to remove free radicals (Hao *et al*., 2012). It is known that this species have cardiotonic, tonic, hypotensive and stimulating properties (Akopian *et al*., 2020). It can be used in bioremediation of soils containing cesium and hydrocarbons (Friesen *et al*., 2009).

A study in Thailand showed that this plant caused allergic reactions to pollen in humans, where 14% out of 100 patients reported to have allergic rhinitis in response to it (Pumhirum, Towiwat, Mahakit, 1997).

B. scoparia is used as animal feed because it has a similar nutritional value as alfalfa (*Medicago sativa*), but it can be poisonous to livestock if ingested in large quantities. The death of sheep, cows and horses has been reported. Toxic substances are saponins and alkaloids, oxalates and nitrates (Friesen *et al*., 2009).

Bassia prostrata (L.) Beck - (syn. *Kochia prostrata* (L.) Schrad.) is a perennial, semi-shrubby plant with a cylindrical root. It has many above-ground shoots up to 60 cm, which are hairy or later more or less smooth. The stem is woody and bears thick and thin branches from the base. The leaves are alternate or in vertebrae, up to 1 mm wide. They are conical, pointed or narrowly linear. The inflorescence is composed of apical and lateral, loose or compact spikes. The glomeruli are composed of 3 to 5 flowers. The seeds are up to 2 mm long and dark gray. It grows on alkaline soil, on steppes. It is resistant to wind and drought. It is widespread in the Southern Europe, Asia and North Africa (Slavnić, 1972).

In addition to the alkaloids harmen and harmin, *B. prostrata* contains organic acids, flavonoids, and saponins (Akopian *et al*., 2020). The content of proline and flavonoids, which have a protective role and participate in adaptation to habitat conditions, was determined in the shoots of this plant. Since a high content of proline and flavonoids, especially naringin and rutin, was identified, this species was concluded to be well adapted to salinity conditions (Rakhmankulova, Shuyskaya, Shcherbakov, 2015).

This plant is considered to be good for grazing and is used on the Asian continent to feed sheep, goats, camels and horses. It is a good source of protein and carotene, without the risk of poisoning caused by tannins or oxalates, as in *B. scoparia* (Davis, 1979).

B. prostrata had a crude protein content that was higher than the minimum content required to maintain the activity of microorganisms in ruminant rumen. These results suggest that this species can be a significant source of feed, especially in critical dry periods of certain areas (Ramazan *et al*., 2021). It is known to be used as an anthelmintic (Akopian *et al*., 2020).

Genus *Beta*

Beta trigyna W. et K. is the perennial plant growing from 50 to 90 cm in height. The lower leaves are broad and ovate, narrowed into a petiole. The leaves of the perigon are hairy, yellow-white, 5-7 mm long, thickened and initially shrunken (Slavnić, 1972). The flower has an outer spiral containing five perigons, a spiral having five anthers connected in a ring, and a pistil with three carpels. The perigon resembles a corolla and can be whitish, yellowish or reddish (Kadereit, Hohmann, Kadereit, 2006). It is present on steppes, sea shores, arable land and can be found along roads. It grows on acidic, neutral and basic soils, but also on saline, moist soils. This is a weed, less often a ruderal plant. It is widespread in Southeast Europe and Asia Minor (Slavnić, 1972). The center of distribution of this species is in Turkey, Russia, Georgia and Armenia. It occurs around the Black Sea and the Caspian Sea, as well as in Persia, Crimea and Southern Ukraine. It spreads to the east in Hungary, Romania, Slavonia and some parts of the Balkans, as well as in Macedonia. It has been found to occur naturally in Iran, while no specimens have been recorded in Japan (Srivastava *et al*., 1991).

B. trigyna is used in traditional medicine for asthma and bronchitis, and its use in the nutrition was previously noted (Ezer, Arisan, 2006). It is also used in Turkey in the diet of the local population, especially in the area of Agri. It has a good CI (The Cultural Importance index) value and is considered as nutritionally and economically important species. Only shoots and leaves whose preparation requires cooking are consumed (Kadioglu *et al*., 2020).

Genus *Camphorosma*

Camphorosma annua Pall. is a therophyte with the ground habitus. Flower branches can be 5 to 40 cm long. The leaves are succulent, hairy and with a thick cuticle. It germinates in the period from the end of February or the beginning of March and flowers in June (Murakeözy *et al*., 1999; Murakeözy, Nagy, Tuba, 2003). This species is present in the Pontopannonian floristic area and mainly in Southeast Europe. It grows on continental saline places that are thermophilic and sunny. The presence of *C. annua* is an indicator of dry and saline habitats with a hard mechanical composition (Janjatović *et al*., 1992). This plant is characteristic for the sodicidal type of solonchaks with the highest salt content (Murakeözy *et al*., 1999). It is suited to a highly alkaline substrate dominated by chloride (Janjatović *et al*., 1992). It has been found in alkaline habitats such as alkaline steppe, open alkaline grassland and alkaline meadow (Riba *et al*., 2020). *C. annua* is bound to saline soil and it is not able to germinate below a certain level of salinity. Due to this fact it is classified as an obligate halophyte suffering even periodic flooding with salt water that would destroy most other plants (Josifović, 1980). *C. annua* is a plant with a large ecological spectrum so it can grow in other saline habitats (salty sand or populated areas), as well as in less saline areas. This is the reason why Grigore and Toma (2010) called this species “a reversible” halophyte. *C. annua* is a pioneer species in the succession of steppe habitats. It successfully resists high salt concentrations forming almost monotypic vegetation (Josifović, 1980). It is the dominant species in *Camphorosmetum annuae* community being especially widespread on solonetzes. This community occurs on bare depressions with the highest salinity and such areas can be considered the most extreme for vegetation in lowland conditions. These are mainly areas with scarce vegetation cover that make up a small number of species (Levente, Codrin, 2014).

The specific habitat conditions of this species growth have influenced the creation of a large number of anatomical adaptations such as succulent leaves, thick cuticles, concave stoma, developed palisade and tissue for water storage (Janjatović *et al*., 1992). Also, some other specific anatomical features may appear, such as successive cambium, Kranz anatomy, and hair follicles (Grigore, Toma, 2010).

The osmolites have a role in maintaining the vital osmotic concentration in halophytes. When plants are exposed to a higher concentration of salt, the level of osmolyte is subjected to change. Seasonal changes in osmolytes of halophytic plant leaves were also investigated in *C. annua*. It was determined that this species accumulates glycine, betaine and pinitol in leaves, mostly during the spring months. The concentration of these osmolytes is lower in the summer months. An increased production of pinitol was found in the species *Limonium gmelini* during the summer months, but not in *C. annua*, and this finding can be attributed to a larger vacuolar space (Murakeözy, Nagy, Tuba, 2003).

Osmolites betaine and pinitol were found by examining seasonal changes in the concentration of osmolytes in *C. annua* leaf tissues (Murakeözy, Nagy, Tuba, 2003). This species usually accumulates small amounts of proline, but a relatively large amount of this amino acid was found in this species in March (Murakeözy *et al*., 1999), when the main constraints on plant development were low temperatures, hypoxic conditions, and high salt concentrations (Murakeözy, Nagy, Tuba 2003).

Among the organic anions present in *C. annua*, malate, citrate, and oxalate were observed to bear quantitative significance (Albert, Popp, 1977).

Camphorosma monspeliaca L. (Figure 1) is a perennial shrub that can reach a height up to 60 cm (Moghimi, 2006). The leaves have hairs on the surface. The lower ones are linear, and the upper ones are shorter and triangular (Slavnić, 1972). The stem and leaves have an intense camphor-like odor. The flowers are hermaphroditic and pollinated by insects (Thomas, 1992). This is a plant characteristic of steppe zones and solonetz-type soil (Goryaev, Korablev, 2020). It prefers well-drained soil and is suitable for light sandy and medium loamy soils. It can tolerate drought and grow on highly alkaline saline soils (Genders, 2001; Moghimi, 2006). In addition to saline habitats, *C. monspeliaca* can be detected on unsalted and alkaline soils with low content of organic matter and gypsum. The texture of these soils may consist of clay, loamy and calcareous soils (Gharibvand *et al*., 2011). This species is present in the Mediterranean area (Hasanuzzaman, Shabala, Fujita, 2019). It occurs as a dominant species in the community of *Camphorosmetum monspeliaceae* (Goryaev, Korablev, 2020), but also as a part of the Puccinellion convolutae in the southern Balkans (southern Serbia, the Republic of Northern Macedonia and Bulgaria) (Eliáš *et al*., 2013; Stevanović *et al*., 2016).

C. monspeliaca contains alkaloids, organic acids, saponins, flavonoids, coumarins, betaine, steroids, oils, vitamins B1, B2, C1, E, carotene and others. It is used in folk medicine to treat various diseases. It is known to be used as a diaphoretic and diuretic (Akopian *et al*., 2020).

This plant is important as a food source for camels, sheep and goats. It contains essential oils with camphor giving it a strong scent. It is used in folk medicine due to its antiasthmatic and diuretic properties (Tajali *et al*., 2007), but also as a diaphoretic, expectorant and stimulant (Usher, 1974). Significant phenol content was confirmed (Table I), as well as an antioxidant activity of this species (Stanković *et al*., 2015).

Under stressful conditions, this species accumulates the amino acid proline, the concentration of which depends on the intensity of stress (Öncel, 1988).

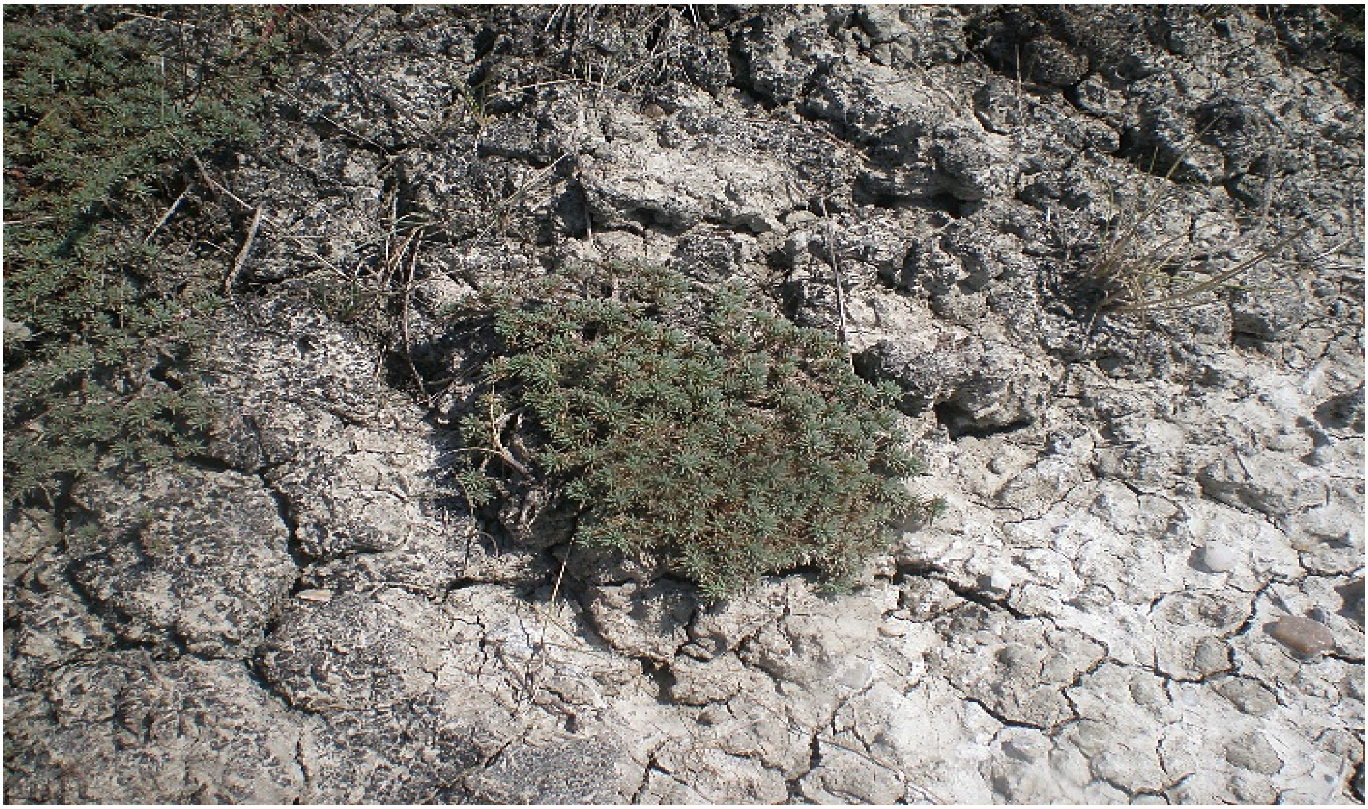

FIGURE 1 - *Camphorosma monspeliaca* L.

Genus *Chenopodium*

Chenopodium ambrosioides L. is an annual or perennial plant that can reach a height up to 1 m (López de Guimaraes, Neyra Llanos, Romero Acevedo, 2001). It is aromatic and has a strong odor (Kumar *et al*., 2007). The stem is bent, with leaves having a length of 4 cm and a width of 1 cm (Gadano *et al*., 2006; Jamali *et al*., 2006). The leaves are serrated and lanceolate. The flowers are greenish or purple (Mishra, *et al*., 2002; Lans *et al*., 2006). They are collected in thick brooms and each has 5 calyx leaves. The seed is up to 0.8 mm long and black (Gadano *et al*., 2006; Jamali *et al*., 2006). It is native in Central and South America and considered as invasive due to its ability to adapt to different conditions. It has successfully spread to other continents hence being a cosmopolitan species (Lorenzi, Matos, 2002).

Some previous studies indicate that this species affects the growth of some plants, ie. it has an allelopathic effect. Extracts of *Ch. ambrosioides* were tested for germination and hormone growth inhibition on *Amaranthus hypochondriacus* and it was concluded that the essential oil of *Ch. ambrosioides* inhibited the germination of *A. hypochondriacus*. Based on this deduction, the usage of *Ch. ambrosioides* as an allelopathic agent for pest control in agroecosystems could be considered (Jimenez-Osornio, Kumamoto, Wasser, 1996).

Infusion showed higher antioxidant activity, while methanol extract was the only one to exhibit antitumor effects. Toxicity in tumor cells was not observed for either infusion or extract. *Ch. ambrosioides* was confirmed to be a good source of natural antioxidants (Table I) with potential application in industry (Barros *et al*., 2013). It was found that extracts of this species showed strong fumigant activity on the corn borer *Sitophilus zeamais*. The essential oil of this species and its main active component, ascaridol, could be investigated as a fumigant with natural potential (Chu, Hu, Long Liu, 2011). Essential oil and its main components (ascaridol, carvacrol and caryophyllene oxide) exhibited a leishmanicidal effect on the parasite *Leishmania amazonensis*. All tested substances had strong inhibitory activities on promastigote and amastigote forms, and ascaridol exhibited the best activity (Monzote *et al*., 2014).

According to the WHO, this plant is considered as one of the most commonly used medicinal plants in the world (Lorenzi, Matos, 2002). It is used in folk medicine in the form of teas and infusions for inflammatory problems, contusions and lung infections, as well as an antifungal agent (Trivellato Grassi *et al*., 2013). Chekem *et al.* (2010) recorded the antifungal effect of *Ch. ambrosioides* essential oil. *In vitro* method showed that the activity was dependent on concentration, while *in vitro* method demonstrated that the antifungal activity was not dose dependent. All of the three tested doses had an effect after 12 days. The analysis of the bactericidal activity showed that *Ch. ambrosioides* had an active effect *in vitro* on *Helicobacter pylori*, an antibiotic-resistant bacterial species (Liu *et al*., 2012).

Powders and essential oil obtained from the dried leaves of this plant were tested in laboratory conditions and they were established to have the ability to protect grains from damage done by six insect pests: *Callosobruchus chinensis*, *C. maculatus*, *Acanthoscelides obtectus*, *Sitophilus granarius*, *S. zeamais* and *Prostephanus truncatus* (Tapondjou *et al*., 2002). The essential oil of the leaves of *Ch. ambrosioides* was tested against the aflatoxigenic strain of the fungus *Aspergillus flavus*. The oil inhibited mycelial growth to 100 µg/mL. It also showed a broad fungitoxic spectrum against *Aspergillus niger*, *A. fumigatus*, *Botryodiplodia theobromae*, *Fusarium oxysporum*, *Sclerotium rolfsii*, *Macrophomina phaseolina*, *Cladosporium cladosporioides*, *Helminthosporium oryzae* and *Pythium debaryanum*. During *in vivo* research, the essential oil protected wheat from various storage fungi for one year time frame. It also exhibited strong antioxidant activity. All these observations indicate the possible exploitation of the oil of this plant as a potential botanical fungitoxicant (Kumar *et al*., 2007).

Chenopodium polyspermum L. is an annual plant reaching the height from 20 to 80 cm. The shoots are smooth and branched. At the beginning of the growth, it is close to the ground, and later it is upright. The older plant eventually becomes reddish by the time. The leaves are also smooth, ovate and not serrated. It has inflorescences in the axils of the leaves and at the top of the branches. They have the shape of oblong clusters. It blooms in summer (Fuentes-Bazan, Pertti, Thomas, 2012). *Ch. polyspermum* is a weed species present from the lowlands to mountainous areas and grows in wet cultivated or uncultivated areas (Slavnić, 1972). It is common in coastal places (Kokanova-Nedialkova *et al*., 2009). It also occurs in ruderal habitats, fields and gardens where sandy soil is present (Pokorná *et al*., 2018). Soils with a high content of nitrates, nitrogen and phosphorus are suitable for this plant (Woźnica *et al*., 2016). It is widespread in Europe and Asia (Slavnić, 1972).

Ch. polyspermum has a rich content of flavonoids (Table I) (Vysochina, 2010) and it is characterized by the presence of the flavonoid rutin (Uslu *et al*., 2020). Quercetin and rutin were identified in leaves and flowers, while procyanidin and epicatechin were identified only in flowers (Dadáková *et al*., 2013).

Limonene and ascaridol were found to be the two most abundant compounds of leaf essential oil. Safrole, saponin, ascaridol, camphor, histamine, cinnamon, methyl salicylate and trimethylamine were also identified (Dembitsky, Shkrob, Hanus, 2008). The presence of oxalic acid and hydrocyanic acid was determined as well. Due to the presence of these compounds, *Ch. polyspermum* causes hemolytic and renal toxicity when consumed by human (Acık *et al*., 2012).

Ch. polyspermum has antimicrobial, antiviral, antifungal, anthelmintic, and trypanocidal action; it possesses neoplastic and immunomodulatory properties and exhibits antioxidant activity. Due to these pharmacological properties, it has application in alternative medicine (Acık *et al*., 2012).

Chenopodium vulvaria L. is an annual plant which can reach a height from 5 to 40 cm. It is sticky and gray-green (Medwecka *et al*., 2012). The lower branches are flat and often spread on the surface. The lower leaves are ovate or broadly rhombic. They are wedge-shaped at the base and may have a slight depression at the widest part. The flowers are small and inconspicuous. They are collected in false spikes or brooms. The fruit is a spherical or slightly flattened achenia. The seeds are black and kidney-shaped (Mochnacký, 2012). *Ch. vulvaria* is recognizable by its unpleasant odor similar to the smell of rotten fish. This plant mainly grows in places exposed to anthropogenic influence (Groom, 2015). It grows in ruderal environments, near city paths, buildings and walls. It is an integral part of the phytobiodiversity of urban ecosystems (Mochnacký, 2012). *Ch. vulvaria* is often found in eutrophic and coastal habitats and its number in such habitats is increasing in northern Europe (Van Landuyt *et al*., 2008; Groom, 2013). This species grows naturally in Europe and Asia (Mochnacký, 2012). In the west, it is widespread in the countries bordering the Mediterranean, and in the east it is present as far as Afghanistan and Mongolia (Jalas, Suominen, 1988). It has been introduced to North America, Northern Patagonia, Chile, Australia, and New Zealand (Mochnacký, 2012).

It is known that the volatile oil of *Ch. vulvaria* can be used as a bacteriostatic, bactericidal and antioxidant product. It can be obtained by steam distillation or supercritical CO_2 extraction. It has the effect of inhibiting bacteria such as *Staphylococcus* sp., *Streptococcus* sp., *Enterobacter* sp., *Salmonella* sp., *Shigella* sp., *Pseudomonas* sp., *Bacillus* sp., *Escherichia* sp., as well as fungi such as *Candida* sp., *Cryptococcus* sp., *Aspergillus* sp., *Trichophyta epidermophyton* sp., etc. Also, the diphenyl-picryl-phenylhydrazine (DPPH) method shows that the essential oil has a high antioxidant activity and can be widely used in the food, medicine, cosmetics and health care products industry. People with a tendency to rheumatism, arthritis and gout should be careful since the usage of this plant can worsen their condition (Chao *et al*., 2002).

Chenopodium hybridum L. is an annual plant with an upright stem. It reaches a height of 1 m. At first, the stem is a little rough, and later completely smooth. All leaves are green, pointed at the top. The lower leaves are large, round at the base, and the upper ones are smaller. The flowers are light green, up to 2 mm long. There are 5 anthers, and the fruit is 1.5-2 mm wide and with sharp ends. The seeds are shiny and black. It is characteristic of arable land and avoids open, very sunny places. It is widespread in Eurasia and North America (Slavnić, 1972).

In vitro analysis of ethanolic extracts has shown that some species of the genus *Chenopodium* can suppress cancer cells. Unfortunately, these properties are often accompanied by high toxicity to skin fibroblasts. The extract of *Ch. album* caused inhibition of about 95% of accumulating ovarian and endometrial cancer cells. These data are similar to those obtained for *Ch. hybridum*. However, the toxicity of both of these extracts on skin fibroblasts was also high. Cell mortality after 72 h was 90%. *Ch. hybridum* exhibited cytotoxic activity against ovarian cancer cells (55%). Moreover, 30% activity of *Ch. hybridum* extracts on human lung cancer cells was also recorded with probable cytopathic effects on skin fibroblasts (Nowak *et al*., 2016).

Extracts of this plant exhibited multidirectional biological activity, such as anticancer and antioxidant abilities, as a result of which this species can be used as an easily accessible source of natural antioxidants, as well as for the production of food supplements and in the pharmaceutical industry (Kokanova-Nedialkova *et al*., 2009).

A high phenol content was found in the aerial parts and seeds. Extracts of these parts of the plant showed a significant antiproliferative effect on the TOV-112 cell line (Nowak *et al*., 2016).

Chenopodium album L. is herbaceous and an annual species growing up to 1 m in height. The stem is grayish, with upright or raised branches. The leaves are alternate. The lower leaves have the greatest width, the middle ones are elongated with sharp ends, and the upper ones are narrow and pointed. This is a monoecious plant. The flowers are clustered in glomerulus. The perianth basically shrinks and almost closes the ripe fruit. It has five anthers and two stamps. The pericarp is smooth. The seeds are mostly round and black. Flowering lasts from late May to October. Pollination is done by wind. The species grows on substrates varying from strongly acidic to alkaline. It prefers well-drained conditions and is found on chernozem, podzol or gley soils. It is found in open habitats exposed to anthropogenic influence and grows in association with other weed species (Slavnić, 1972).

Ch. album is a good source of functional nutrients and has healing properties. It has a high functional potential in addition to basic nutritional benefits. It is used in the diet in order to provide minerals, fiber, vitamins and essential fatty acids, improving the sensory and functional value of food. It can be incorporated into various extruded food products to make them more nutritious and healthier. Adding leaves of this species to products can improve chemical and nutritional parameters (Kokanova-Nedialkova *et al*., 2009).

Ch. album shows a zone of inhibition against *Staphylococcus aureus*, *Bacillus subtilis*, *Streptococcus faecalis*, *Pseudomonas aeruginosa*, *Salmonella typhi*, *Vibrio colerae*, *Shigella disenteriae*, *Escherichia coli*, *Penicillium notatum*, *Aspergillus niger* and against *Candida albicans*. *Ch. album* prevents cell growth progression and increases cell toxicity in breast cancer cell lines. The findings highlight the potential of this plant to become a clinically used bioagent with ability to suppress the development of breast cancer malignancy (Khoobchandani *et al*., 2009).

Ch. album is traditionally used for blood purification and as a sedative. It exhibits hepatoprotective and antiscorbutic activities. Pharmacological studies have revealed that the plant has antihelmintic properties, the ability to immobilize sperm and has a role in contraception. The antipruritic and antinociceptive effect was also confirmed (Kokanova-Nedialkova *et al*., 2009). This plant is also acknowledged to be used as a cardiotonic, digestive, diuretic and laxative drug. Its action has been proved against dyspepsia, bloating, pharyngopathy and splenopathy. The leaf powder is made to suppress irritation, and the leaf juice is used to treat burns. The use of this plant has also been documented in the treatment of liver disorders and blindness. It is also used as animal feed. The leaves are rich in potassium and vitamin C (Sarma, Sarma, Sarma, 2008).

Commercial exploitation of *Ch. album* in many regions of the world is still far from reality. Its active ingredients can be isolated and further evaluated for the development of useful drugs (Table I) since the established antioxidant and antibacterial activities have additionally confirmed its biological value. The studies should stimulate the use of *Ch. album* in areas where it can be grown (Kokanova-Nedialkova *et al*., 2009).

Chenopodium rubrum L. has an upright and smooth stem of green or reddish color. It is an annual, herbaceous plant which can reach a height up to 50 cm. The stem and leaves are succulent and the leaves are rhombic or triangular. Flower glomeruli are small and arranged in clusters being gathered into compact or loose complex inflorescences. The leaf sheath is composed of 5 free leaves at the apical flowers and 3 fused leaves at the lateral ones. It has 2 to 5 anthers and 2 stamps. The seeds are black. This plant is found in open vegetation, on the shores of saline or unsalted waters. It is widespread in Europe, Asia and North America (Slavnić, 1972).

A high phenol content was found in aerial parts and seeds. The extracts of the aerial part of *Ch. rubrum* showed a good antioxidant effect (Nowak *et al*., 2016). Methanolic extracts were reported to exhibit high antioxidant potential through various tests (Mynarski *et al*., 2018).

In methanolic extracts of different parts of this plant, eleven phenolic acids were identified. The most common were p-coumaric, ferulic and salicylic acid. The highest concentration of phenolic acids was in the leaves and roots (Mynarski *et al*., 2018).

The toxicity of oxidized phytosterols of this plant was analyzed on the type of roundworm (*Tenebrio molitor*) (Meyer *et al*., 1998). By testing the cytotoxic effect, the seed extract showed activity against malignant melanoma of the VM 793 cell line. The extracts were reported to have cytotoxic effects on cell lines such as TOV112D, HT-15, HT-27, IMR-32 and A-549 (Mynarski *et al*., 2018).

This plant is considered to be good for grazing and is used on the Asian continent to feed sheep, goats, camels and horses. It is a good source of protein and carotene, without the risk of poisoning caused by tannins or oxalates, as in *Bassia scoparia* (Davis, 1979).

Genus *Salicornia*

Salicornia europaea L. (Figure 2) is an annual halophytic species (Piernik *et al*., 2017) that has a succulent structure and a leafless stem (Davy, Bishop, Costa, 2001). The stem consists of a series of cylindrical internodes evenly branching out. The internodes consist of the central marrow and the external photosynthetic cortex surrounding it. Those at the base generally reject the external cortex and undergo secondary thickening and lignification (Ellison, Niklas, Shumway, 1993). Under conditions of increased salinity, many genes involved in lignin biosynthesis and the lignification process are regulated in this species. This is consistent with reports claiming that reduced cellulose synthesis induces lignification (Fan *et al*., 2013).

FIGURE 2 - *Salicornia europaea* L.

S. europea is present in habitats exposed to salt. These can be shores, tidal streams, salt lakes, and salt water springs (Piernik *et al*., 2017). It can be found on the Atlantic coasts in Western and Northern Europe, on the shores of the Baltic, the Mediterranean, the Black Sea and the Caspian Sea, as well as on the continental salt habitats of the Iberian Peninsula, Pannonian and Wallachian lowlands and on the steppes of Ukraine and Russia (Stevanović, 1999).

This is one of the most resistant (Davy, Bishop, Costa, 2001) and the most salt-tolerant plants (it can tolerate concentrations greater than 1M NaCl) (Rozema, Schat, 2013; Zare-Maivan *et al*., 2015). It requires an appropriate concentration of NaCl for normal growth and development. It accumulates high concentrations of inorganic ions in cell vacuoles, mainly sodium and chloride, thereby managing to maintain a low water potential in its tissues (Davy, Bishop, Costa, 2001). In addition to the bladder and glands, it is able to accumulate significant amounts of Na^+ in the shoots (Davy, Bishop, Costa, 2001; Ushakova *et al*., 2005).

This species is a source of secondary metabolites that exhibit various biological activities. This species has therapeutic properties such as antioxidant, antidiabetic, anti-inflammatory, cytotoxic and anti-obesity. In Asia, it is used as a traditional medicine for diabetes, nephropathy, hepatitis, diarrhea (Kim *et al*., 2021). Also, it is used in the treatment of hypertension and as an anticancer, antihypertensive and anti-inflammatory agent (Tundis *et al*., 2009).

S. europaea is especially rich in oil and oleic acid. Ethanol, methanol and aqueous extracts have shown strong antimicrobial and antifungal effects. Methanol extract had the strongest effect (Karan *et al*., 2021). Immunomodulatory compounds were identified in crude extracts (Im, Kim, Lee, 2003). Antihyperglycemic and antihyperlipidemic activity was found in mice whose diet was high in fat (Park *et al*., 2006). The polysaccharide extract had anti-inflammatory action *in vivo* and *in vitro* (Park *et al*., 2006). Isolated polysaccharides were recorded to activate macrophages playing a significant role in the host defense system (Ksouri *et al*., 2011; Lee *et al*., 2006).

Since high salt intake causes arterial dysfunction and hypertension, the effect of *S. europaea* on vascular function and blood pressure was investigated. It was determined that it caused no coronary artery dysfunction, despite the high salt content in it. The vascular protective effect is attributed to trans-ferulic acid. These results indicate the potential use of this species as an alternative for salt purification and prevention and alleviation of hypertension (Panth *et al*., 2016).

Some previously done researches showed that desalinated powder of this species, due to its antihypertensive and antidiapogenic properties, can be used in the diet with the aim of controlling obesity (Rahman *et al*., 2018). The extracts showed hypoglycemic effects by inhibiting the enzyme α-amylase (Li *et al*., 2007).

S. europaea was also recorded to have a beneficial effect on chronic diseases associated with oxidative and inflammatory stress. Desalinated and enzyme-digested ethanol extract has bioefficiency since it possesses significant polyphenols and flavonoids. This extract shows multifactorial disease modification activities and can be used as an effective therapeutic or dietary supplement for the treatment of amnesic neurodegenerative complications and neuroinflammatory disorders (Karthivashan *et al*., 2018).

Ethanolic extracts showed strong antifungal activity and were effective at very low concentrations. They had an inhibitory effect on four species of fungi: *Alternaria alternata*, *Cladosporium sphaerospermum*, *Fusarium oxysporum* and *Botritis cinerea* (Al-Abbasi, 2018).

S. europea has been noted to exhibit significant cytotoxic activity against *Artemia salina* Leach and *Daphnia magna* Straus. An extract of this plant also showed antineoplastic activity in a potato test (Lellau, Liebezeit, 2003). *S. europea* is collected in salty semi-deserts in Central Asia in order to obtain soda. It is otherwise poisonous because it contains oxalic acid, bound to sodium ions (Stevanović, 1999).

An appropriate coordination of carbon fixation and nitrogen metabolism in *S. europea* chloroplast was determined under saline conditions. This plant could be used to fix carbon from saline soil. Since the photosynthesis is regulated under a high degree of salinity, the possibility of exploiting this pioneer plant should be considered in the future (Fan *et al*., 2011).

Genus *Suaeda*

Suaeda maritima (L.) Dumotr. (Figure 3) is an annual, upright plant that has a hard stem up to 60 cm in height. In the upper part it is branched and hairless, with densely distributed leaves. The leaves are alternate, succulent, gray-green or reddish, 1-2 cm long. The flowers are located in groups of 3 to 5 in the axils of the leaves and form clusters. It is pollinated by anemophilia and dispersed by anemochoria. The seeds are smooth, black and about 8 mm long. This plant blooms from July to September (Stevanović, 1999). It is a typical halophyte that grows on highly saline habitats such as the solonchak type of soil. It is found in the Pannonian area of Europe, in Austria, Hungary, Serbia, Romania (Slavnić, 1972).

FIGURE 3 - *Suaeda maritima* (L.) Dumotr.

Individuals of this plant grown in conditions of high salinity have higher fresh and dry weight in comparison to the plants grown on standard medium. Improved plant growth at high salt concentrations was evident only after prolonged exposure to high salinity and was attributed to increased cell size. No growth increase was recorded at low NaCl concentrations. In the state of salinity stress exposure, *S. maritima* was able to maintain high turgor and relative water content, which can be attributed to its prominent capacity for osmotic adjustment. The main osmotics are Na^+ and glycine betaine and the expression of the betaine aldehyde dehydrogenase gene in this species was observed to increase with increasing salt and salt stress. However, at lower salt concentrations, the plant accumulated higher levels of proline in their leaves (Moghaieb, Saneoka, Fujita, 2004).

In biological tests of antioxidant activity, the extracts of leaves and stems showed a strong antioxidant property of 70% to 92% for phenol and total antioxidant capacity. They also displayed a fairly good content of ascorbic acid, as well as the ability to chelate metals. From the four extracts estimated to have antimicrobial activity, two leaf extracts (acetone and ethanol) showed pronounced antimicrobial activity. The methanolic extract of the stem demonstrated the activity against one pathogenic bacteria compared to standard amoxicillin. The potential antioxidant and antimicrobial properties of this plant extract can be applied in the pharmaceutical industry (Patra, Dhal, Thatoi, 2011).

Nutritional values, such as dietary fiber, calcium and antioxidant substances with non-toxic properties, were identified in the dried plant of *S. maritima* and remained present after the storage period at 25 °C, for a period of 3 months. High levels of dietary fiber and calcium were measured. However, due to the high amount of sodium, the use of this plant should be avoided in some risk groups (hypertension, cardiovascular disease and kidney disease) (Sudjaroen, 2015).

The dried parts of *S. maritima* extracted with water exhibited higher antioxidant activity than ethanol extract. By comparing the antioxidant activities of dried and fresh plants it was proved that these activities were reduced in dried plants, but the antioxidant effect remained (Patra, Dhal, Thatoi, 2011; Ravikumar *et al*., 2011). Natural antioxidants inhibit tumor growth selectively due to different redox status between normal cells and cancer cells (Nair *et al*., 2021).

A cytotoxic activity test showed that hexane and ethanol extract of *S. maritima* produced no toxic effects (Sudjaroen, 2015). Hepatoprotective and antioxidant properties of this species were also recorded. Preliminary phytochemical analysis showed the presence of triterpenoids (Table I), which may be responsible for hepatoprotective activity. This can be useful for the development of herbal medicine through the usage of this species in the treatment of hepatitis (Ravikumar *et al*., 2011).

Genus *Salsola*

Salsola soda L. (Figure 4) is an annual plant reaching a height from 5 to 70 cm. The stem is smooth, gray-green or gray-red and branches strongly from the base. The branches are upright or lying down. The leaves are opposite and succulent, 2-3 mm thick. They are linearly lanceolate and initially pointed, and later have a rounded tip. The lower ones are longer and opposite, and the upper ones are alternating and short. The flowers in the axils have 1 or 2 classes. The bracts are triangular. The leaves of the flower sheath are ovate, more or less serrated at the top. The fruit is ovoid and together with the shell about 5 mm wide. The seeds are globular, black, shiny and 4 mm wide. It is found in occasionally flooded habitats and very salty places on solonchaks. It is widespread in Europe and Asia (Slavnić, 1972).

FIGURE 4 - *Salsola soda* L.

Four flavonoids (rutin, quercetin 3-O-glucuronopyranoside, isorhamnetin 3-O-rutinoside and isorhamnetin 3-O-glucuronopyranoside) were isolated from *S. soda* and their activity was tested on three human recombinant enzymes: aldose reductase (*h*AKR1B1), aldose-reductase-like protein (*h*AKR1B10) and carbonyl reductase 1 (*h*CBR1). All flavonoids inhibited these three enzymes and quercetin 3-O-glucuronopyranoside was the most effective one. These findings indicate the potential use of this species due to its beneficial effect on pathological conditions associated with diabetic complications and inflammatory processes, as well as in cancer therapy (Iannuzzi *et al*., 2020).

The recent studies have shown that it can potentially be used in phytostabilization of contaminated areas since it accumulates moderate amounts of heavy metals (Milić *et al*., 2012). The species can accumulate selenium and can be used in the diet as a selenium-rich vegetable (Centofanti, Bañuelos, 2015). Extracts of *S. soda* exhibited a good activity in the treatment of hypertension (hypotensive properties) (Loizzo *et al*., 2007). An alkaloid extract was obtained from the aerial parts and its anticholinesterase activity was tested. This plant showed selective inhibitory activity against butyrylcholinesterase suggesting the potential use of this species against Alzheimer's disease (Tundis *et al*., 2009).

It is used as a vegetable and it is served in restaurants in Italy. It has recently been documented as one of the endemic species on alkaline soils typical of Central and Eastern Europe, as well as the Carpathian Basin (Török, Kapocsi, Deak, 2012).

TABLE I - Secondary metabolites of presented halophytic Amaranthaceae species

Species	Bioactive compounds	Compound	References
Atriplex littoralis	Flavonol glycosides	Patuletin 3-*O*- [5 '''- *O*-feruloyl-*β*-D-apiofuransil (1''' → 2 '') - *β*-D-glucopyranoside]; Patuletin 3-*O*-*β*-D-glucopyranoside;	Bylka, 2004;
	Flavonoid glycosides	Spinacetin 3-*O*-*β*-D-glucopyranoside; arbutin; 4-hydroxybenzyl-*β*-D-glucopyranoside;	Gođevac *et al*., 2015;
Atriplex halimus	Flavonoids	Myricetin; Quercetin	Clauser *et al*., 2013;
	Glycosylated flavonoids	3', 5'-dimethoxymyricetin-3-*O*-*β*-D-Xylopyranosyl-7-0-fucopyranosyl- (1 → 3) -*β*-D-glucopyranoside; 3'-methoxykercetin-7-*O*-*β*-D-fucopyranosyl-(1 → 3) -β-D-glucopyranosyl-3-*O*-*P*-Xylopyranosyl- (1 → 4) -b-xylopyranoside; 3'-methoxykercetin- 7-*O*-*α*-L-ramnopyranosyl-3-*O*-arabinofuranosyl- (1 → 6) -*β*-D-Glucopyranoside; 5'-dimethoxymyricetin-7-*O*-fucopyranosyl-(1 → 3) -*β*-D- glucopyranoside; Isorhamnetin glycoside;	
Camphorosma monspeliaca	Essential oil	*α*-pinene; Citronellyl pentanoate; Limonene; Pinocarvone; Camphene; *α*-cadinol; Octen-3-ol; *β* -eudesmol;	Tajali *et al*., 2007; Bahernik, Mirza, 2003;

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Species	Bioactive compounds	Compound	References
Chenopodium ambrosioides	Flavonoid glycosides	Quercetin (acyl)glucuronide-*O*-rhamnoside; Quercetin *O*-rhamnosyl-glucuronide; Quercetin dirhamnoside; Quercetin-3-*O*-rutinoside; Quercetin *O*-rhamnosyl-pentoside; Kaempferol *O*-pentosyl-rhamnosyl-hexoside; Kaempferol dirhamnoside-*O*-hexoside; Kaempferol 3-*O*-rutinoside; Kaempferol dirhamnoside-*O*-pentoside; Kaempferol *O*-rhamnosyl-pentoside; Kaempferol *O*-rhamnosyl-glucuronide; Kaempferol (acyl)glucuronide-*O*-rhamnoside;	Barros *et al*., 2013;
	Essential oil	*α*-terpinene; *p*-cymene; Ascaridol; Carvacrol; Caryophyllene oxide;	Onocha *et al*., 2011; Monzote *et al*., 2014;
	Sterols	Avenasterol; Spinasterol;	Kokanova-Nedialkova *et al*., 2009;
	Terpenes	*β*-myrcene; Cis-*β*-ocimene; Nerol; Geraniol; Limonene; *α*-terpinene; *α*-terpinolen; *β*-phellandrene; *p*-cymene; Trans-pinocarveol; *α*-terpineol; Isoascaridole; Dihydroascaridole; Cariophyllenepoxide; δ^3-carene; δ^4-carene; *γ*-curcumene; *α*-carotene; *β*-carotene;	

TABLE I - Secondary metabolites of presented halophytic Amaranthaceae species

Species	Bioactive compounds	Compound	References
Chenopodium album	Flavonoids	3-*O*-glycosides campherol; quercetin; Isoramnetin;	Khoobchandani *et al*., 2009;
	Phenolic acids	Gallic acid; Protocatechuic aldehyde; Vanillic acid; Caffeic acid; Syringic acid;	Sarma, Sarma, Sarma, 2008; Laghari *et al*., 2011;
	Essential oil	p-cymene; Ascaridole; Ethyl cinnamate; α-pinene; β-pinene; Limonene; Linalool; Pinan-2-ol; α-terpineol; Linalyl acetate	Usman *et al*., 2010;
	Sterols	Sitosterol; Stigmasterol; Avenasterol; Spinasterol; 20-hydroxyecdysone; Polypodine B; Poststerone; Ecdysteroid;	Kokanova-Nedialkova *et al*., 2009;
	Terpenes	Limonene; *p*-cymene; α-pinene; β-pinene; Cryptomeridiol; 8-α-acetoxy; Apocarotenoids; Blumenol A; Racemic allenic ketones;	

TABLE I - Secondary metabolites of presented halophytic Amaranthaceae species

Species	Bioactive compounds	Compound	References
Chenopodium polyspermum	Flavonoids	Rutin; Quercetin; Procyanidin; Epicatechin;	Uslu *et al*., 2020; Dadáková *et al*., 2013
	Essential oil	Limonene; Ascaridol; Cymene; Camphor; Carene; Histamine; Safrole; Saponin;	Dembitsky, Shkrob, Hanus, 2008; Acık *et al*., 2012;
	Terpenes	β-myrcene; Limonene; α-terpinene; γ-isomer; *p*-cymene; δ^3-carene;	Kokanova-Nedialkova *et al*., 2009;
Chenopodium rubrum	Phenolic glycoside	Hydroxycinnamic acylglycosides;	Kokanova-Nedialkova *et al*., 2009; Dembitsky, Shkrob, Hanus, 2008; Kokanova-Nedialkova *et al*., 2009;
	Essential oil	α-terpinene Ascaridole	
	Sterols	Sitosterol; Stigmasterol; Campesterol; Avenasterol; Spinasterol;	
	Terpenes	Limonene; α-terpinene; β-Elemene; β-caryophyllene; β-selinene; δ^3-carene;	
	Aromatic cytokinins	6-[2-(β-D-Glucopyranosyloxy)benzylamino]purine; 6-[2-(β-D-glucopyranosyloxy) benzylamino]-2-methylthiopurine; 6-benzylamino-9-β-D- glucopyranosylpurine;	
Chenopodium vulvaria	Essential oil	Ascaridole α-terpinyl acetate	Dembitsky, Shkrob, Hanus, 2008;
	Terpenes	α-terpinene; γ-isomer; α-terpinolen; β pinene; Piperitone oxide;	Kokanova-Nedialkova *et al*., 2009

TABLE I - Secondary metabolites of presented halophytic Amaranthaceae species

Species	Bioactive compounds	Compound	References
Salicornia europaea	Flavonoids	Rutin; Quercetin-3-*β*-D-glucoside;	Jiang *et al*., 2012;
	Phenolic acids	*p*-coumaric acid; Trans-ferulic acid;	Panth *et al*., 2016;
Suaeda maritima	Phenolic acids	*n*-tetradecanyl dihydro caffeate; *n*-hexadecanyl dihydro caffeate; *n*-nonanyl-*n*-octadec-9-enoate;	Bilal, Hossain, 2019;
Salsola soda	Flavonol glycosides	Quercetin trisaccharide; Quercetin disaccharide; Quercetin 3-*O*- glucuronopyranoside; Rutin; Kaempferol glucuronide; Isorhamnetin 3-*O*-rutinoside; Isorhamnetin 3-*O*- glucuronopyranoside; Saponin; Dihexosyl-pentosyl-glucuronosyl oleanolic acid; Momordin IId; Momordin IIc;	Iannuzzi *et al*., 2020;

DISCUSSION

Halophytes are used in traditional medicine in several ways and in the treatment of various diseases (Ksouri *et al*., 2011; Zhao *et al*., 2010), such as diabetes, asthma, hypertension, rheumatism, gout, etc. Also, they can be used as diuretics, antiparasitics, antipyretics, laxatives and other (Stanković, 2019). Many species of the family Amaranthaceae are obligate halophytes (*Atriplex*, *Bassia*, *Camphorosma*, *Salicornia*, *Suaeda*, *Salsola* species) and are present exclusively on saline soils and saline habitats (Stanković, 2019). Most species of the family Amaranthaceae have economic significance. *Chenopodium* and *Atriplex* species have been used in human nutrition for a long time due to their nutritional properties (source of protein, minerals, vitamin A). *Salsola soda* is also used in diets as a vegetable (Török, Kapocsi, Deak, 2012), while *Salicornia europaea* is used as a salad and as a spice (Kim *et al*., 2021; Patel *et al*., 2016). *Chenopodium* and *Atriplex* species are also used as animal feed (Dadáková *et al*., 2013), as well as *Kochia* species since its seeds contain 84% of unsaturated fatty acids (Salehi *et al*., 2012).

Chenopodium, *Salicornia*, *Suaeda*, and *Salsola* species are used in medicine and pharmacy, but also in traditional medicine due to their medicinal properties. *Ch. album* is used as a diuretic, laxative, and sedative (Ibrahim *et al*., 2007) and has antirheumatic, anthelmintic, and antiphlogistic properties (Kokanova-Nedialkova *et al*., 2009). The whole plant *Ch. ambrosioides* has analgesic, carminative, antiasthmatic, and vermifuge properties and is used to treat intestinal and abdominal pain (Kokanova-Nedialkova *et al*., 2009). It also exhibits antifungal (Kumar *et al*., 2007), anthelmintic (Ketzis, 1999), trypanocidal (Kiuchi *et al*., 2002) and Antileishmanial activity (Monzote *et al*., 2006). *Ch. hybridum* possesses analgesic, while *Ch. vulvaria* has antispasmodic properties (Kokanova-Nedialkova *et al*., 2009).

A large number of species of the family Amaranthaceae form an integral part of arid or ruderal environments and are adapted to these conditions (Gelin, Mosyakin, Clemants, 2003). Some of them represent weed species (*Beta* spp., *Chenopodium* spp., species *Atriplex rosea*).

Most of the described species have a high content of secondary metabolites, especially phenolic compounds and flavonoids. Flavonoids are mainly present in the *Atriplex*, *Beta*, *Chenopodium* and *Suaeda* species. Phenolic compounds are present in *Atriplex*, *Chenopodium*, *Salicornia*, and *Suaeda* species. *Chenopodium* species, as being representative of this family, can be considered as a very good source of natural antioxidants, since all the described species have a high content of phenolic compounds or flavonoids and exhibit antioxidant activity. Phenols, sterols and terpenes were identified in species *Ch. album*, *Ch. ambrosioides* and *Ch. rubrum*, while only terpenes were observed in species *Ch. rubrum* and *Ch. vulvaria* (Kokanova-Nedialkova *et al*., 2009).

Chenopodium species have essential oils with a large number of active compounds. Ascaridol is among the two most abundant compounds in the described *Chenopodium* species. Limonene is the second main ingredient of the essential oil of species *Ch. album* and *Ch. polyspermum*. Compound α-terpinene was detected in *Ch. rubrum* and α-terpinyl acetate in *Ch. vulvaria* (Dembitsky, Shkrob, Hanus, 2008).

CONCLUSION

Many species of Amaranthaceae family are adapted to saline environments and inhabit coastal and continental habitats, arid areas, and deserts. Presented halophytic species from the family Amaranthaceae represent a source of biologically active substances exhibiting various activities such as antioxidant, anticancer, antibacterial, antifungal and others. Due to these activities, these species have wide application in traditional and modern medicine. Their extracts can be used in the pharmacological industry, while the aerial parts are often used for making teas and infusions. Also, some of them are a rich source of functional nutrients and can be used in food industry. In addition to numerous economic properties, certain species could be used in phytoremediation, phytostabilization and revegetation. The species of the family Amaranthaceae can have multi-purpose applications, but additional pharmacological studies are needed since a small number of halophytes have been tested so far.

CONFLICT OF INTEREST

The authors declare that they have no competing interests.

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