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Habitat Range of Four *Atriplex* Species Growing in the Mediterranean Coast of Egypt

Mamdouh S. Serag*, Abdel-Hamid A. Khedr, Reham M. Nada and Nesma M. El-Qashlan

Department of Botany and Microbiology, Faculty of Science, Damietta University, New Damietta, Egypt.

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*Corresponding author's E-mail: mserag@du.edu.eg; mamdouhserag054@gmail.com

Mobile: +201003489609

Abstract

Atriplex species are tolerant to salinity and drought, therefore; they are an appropriate for restoration of degraded arid and semi-arid lands. Lots of *Atriplex* species offer a high benefit as non-traditional forages as well. The purpose of this study is to evaluate the habitat range of four *Atriplex* species in the coastal area of the Mediterranean Sea of Egypt. Two of these species have C_3 photosynthesis; they are namely: *A. portulacoides* and *A. prostrata* and the other two are C_4 photosynthesis (*A. halimus* and *A. nummularia)*. The four species are growing in the different habitats along the Mediterranean Coast from New Damietta to Burullus Lake. Associated species with *Atriplex* were determined and soil samples were collected to identify the types of habitats.

Soil samples were analyzed to compare between C_3 and C_4 species on the basis of habitat. Results of soil analysis indicated that EC of the soil in which C_4 species grow is more than that of C_3 species and the percentages (%) of Cl^-, CO_3^- and organic carbon of the soil in which C_4 species grow are more than that of C_3 species, moreover, the moisture content of the soil in which C_3 species grow is higher than that of the soil in which C_4 species grow.

The obtained results from the soil variables will be useful for the understanding of the optimal habitat for C_3 and C_4 *Atriplex* species in the Mediterranean Coast of Egypt**.** Furthermore, the obtained data will help for the agro-application of these important halophytes**.**

Keywords: Arid and semi-arid lands; *Atriplex* species; soil variables; habitat range; C_3 and C_4 photosynthesis; halophytes, soil moisture.

Introduction

The growth of plants in various habitats develops with differentiated photosynthetic capacities which are called developmental acclimation of photosynthesis (Athanasiou et al. 2010). C_4 plants approximately have 50% higher photosynthetic efficiency than those of C_3 plants (Kajala et al. 2011). This is due to the different mechanisms of carbon fixation by the two types of photosynthesis (Fig. 1). C_4 plants have the ability to manage different environments because of their efficient C_4 photosynthetic system (Brown 1999; Sage 1999).

C_3 and C_4 plants are progressed in changed climates and as a result they vary from each other both functionally and structurally besides for their climatic conditions. While C_3 plants are supposed to have a moderate origin, C_4 plants are grown in arid and tropical habitats (Ward et al., 1999). C_4 plants are distinguished from C_3 plants in possessing a distinctive leaf anatomy owing to the existence of: (i) a characteristic bundle sheath known as kranz anatomy; (ii) dimorphism of chloroplast; (iii) insignificant photorespiration because of CO_2 concentrating mechanism in bundle sheath cells; (iv) two carboxylation pathways including ribulose 1, 5-bisphosphate carboxylase (RUBISCO) in bundle sheath cells and phosphoenolpyruvate carboxylase (PEPC) in mesophyll.

C_4 photosynthesis is a carbon-concentrating mechanism which evolved from C_3 ancestors as a minimum 65 times (Sage et al. 2012). Throughout C_4 evolution, an organized chain of biochemical and anatomical adjustments created the enzyme activities and compartmentation needed to concentrate CO_2 around Rubisco effectively (Monson and Rawsthorne, 2000).

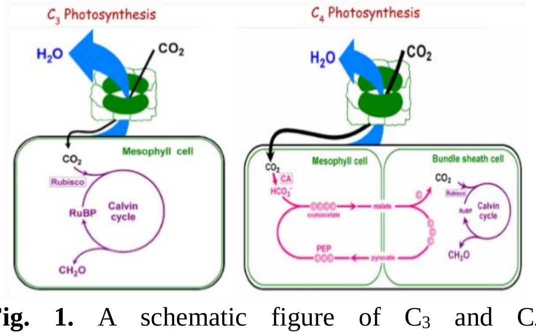

Fig. 1. A schematic figure of C_3 and C_4 photosynthetic pathways (Wang et al. 2012).

The genus *Atriplex* comprises C_3 and C_4 species. In Egypt, few species of *Atriplex* use C_3 photosynthesis such as *A. portulacoides*, *A. patula* and *A. prostrata* while most species of *Atriplex* use C_4 photosynthesis, for example *A. halimus, A. nummularia, A. rosea, A. inflata* and *A. semibaccata.*

Drought and soil salinity compromise water uptake and cause osmotic adjustment in xero-halophyte plant species. The genus *Atriplex* is almost distributed worldwide from subtropical to temperate and to subarctic zones. Many species are halophytes, they are acclimated to salty soils of dry environments. Species of genus *Atriplex* are perennial or annual herbs, shrubs or subshrubs. *Atriplex* currently has more than 260 recognized species distributed mostly in arid regions of the world. It is the richest genus of the Amaranthaceae family (Čalasan et al. 2022). It lives in a variety of soils from fine to coarse texture with altering degrees of salinity (Walker 2014). There are about 40-50 species are restricted to the Mediterranean coast (Dorda et al. 2005). It contains various desert, halophytes and seashore plants in addition to plants of moist environments. *Atriplex* is characterized by its high content of sodium chloride (El-Amier and El-Hayyany 2020).

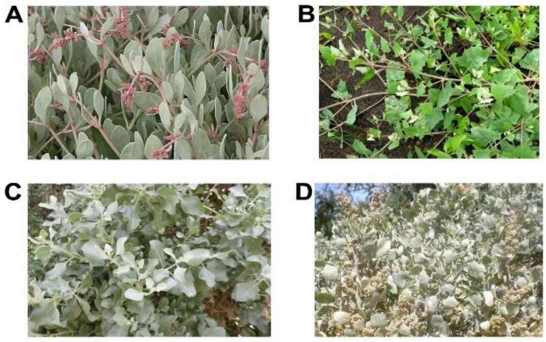

Fig.2. Four *Atriplex* species namely: A=*A. portulacoides*, B=*A. prostrata*, C=*A. halimus* and D=*A. nummularia*.

Atriplex species are common in several arid and semi-arid regions of the world, mainly in areas that considerably blend aridity with high soil salinity (McArthur and Sanderson 1984). *Atriplex* spp. are used as forage for domestic and wild animals and for reintegration of degraded land such as saline/alkaline soils, sand dunes, badlands and mine-affected soils.

This study will focus on the habitat range of four *Atriplex* species along the Egyptian Mediterranean coast. Two of these species possess the C_3 pathway (*A. portulacoides* and *A. prostrata)* and the other two possess the C_4 pathway (*A. halimus* and *A. nummularia)*

(Fig. 2).

Materials and Methods

Study Area

A field survey was carried out during 2019/2020 along the Mediterranean coast of Egypt from New Damietta to Burullus Lake to identify the habitat types and the associated species of *Atriplex* species (Fig. 3). Soil samples were collected from different sites according to habitat physiognomy and physiography. Three habitat types were identified namely: salt marsh, sand flats, and road sides. Species found with *Atriplex* spp. were listed. Voucher specimens of plant species were placed in the Herbarium of the Botany and Microbiology Department, Faculty of Science, Damietta University. Nomenclature follows Taeckholm (1974) and Boulos (2009). The climate of the area is typically Mediterranean type and belongs to the arid province. The climatic conditions were 35/30ºC day/night temperature, 49% relative humidity (RH) during the day and the light intensity was 1221 μmol m^{-2} s^{-1}.

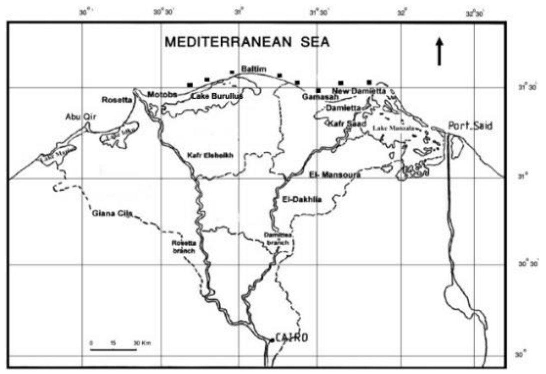

Fig.3. Location map of study area showing the different sites where the four *Atriplex* species and soil samples were collected.

Soil Sampling and Analysis

Among different sites in the field occupied by *Atriplex* species along the deltaic Mediterranean coast, twenty sites were selected. Soil moisture content had been determined by using soil moisture meter (model PMS-714). Five replicates from each site were used. Soil samples were collected from the rhizosphere of plants (0-10 cm depth), the samples were sieved through a 2 mm sieve to throw out debris and coarse gravel and then dried in oven at 105°C for 24 hours or until completely dried. About 20 g of oven-dried soil sample (for each treatment) was extracted in ratio of 1:5 (soil: water) and used to determine pH using Beckman Bench type pH meter (Model 5995), conductivity (EC) using Conductivity meter (Model 35) and also used for chemical soil analyses including determination of the percentage of chlorides, carbonates and bicarbonates. The percentage of calcium carbonates and organic carbon matter were also determined. Three replicates were used for each analysis. The practical procedures of soil variables were carried out according to (Jones 2018).

Statistical Analyses

All measurements were replicated as explained. Box plot chart was performed using Excel 2021 to compare between samples.

Results

Floristic Features

Atriplex species were recorded in three different habitats along the deltaic Mediterranean coast of Egypt. Twenty-nine species that recorded as co-dominant or associated species with *Atriplex* were listed in Table (1). The most common associates in salt marsh habitat are *Arthrocnemum macrostachyum* (P=100%), *Mesembryanthemum crystallinum* (P= 50%), *Lambarda crithmoides* (P= 70%), *Phragmites australis* (P= 80%) and *Tamarix nilotica* (P=40%). In roadside habitat, the most associated species with *Atriplex* are *Phragmites australis* (P= 70%) and *Chenopodium album* (P= 80%). In the sand flats habitat, fewer associates were recorded, the most common is *Lycium schweinfurthii* (P= 40%).

Data in (Fig. 4.A) showed that the highest and the lowest soil pH was in the soil in which *A. halimus* grows. The range of pH in all species is from neutral to weak alkaline. Data in (Fig. 4.B) showed that the highest soil salinity was in the soil in which *A. nummularia* grows and the lowest soil salinity was in the soil in which *A. halimus* grows. Data in (Fig. 4.C) showed that the highest percentage of chloride (Cl^{-}%) was in the soil in which *A. nummularia* grows and the lowest percentage was in the soil in which *A.*

halimus grows. Data in (Fig. 4.D) showed that the highest percentage of carbonates (CO_3^{--}%) was in the soil in which *A. nummularia* grows and the lowest percentage was in the soil in which other species grow. Data in (Fig. 4.E) showed that the highest percentage of calcium carbonates ($CaCO_3$%) was in the soil in which *A. prostrata* grows and the lowest percentage was in the soil in which *A. halimus* grows. Data in (Fig. 4.F) showed that the highest percentage

Table 1. Presence (%) of plant species associated with *Atriplex* in the different habitats along the Deltaic Mediterranean coast of Egypt.

Species	Habitat types		
	Salt marsh	Sand flats	Road sides
Atriplex halimus L.	100	100	100
Atriplex nummularia L.	100	100	100
Atriplex portulacoides L.	100	100	100
Atriplex prostrata L.	100	100	100
Arthrocnemum macrostachyum Moric.	100		
Mesembryanthemum crystallinum L.	50		
Chenopodium album L.			60
Atriplex semibaccata	40	30	
Atriplex inflata			50
Aster squamatus (Spreng.) Hieron	30		10
Cressa cretica L.	10		
Cynodon dactylon (L.) Pers.			10
Echinops spinosissimus Turra.		20	
Halocnemum strobilaceum (Pall.) M. Bieb.	20		
Hordeum marinum Huds.		20	10
Juncus rigidus Desf.	30		
Lambarda crithmoides L.	70		
Lycium schweinfurthii Dammer		40	
Malva parviflora L.			40
Phoenix dactylifera L	10		
Phragmites australis (Cav.) Trin. Ex Steud.	80		70
Rumex pictus Forssk.		10	
Senecio glaucus L.		10	10
Tamarix nilotica (Ehrenb.) Bunge	40		10
Zygophyllum aegyptium Hosny.	20	10	
Bassia indica (Wight) A. J. Scott	20		40
Avena fatua L.			20
Beta vulgaris L.			30
Chenopodium ambrosiodes L.			20

Habitat characteristics

bicarbonates (HCO_3^-%) was in the soil in which *A. prostrata* grows and the lowest percentage was in the soil in which *A. halimus* grows. Data in (Fig. 4.G) showed that the highest percentage of organic carbon was in the soil in which *A. nummularia* grows and the least percentage of the organic carbon matter was in the soil in which *A. halimus* grows. Data in (Fig. 4.H) showed that the highest percentage of soil moisture was in the soil in which *A. portulacoides* grows and the least percentage of soil moisture was in the soil in which *A. nummularia* grows.

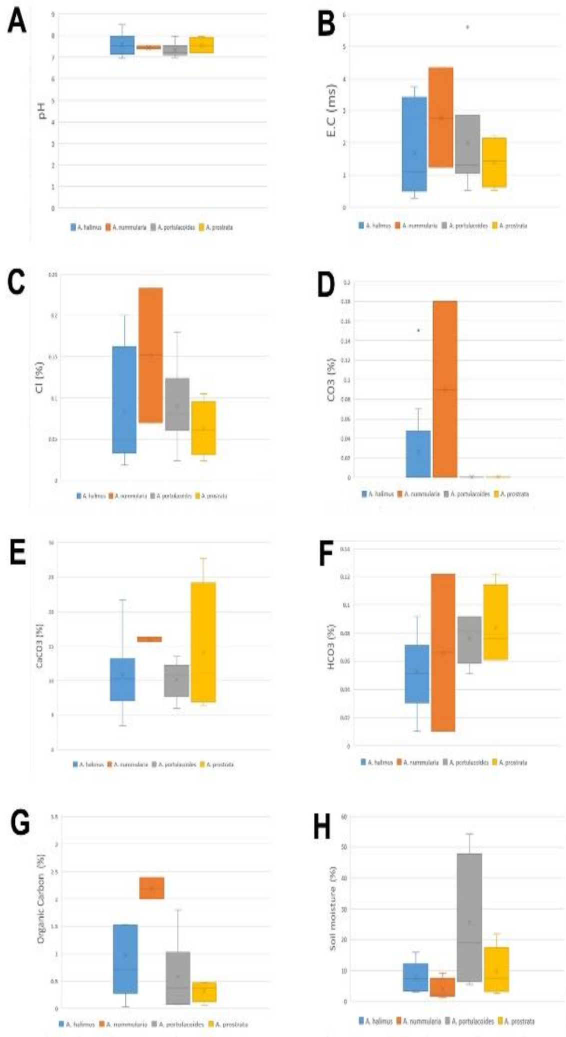

Fig.4. Box plot for the soil chemical analysis (measurement of pH, EC, and soil moisture and determination the percentage of Cl^-, CO_3^{--}, HCO_3^-, $CaCO_3$ and organic carbon) of the four *Atriplex* species.

Discussion

The present study aims to assess the relation between the soil analysis and the different habitats characterizing the Mediterranean region of Egypt. Salinity is one of the greatest critical environmental problems, since it is undesirably affecting production by limiting the productivity and growth of plants specifically in arid agricultural and semi-arid areas of the world. Most developing countries suffer from a lack of fresh water supply and cultivated lands as a consequence of the negative effect of climate changes. Hence, growing of non-traditional crops such as halophytes could be a good solution to solve the trouble of salty environments (Tawfik et al. 2019). In saline and arid regions, plants develop different shapes of photosynthetic pathways to cope with the severe conditions (Atia et al. 2014).

pH is a measure of soil acidity. Hydrolysis of basic cations tends to sustain a stable pH with dilution in the soils that have higher values of pH. A main factor affecting pH of soils is the salt content of the soil solution (Thomas 1996). The analysis of soil is complex due to the many factors that make the soil good. EC is an evaluation of salt content or chemical source. It is used to evaluate the soil quality. The measurement of both EC and pH gives a more perfect indication of the soil chemical nature (Smith and Doran 1997).

In soil solution, Cl found mainly as chlorides anions (Cl^-). Chlorides are major osmotically active solutes in the vacuole and is involved in both osmoregulation (White and Broadley 2001).

Secondary carbonates are found in calcareous soils. They are essential components of the soil mineral medium; they are abundant in a lot of arid and semi-arid regions. The carbonates of the soil had been described as an organic matter stabilization agent, essentially by reason of their mechanisms of chemical stabilization (Virto et al. 2018).

Soil organic carbon sometimes improves the soil water content estimation (Manns and Berg 2014).

Soil moisture content is a key variable of the climatic system. It obliges plant transpiration and photosynthesis in frequent regions of the world. It is concerned with numerical feedback at the local and global scales and it plays a crucial role in climate change forecasts (Seneviratne et al. 2010). Soil moisture content has somewhat significant influence on agronomic, ecological, hydrological and biological behavior of the soil mass (SU et al. 2014).

A. portulacoides distribution inside a saltmarsh had been related to suitable substrate drainage. Armstrong et al. (1985) observed that distribution of species in the salt marshes was alongside stream banks which are discriminated by their high level of aeration. Within a saltmarsh (Cott et al. 2013). It is used for desalination of the saline habitats or phytoremediation of lands affected by salts in the Deltaic wetlands of Egypt (Nafea 2017).

A. prostrata is an annual salt marsh species that grows on changed and nitrified soils whether saline or not (Bueno et al. 2017).

A. halimus is found in arid zones of North Africa. It is common in the Isthmic desert (Bedair et al. 2020). This species shows an excellent tolerance to drought and salinity (Le Houérou 1992).

A. nummularia (common name: old man saltbush) is one of the very important species used for the revegetation of destroyed land in low rainfall areas (Sampson and Byrne 2012). It is found in oases, Nile Delta and the Western Mediterranean (Bedair et al. 2020). It is occurred in the semi-arid zone, sandy coastal bluffs and pure stands on limestone plains or low-lying saline clay soils such as floodplains (Kramer 1982) but also found in a range of habitats. It is highly adaptable and can occur in most soils.

The soil analysis gives us a confirmation about the proper condition for the cultivation and growth of the selected plant species. The results of soil variables indicate that *A. nummularia* grows in a highly saline soil containing a high concentration of chlorides, carbonates, bicarbonates and organic carbon. Another proof is that the moisture content of the soil in which C_3 species grow is higher than the moisture content of the soil in which C_4 species grow.

The C_3 pathway is more common in halophytes whereas the C_4 one is more abundant in the xerophytes, psamo-halophytes, gypso-halophytes and gypsophytes (Atia et al. 2014).

C_4 photosynthesis was associated with high drought and salt tolerance (Glenn et al. 2012). Most of C_4 shrub species distributed in sandy soils. Composition of Amaranthaceae C_4 species was the principal feature for the C_4 species presence in desert regions and this was unusually correlated to the arid conditions of the environment (Wang 2007).

Conclusion

It could be concluded that the C_3 *Atriplex* species are often typical halophytes; they adapted to brackish marshes. Therefore; they prefer the wetland or moist salt marsh habitat while the C_4 *Atriplex* species are xero-halophytes; they can tolerate the dry soil and grow in arid or semi-arid salt marsh habitats.

These halophytes are promising for agro-application and cultivation of these species of *Atriplex* in newly reclaimed lands.

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الملخص العربي

عنوان البحث: المدى البيئي لأربعة أنواع من نبات القطف تنمو على ساحل البحر المتوسط بمصر

ممدوح سالم سراج ، عبد الحميد عبد الفتاح خضر، ريهام محمد ندا، نسمة محمد رضا القشلان

قسم النبات والميكروبيولوجى – كلية العلوم- جامعة دمياط - مصر.

تتميز أنواع نبات القطف *Atriplex* بأنها تتحمل الملوحة والجفاف، وبالتالي فهي مناسبة لاستعادة الأراضي القاحلة وشبه القاحلة المتدهورة. بالإضافة إلى ذلك، فإن العديد من أنواع القطف (*Atriplex*) تقدم قيمة جيدة كأعلاف غير تقليدية. الهدف من هذه الدراسة هو تحديد المدى البيئي لأربعة أنواع من نبات القطف (*Atriplex*) في المنطقة الساحلية للبحر المتوسط في مصر. يستخدم اثنان من هذه الأنواع عملية التمثيل الضوئيC_3؛ وهما: *A. portulacoides* و *A. prostrata* والاثنان الآخران يستخدمان عملية التمثيل الضوئي C_4 (*A. halimus* و *A. nummularia*) وتنمو الأنواع الأربعة في بيئات مختلفة على طول ساحل البحر المتوسط من دمياط الجديدة إلى بحيرة البرلس للتعرف على أنواع الموائل والأنواع المرتبطة بالقطف وقد تم تحليل عينات التربة هذه للمقارنة بين الأنواع C_3 و C_4على أساس الموائل. أشارت نتائج تحليل التربة إلى أن ملوحة التربة التي تنمو فيها أنواع C_4 أكثر من تلك الموجودة في أنواع C_3 وأن النسب المئوية (٪) للكلور والكربونات والكربون العضوي في التربة التي تنمو فيها أنواع C_4 أكثر من تلك الخاصة بأنواع C_3 وعلاوة على ذلك، فإن محتوى الرطوبة في التربة التي تنمو فيها الأنواع C_3 أعلى من محتوى الرطوبة في التربة التي تنمو فيها الأنواع C_4.

النتائج المتحصل عليها سوف تفيد في معرفة الموطن الأمثل لأنواع القطف المستخدمة للتمثيل الضوئي C_3 وC_4 في المنطقة الساحلية للبحر المتوسط كما أن البيانات التي تم الحصول عليها ستساعد في التطبيق الزراعي لهذه النباتات الملحية المهمة.