Mini Review

BIOMEDICAL Journal of Scientific & Technical Research

ISSN: 2574 -1241

DOI: 10.26717/BJSTR.2024.56.008904

The Biology of the Facultative Halophyte *Atriplex patula* L.

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ARTICLE INFO

Received: May 20, 2024

Published: May 28, 2024

Citation: Richard Stalter and Robert I Lonard**.** The Biology of the Facultative Halophyte Atriplex Patula L. Biomed J Sci & Tech Res 56(5)-2024. BJSTR. MS.ID.008904.

ABSTRACT

Atriplex patula L. is a facultative halophyte that tolerates low to moderate levels of salinity and occurs on the margins of coastal salt marshes, roadsides, in agricultural fields, and in other areas where disturbance has occurred. The genus *Atriplex* L. is represented by about 250 species globally and has recently been included in the family Amaranthaceae subfamily Chenopodioidae. *Atriplex patula* was possibly introduced in North America from Europe, Asia or North Africa in the 18th century. Because the stems and leaves accumulate and store heavy metal pollutants, *A. patula* has been suggested for use in habitat remediation.

Keywords: Spear Orach; Taxonomy; Geographical Distribution; Dimorphic Seeds; Germination; Facultative Halophyte; Physiological Ecology; Range of Habitats

Introduction

The genus *Atriplex* L. is represented by about 250 species globally. Molecular and morphological data have provided some evidence supporting the inclusion of the Chenopodiaceae in the family Amaranthaceae with the former family Chenopodiaceae now listed as a subfamily Chenopodioideae [1]. However, Welsh et al. [2] and others still use the *nomen* Chenopodiaceae in systematic treatments. *Atriplex patula* L. (spear orach, spearscale) is a facultative halophyte that tolerates low to moderate levels of soil salinity [3]. It is a widespread weedy species that occurs in agricultural fields, on roadsides, on the margins of coastal salt marshes, and in other areas where disturbance has occurred. *Atriplex patula* produces dimorphic seeds which allows the species to be established in unstable habitats [4, 3]. Welsh [1] indicated that *A. patula* was possibly introduced in North America from Europe, Asia, or North Africa in the 18th century, and its occurrence has been documented in at least 10 provinces in Canada and 29 states in the U.S.A. Chetina et al. [5] have reported that *A. patula* occurs in saline sites at 59º N near Perm Krai, Russia, and De Cauwer et al. [6] noted that this species is a weed control problem in sugar beet fields in Belgium. *Atriplex patula* has been suggested for use in habitat remediation because stems and leaves accumulate and store heavy metal pollutants [7]. Herein, we summarize important aspects of this widespread facultative halophyte.

Synonyms, Taxonomy, Variation

Synonymy of the *Atriplex patula* complex is in a state of confusion. Synonyms of *Atriplex patula* L. (spear orach, spreading orache, spearscale) in North America have primarily been listed as *Atriplex hastata* L. subsp. *patula* (L.) S. Pons, *A. hastata* var. *patula* (L.) Farwell, and *Teutiopsis patula* (L.) Selak [1], whereas Correll and Correll [8] listed *A. patula* L. as *A. patula* L. var. *hastata* (L.) Gray. The nomens *A. prostrata* Boucher and *A. hastata L. sensu* Aellen *non* L. have also been listed as synonyms by Stalter and Lamont [9]. The following taxonomic description of *A. patula* is summarized from treatments of the species by Correll and Correll, [8], Stalter, [10], Taylor and Wilken, [11], and Welsh, [1]. *Atriplex patula* is a monoecious annual with a root system that typically extends between 10 to 18 cm below the substrate surface. Stems are erect and branched, glabrous to scaly, and range from 30 cm to 1.5 m in height. Leaves are opposite below and alternate above.

Petioles of lower leaves are up to half as long as the blades. Blades are bright green, 2.5 to 7.0 cm long and nearly as broad, truncate at the base, and acute or obtuse at the apex. The staminate flowers bearing 5 tepals and 5 stamens are borne in a terminal spike or panicle. The pistillate flowers are usually borne in few-flowered axillary or spike-like cymes. Pistillate flowers have 2 stigmas, and the base of the ovary is enclosed in a pair of bracts often reddish at maturity and up to 7 mm long. Seeds are dimorphic. Brown seeds are 2.5 to 4.0 mm wide, and black seeds are 1.0 to 2.0 mm wide. Chromosome numbers for the *A. patula* complex are 2n = 18 and 2n = 36. In the Netherlands, Van Der Meyden [12] tentatively recognized *A. patula* L. and *A. hastata L*. as separate species. However, he noted that there are no sharp distinctions between the two taxa, and numerous overlapping morphological variations exist in leaf blade morphology between the two entities. Van Der Meyden [12] stated that different ploidy levels occur in the complex. *Atriplex hastata* is a diploid and *A. patula* is a tetraploid.

Geographic Distribution

Atriplex patula is an annual, weedy, facultative halophyte that has a wide distributional range in North America, Europe, North Africa, and Asia. Correll and Correll [8] reported its range in North America from Newfoundland westward to British Columbia in Canada, and from Newfoundland to South Carolina in the U.S.A. Stalter et al. [13] reported the occurrence of the species in coastal sites in northern Florida. On the Pacific coast of North America, it occurs from British Columbia to California. Ungar [3] indicated that it occurs in low to moderately saline sites in Kansas and Nebraska, and Correll and Correll [8] and Proffitt et al. [14] stated that *A. patula* is often present in saline sites in Texas and Louisiana. *Atriplex patula* in widespread in Europe. De Cauwer et al. [6] reported that *A. patula* is a weed control problem in sugar beet fields in Belgium, and Chetina et al. [5] reported the occurrence of this species in salinized alluvial soils at 59º N latitude at Perm Krai, Russia.

Range of Habitats

Atriplex patula is a weedy, facultative halophyte that occurs in a wide variety of soil types including sandy loams and clays [6], salt impacted alluvial soils [5, 15], and water-logged soils [16]. In sugar beet fields in Belgium, De Cauwer et al. [6] reported that the species is less common in acid sandy soils and is less tolerant to drought than to water-logging. Ungar [3] indicated that *A. patula* is a summer annual in the Central U.S.A. and can tolerate moderately saline soils under field conditions ranging from 2 ppt to 13 ppt total salts. In North Carolina, Stalter and Lamont [9] stated that habitats for *A. patula* are beaches and upper margins of brackish and salt marshes. In New England salt marshes, Rand [17-19] reported that this species is usually found in bare areas in the mid to high marsh in topographic zones usually dominated by *Juncus gerardii* or *Iva frutescens*. She noted that the annual halophyte *Salicornia europaea* may compete with *A. patula* in this harsh physical environment. Proffitt et al. [14] found a similar case in salt marshes in Louisiana where *A. patula* occurs in bare patches within sites dominated by *Sporobolus alterniflorus* (*Spartina alterniflora*).

Physiological Ecology

Atriplex patula has Kranz anatomy in leaves which is indicative of the associated C_4 carbon fixation pathway of photosynthesis [1]. The C_4 pathway increases efficiency of CO_2 usage and subsequent carbon fixation. Salinity is an important factor that affects imbibition of water in seeds, germination, root elongation, and overall plant vitality [20]. NaCl in the substrate affects osmotic balance and specific ions. Salinization influences the production of the low molecular weight amino acid proline in *A. patula* leaves. Proline acts as an antioxidant and protects cellular protein structure and ultimately increases *A. patula* resistance to salt in acidic soil conditions [5].

Dimorphic Seeds and Germination

Two types of seeds occur in *A. patula*. One is black and ranges in size from 1.0 to 2.0 mm in diameter, and the other seed type is brown and ranges in diameter from 1.3 to 3.0 mm [4, 3, 1]. Large brown seeds have three times the mass of smaller black seeds, a thin seed coat, a larger embryo, and absorbs water 100 times faster than unscarified black seeds [20-21]. Nurse et al. [21] stated stated that seed dimorphism enhances survival of the species in variable habitats. Larger brown seeds have a limited dormancy period and germinate rapidly in spring. However, brown seeds are more susceptible to fungal attack than black seeds [21]. Ungar [22] reported that black seeds have a hard seed coat, a long dormancy period, and scarification is required to break dormancy. In the laboratory, unscarified black seeds did not germinate. However, 73% of scarified black seeds germinated [4, 22]. Black seeds have greater resistance to high salinity stress than brown seeds and retain their viability longer than brown seeds [21]. In the laboratory, Ungar [22] found that seeds germinated and seedlings survived salinity concentrations up to 20 ppt. Germination was reduced at salinity values greater than 10 ppt, and germination declined to 17% of controls at 20 ppt. Ungar [22] also noted that seeds are less inhibited to high salinity levels that growing seedlings. In Oregon, Keammerer and Hacker [23] stated that *A. patula* seed viability was 91% in the high intertidal zone, but they did not mention seed dimorphism.

Competition and Herbivores

Atriplex patula does not fare well in competition with taller or more aggressive species in salt marshes. Minchinton et al. [24] reported that the common reed (*Phragmites australis*), in the upper margins of New England salt marshes, modifies soil and light conditions and produces a heavy cover of litter. These factors exclude the perennial *Solidago sempervirens* and the annual *A. patula* from this topographic zone. *Atriplex patula* seedling establishment and survival of mature plants only occurs at sites that have not been invaded by

P. australis. A chrysomelid beetle (*Erynephala maritima*) is a herbivore that damages *A. patula* and the succulent annual halophyte *Salicornia europaea* in salt marshes in Rhode Island [25]. Damage to *A. patula* is extensive at mid-tidal elevations which are frequently inundated [17]. She also found that *A. patula* plants are more extensively damaged when they are not present in dense stands of S. *europaea* [17]. In field plots cleared of S. *europaea* beetle herbivory reduced *A. patula* survival by about 50% and reduced reproduction by 37% [18, 19].

Phytoremediation

Atriplex patula is a species that removes significant amounts of Na ions from salt-impacted soils and stores salt in cellular vacuoles in stems and leaves [15]. They noted that the deep root system improves soil quality and soil permeability in oil field brine spill sites in Saskatchewan, Canada. Mature plants are removed of spill sites and are disposed off-site. High seed production insures a standing crop in the next growing season.

Vickerman et al. [7] examined *A. patula* for potential habitat improvement and phytoremediation of the heavy metal Se. They found that phytoremediation was greatest in saline sites having low to moderate levels of sulfate. They also indicated that mature plants could be mechanically harvested and disposed off-site.

Management and Role as an Allergen

Atriplex patula is an aggressive annual weed in sugar beet fields in Belgium. Various herbicides have been used to control the species. However, this species exhibits high intraspecific variation in herbicide sensitivity and weed control by herbicides has been shown to be difficult [6]. *Atriplex* species produce extensive amounts of wind-blown pollen and may play a role in allergic sensitization [26]. Ferrer et al. [27] noted that pollen of *A. patula* extracts should be used in a battery of potential allergens for use in diagnosis and treatment of respiratory allergies in patients.

Acknowledgment

We thank Matt Toska and Menahil Shahid undergraduate research students for obtaining reference articles and St. John's University for providing publication expenses.

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ISSN: 2574-1241

DOI: 10.26717/BJSTR.2024.56.008904

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