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Research Article

A new species record for the flora of Türkiye; *Caroxylon vermiculatum* (L.) Akhani & Roalson (*Chenopodiaceae / Amaranthaceae*)

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Abstract: In this study, *Caroxylon vermiculatum* (L.) Akhani & Roalson, which is distributed in Southwest Europe, Northwest and Central Africa, and the Middle East, is recorded for the first time from Türkiye. The species was collected from the Akçakale district of Şanlıurfa province, close to the Syrian border. The description of the species, synonyms, a distribution map, photographs of the specimens, and its morphological characteristics are given. In addition, the diagnostic characteristics of known perennial species of the genus *Caryxylon* from Türkiye were compared.

Özet: Bu çalışmada, Güneybatı Avrupa, Kuzeybatı ve Orta Afrika ile Orta Doğu ülkelerinde yayılış gösteren *Caroxylon vermiculatum* (L.) Akhani & Roalson türünün kaydı ülkemizden ilk defa verilmektedir. Tür, Şanlıurfa ili Akçakale ilçesinden, Suriye sınırına yakın alanlarda toplanmıştır. Türün betimi, sinominleri, Türkiye ve Dünyadaki dağılım haritası, türün genel ve detaylı morfolojik karakterlerinin fotoğrafları verilmiştir. Ayrıca *Caryxylon* cinsine ait Türkiye'den bilinen çok yıllık türlerin diagnostik özellikleri ile karşılaştırılmıştır.

Introduction

Caroxylon Thunberg was first described in 1782, to place the shrubby *Caroxylon salsola* Thunberg in. It was subsequently recognized as a separate genus with 19 species in a study by Moquin-Tandon (1849). However, in 1851, the genus was transferred to the genus *Salsola* L. by Fenzl and recognized as a section of it (*Salsola* L. sect. *Caroxylon* Fenzl) (Fenzl 1851). This taxonomic status has been accepted in all studies carried out since Fenzl's work in 1851, reaching to early 21st century (Il'in 1936, Brenan 1954, Aellen 1967, Freitag & Rilke 1997, Freitag 2001, Aellen & Akeroyd 2003, Zhu *et al.* 2003).

Based on phylogenetic, morphological, and anatomical studies conducted in the last two decades (Akhani *et al*. 2007, Wen *et al*. 2010, Voznesenskaya *et al*. 2013), many new genera have been separated from the genus *Salsola*, which is considered polyphyletic. One of these is the genus *Caroxylon*. The necessary systematic and taxonomic arrangements for the genus and its representative taxa were established by various authors (Akhani *et al.* 2016, Mucina 2017, Mosyakin 2019, Rudov *et al.* 2020). The genus *Caroxylon* currently includes 128 species naturally distributed in Europe, Africa, and Asia (Powo 2023). In Türkiye, it is represented by eight species, of which *Caroxylon stenopterum* (Wagenitz) Akhani & Roalson is the only endemic taxon (Yaprak 2012). Of these eight taxa, four (*C. dendroides* (Pall.) Tzvelev, *C. ericoides* (M.Bieb.) Akhani & Roalson, *C. laricinum* (Pall.) Tzvelev, and *C. nodulosum* Moq) are perennial woody plants and four (*C. inerme* (Forssk.) Akhani & Roalson, *C. stenopterum* (Wagenitz) Akhani & Roalson, *C. incanescens* (C.A.Mey.), and *C. nitrarium* (Pall.) Akhani & Roalson Akhani & Roalson are annual herbaceous plants. All of them are distributed in saline areas and salty steppes in Central, Eastern, Southeastern Anatolia and the Aegean regions of Türkiye.

In this study, *Caroxylon vermiculatum* was recorded for the first time in Türkiye from Akçakale district of Şanlıurfa province. In addition, habitat information, distribution in Türkiye and the world, morphological characteristics of the species are given and these characteristics are compared with other four perennial *Caraxylon* species in Türkiye.

Materials and Methods

Caroxylon specimens with different morphological characteristics were collected in areas close to the Syrian border of Türkiye during field studies conducted by the authors in 2018, 2022, and 2023 in the Akçakale district of Şanlıurfa province. They were pressed, dried, and preserved for identification in accordance with common herbarium procedures. The first attempt to identify the

specimens using the volumes of "*Flora of Turkey"* (Aellen 1967, Davis *et al*. 1988, Güner *et al*. 2000) showed that the specimens did not belong to any previously recorded *Caroxylon* species naturally distributed in Türkiye. Therefore, the specimens were identified using other relevant literature (Boissier 1875, Il'in 1936, Brenan 1954, Tutin *et al*. 1964, Aellen & Hillcoat 1964, Zohary 1966, Tackholm 1974, Castroviejo 1990, Hedge 1997, Boulos 1999, Freitag 2000). Digital photographs of specimens of this species in international herbaria (BR, DES, L, LISI, LUX, MA, MW, P, W, WAG, WU, TAA, U, and US, with acronyms according to Thiers 2023+) were also examined and compared with the identified specimens of the present study. A list of some of the specimens examined is given in the Supplementary Material by country. *Caroxylon vermiculatum* specimens collected in the present study are included in the collection of the herbarium of the Department of Biology, Faculty of Science, Ankara University (ANK). Detailed information about the collection locality is in the Result section.

Digital measurements of all morphological characters were made in dry specimens using a BAB stereo binocular microscope and Bs200Pro BAB image processing and analysis system (BAB Image Analysing Systems). For each taxonomically valuable character of *C. vermiculatum* used to determine the limits of variation, 100 measurements were made separately. Morphological and morphometric measurements were made on both fruiting and flowering specimens collected in different years and at least ten different individuals were examined (see Supplementary Material). Using the obtained data, a comprehensive description of the population of the species in Türkiye was prepared.

Results

Taxonomy

Based on current data, the species is classified within the tribe *Caroxyleae* Akhani & Roalson of the subfamily *Salsoloideae* Raf. family of *Amaranthaceae* Juss.

Caroxylon vermiculatum (L.) Akhani & Roalson, Int. J. Pl. Sci. 168(6): 948 (2007), (Fig. 1, 2).

≡ *Salsola vermiculata* L. in Sp. Pl.: 223 (1753); *Nitrosalsola vermiculata* (L.) Theodorova in Ukrayins'k. Bot. Zhurn. 72: 444 (2015).

= *Chenopodium flavescens* (Cav.) Schult. in J.J. Roemer & J.A. Schultes, Syst. Veg., ed. 15[bis]. 6: 269 (1820); *Nitrosalsola hispanica* (Botsch.) Theodorova, Ukrayins'k. Bot. Zhurn. 72: 443 (2015); *Nitrosalsola portilloi* (Caball.) Theodorova, Ukrayins'k. Bot. Zhurn. 72: 444 (2015); *Itrosalsola rodinii* (Botsch.) Theodorova, Ukrayins'k. Bot. Zhurn. 72: 444 (2015); *Salsola buxifolia* Dum. Cours., Bot. Cult. 1: 622 (1802); *Salsola ericifolia* Masson ex Link, C.L. von Buch, Phys. Beschr. Canar. Ins.: 141 (1828); *Salsola flavescens* Cav., Icon. 3: 45 (1796); *Salsola frankenioides* (Caball.) Botsch., Novosti Sist. Vyssh. Rast. 11: 281 (1975); *Salsola hispanica* Botsch., Bot. Zhurn. (Moscow & Leningrad) 60: 501 (1975); *Salsola microphylla* Cav., Icon. 3: 45 (1796); *Salsola portilloi* Caball., Bol. Real Soc. Esp. Hist. Nat. 36: 143 (1936); *Salsola rodinii* Botsch., Bot. Zhurn. (Moscow & Leningrad) 60: 504 (1975); *Salsola tamariscifolia* Lag., Gen. Sp. Pl.: 12, nom. illeg. (1816); *Salsola vermiculata* var. *flavescens* (Cav.) Moq., A.P. de Candolle, Prodr. 13(2): 181 (1849); *Salsola vermiculata* var. *frankenioides* (Caball.) Maire, Bull. Soc. Hist. Nat. Afrique N. 28: 378 (1937); *Salsola vermiculata* subsp. *frankenioides* Caball., Bol. Real Soc. Esp. Hist. Nat. 36: 141 (1936); *Salsola vermiculata* var. *glabrescens* Moq., Chenop. Monogr. Enum.: 141 (1840); *Salsola vermiculata* var. *microphylla* (Cav.) Moq., A.P. de Candolle, Prodr. 13(2): 181 (1849); *Salsola vermiculata* var. *portilloi* (Caball.) Maire, Bull. Soc. Hist. Nat. Afrique N. 28: 378 (1937); *Salsola vermiculata* var. *pseudopapillosa* Caball., Bol. Real Soc. Esp. Hist. Nat. 36: 141 (1936); *Salsola vermiculata* var. *pubescens* Moq., Chenop. Monogr. Enum.: 141 (1840).

Woody or dwarf shrub with many stems from the base. **Stems** 40-120 cm long, up to 1 cm in diameter, prostrate to erect, branched at the upper part; branches 5-30 cm long, ascending to spreading, alternate; in addition to the flowering shoots often with numerous shorter vegetative shoots; cream or dirty-white at early stage, brown at maturity, cylindrical, with dense short crisped and sparse long pilose hairs 1-3 mm long; stem epidermis partially peeling on the lower parts of the stem at flowering, whole stem epidermis peeling at maturity. **Leaves** (4-)5-12 × 0.30-0.65 mm, linear, needle-like, triangular, green, greenish-gray, with short crisped and long pilose hairs; base slightly widened, margins entire, apex acute, upper parts semi-terete or terete, alternate, older leaves recurved, younger leaves straight or slightly incurved. **Bract** 1, (1.5-)2.0-7.50 × 1.2-3.2 mm, lower bracts leaf-like, longer than bracteoles, the upper scale-like, equal to bracteoles, sessile, succulent, ovate or ovate-lanceolate to subulate, green, greenish-grey, straw-colored at maturity; margins membranous, apex acute or obtuse, abaxial part with short crisped hairs and prominent single vein. **Bracteoles** 2, 1.9-2.8 × (0.8-)1.0-1.9 mm, ovate, sessile, slightly fleshy, green to greenish-grey, connated only at base, single-veined, apex acute or rarely acuminate, margins membranous (0.5 mm part), with short crisped hairs. **Inflorescence** paniculate-spike or thyrse-spike; flowers alternate, in axils of bracts and bracteoles. **Perianth** with 5 free segments, 1.7-2.5 × 0.6-1.5 mm, 1-veined, glabrous, membranous, ovate to ovate-lanceolate, with green triangular blotch on abaxial part, margins entire, apex acute or rarely acuminate. **Stamens** 5, 1.2-4.2 mm long, glabrous; **anthers** 1.0-2.0 × 0.4-1.0 mm, yellow, ovate-oblong, sagittate, opening longitudinally; **filaments** 0.7-3.7 × 0.10-0.60 mm, gray, flat, short in the early period and then elongated (flowering time), dorsifixed. **Pistil** 1, 2-carpellate, 1-locular, 2.5-4.5 mm long, glabrous; **stigmas** 2, 0.4-1.1 mm long, subulate, papillate, light brown; **style** 1, 0.6-1.2 mm in length, cylindrical ovary 0.6-2.0 × 0.7-1.9 mm, globose-rounded

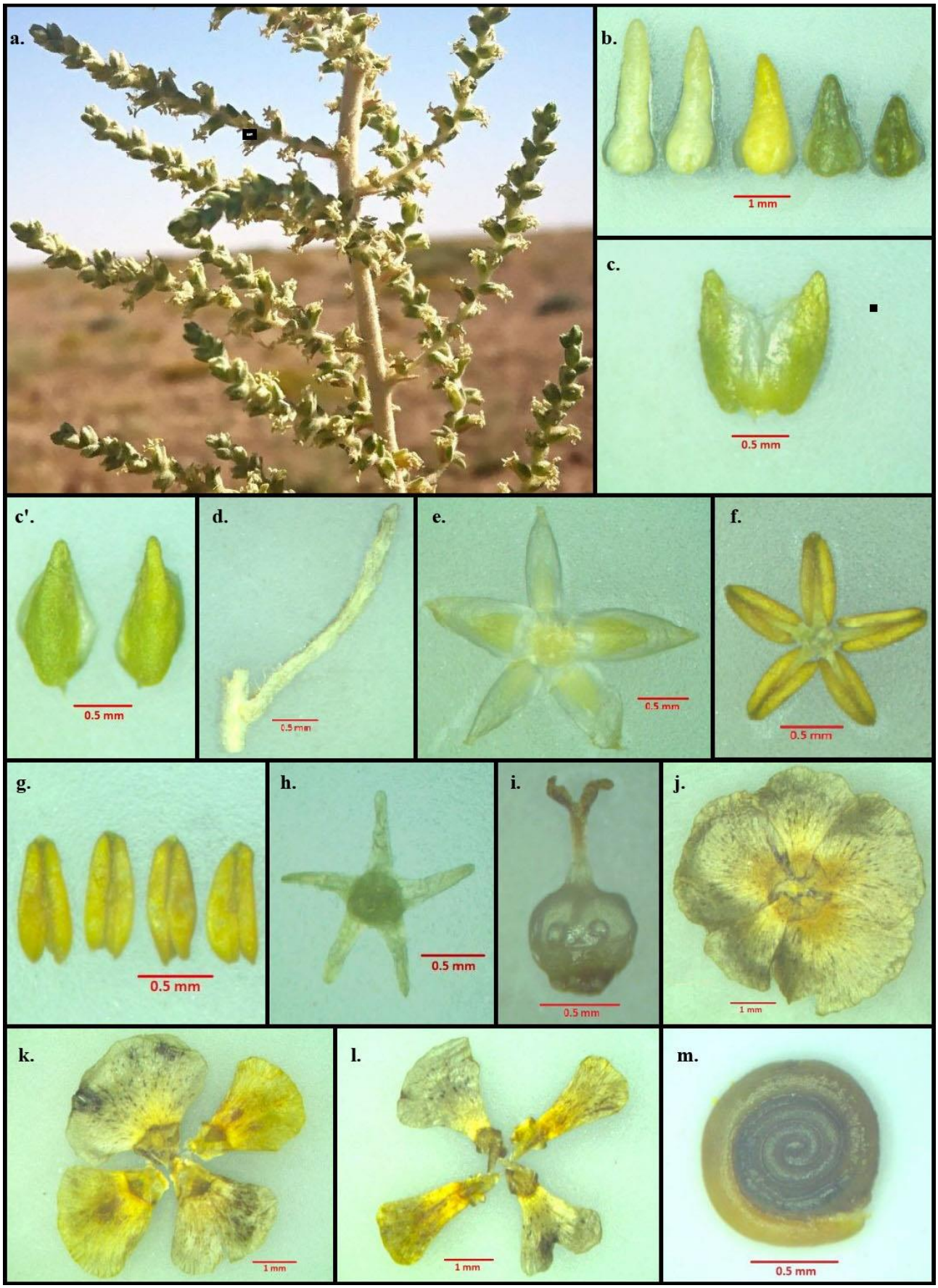

Fig. 1. Morphological characteristics of *Caroxylon vermiculatum*. **a.** Inflorescence, **b.** bracts **c-c'.** bracteoles, **d.** leaf, **e.** perianth segments, **f.** stamens, **g**. anthers, **h.** filaments, **i.** pistil, **j.** fruit, **k.** outer fruit wings, **l.** inner fruit wings, **m.** seed.

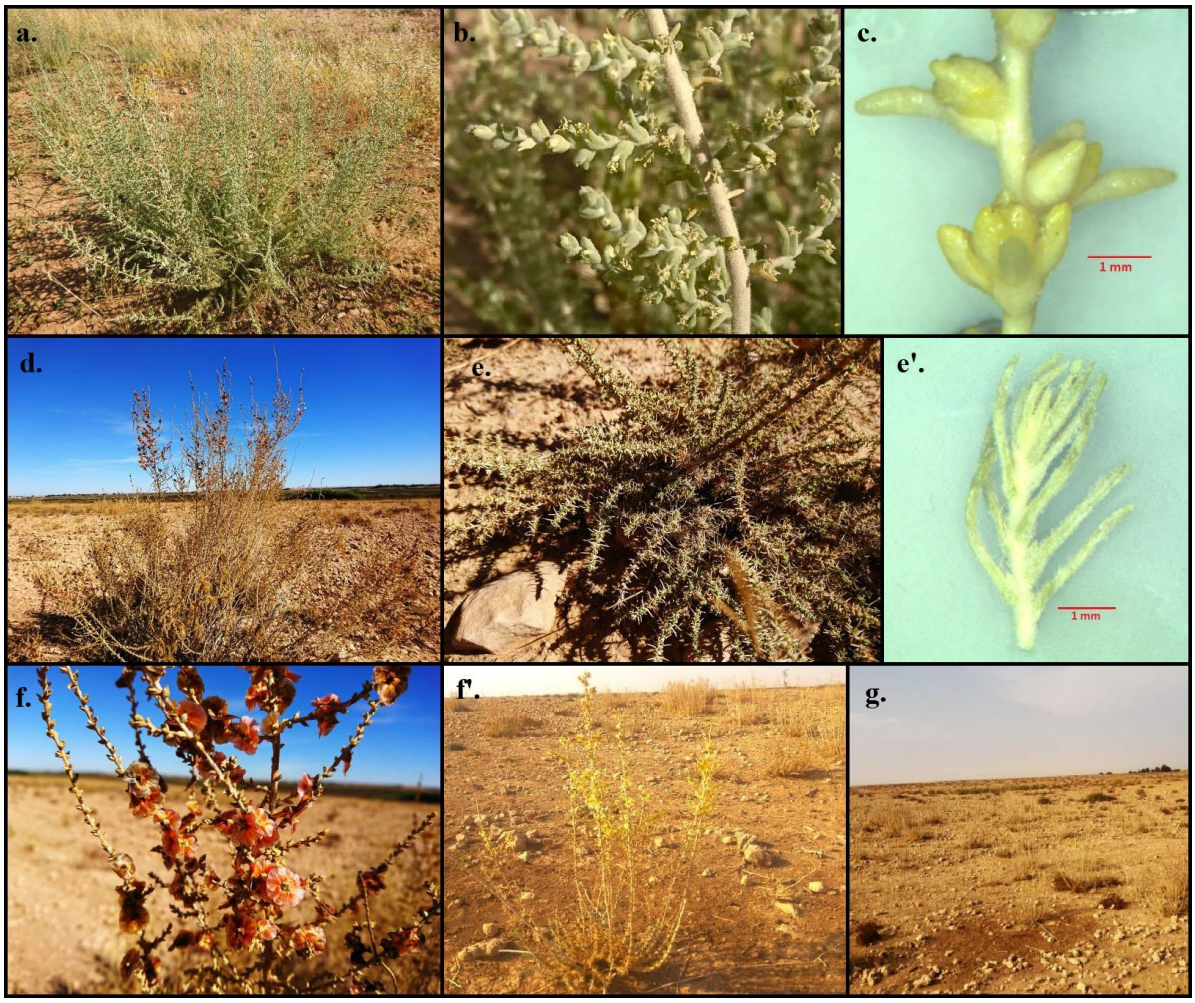

Fig. 2. Habitus, leaf, flower, habitat and fruit structures of *Caroxylon vermiculatum.* **a.** Habitus in flowering time, **b.** inflorescence, **c.** flower structures, **d.** habitus in fruiting time, **e-e'.** leaf structures, **f-f'.** fruit structure (pink, orange and yellow fruit), **g.** habitat.

or rarely pyriform. **Fruit** dry, 8.0-13.0 × 8.0-11.5 mm, rounded or ovoid, glabrous, yellow, orange or pink at early stage, light brown at maturity, with 5 wings, 3 outer and 2 inners; **outer** wings 3.0-5.6 × 3.5-8. 5 mm, obovate, reniform or flabellate, margins entire, tip obtuse or rarely emarginated, sometimes with black spots; **inner** wings 3.2-5.0 × (1.75-)2.0-5.0 mm, obovate or flabellate, margins entire, apex obtuse or rarely emarginated, sometimes with black spots. Seed 1, 1.7-3.0 × 1.7-2.7 mm, horizontally positioned, rounded; testa membranous; embryo spiral, radicle brown, plumula green.

Type: Hispania, L(Oeffling) 200, holotype (LINN. 315.20, photo!)

Locality: C7 Şanlıurfa province, Akçakale district, Öncül village, 2 km east of the village, field or irrigation canal edges, 360 m, 28 October 2018, 36°42'51.84"N, 39° 3'10.81"E, *Başköse-4459* (ANK).

Phenology: The species is flowering in July and August and fruiting in September and October.

Habitat: The species is known from a single locality in Şanlıurfa province, Akçakale district, close to the Syrian border. *Caroxylon vermiculatum* is distributed in slightly saline soils, fallow fields, and field edges or around irrigation canals at an altitude of 360 m a.s.l in Türkiye. The population of the species is represented by about 80 mature individuals and is distributed in an area of 1-2 km². This area is surrounded by agricultural fields and is under great anthropogenic effects. It is also under grazing pressure (cow and sheep) at some periods of the year. In addition, distribution area of the species is rarely used for military activities.

Distribution in Türkiye and the world: *Caroxylon vermiculatum* was first described by Linnaeus in 1753 within the genus *Salsola* as *S. vermiculata.* Today, the species is naturally distributed in Algeria, the Balearic Islands, the Canary Islands, Djibouti, Egypt, Georgia, Iran, Iraq, Israel, Italy (Sicily and Sardinia), Jordan, Lebanon, Mauritania, Morocco, Niger, Portugal, Saudi Arabia, Spain, Sudan, Syria, and Tunisia (Hedge 1997, Gbif 2023, Powo 2023) (Fig. 1). It has also been recorded in the United States, where it is considered an invasive species. With this study, the presence of *C. vermiculata* in Türkiye was confirmed and its distribution in the world was updated (Fig. 3).

Fig. 3. The distribution map of *Caroxylon vermiculatum* in world (**a**, **b**) and Türkiye (**c**).

Discussion

As a result of detailed morphological and morphometric measurements, it was understood that the collected specimens belong to *C. vermiculatum*, which has not been previously recorded from Türkiye. In this study, *C. vermiculatum* is reported from Türkiye for the first time, increasing the number of species of the genus *Caroxylon* in Türkiye to nine. The specimens of *C. vermiculata* were collected from Akçakale district of Şanlıurfa province, close to the Türkiye-Syria border. For identification of new plant records, border regions between countries are particularly important regions in terms of reports of new plant records for the countries in question. For instance, the authors of the present study (Başköse & Yaprak 2021) and other researchers (Kaya *et al.* 2010) have previously reported new plant records from the region where the material of the study was collected.

Caroxylon vermiculatum is the fifth perennial woody species within the genus after *C. dendroides*, *C. ericoides*, *C. laricinum*, and *C. nodulosum* in Türkiye. A comparison of the morphological characteristics of *C. vermiculata* and four other perennial taxa distributed in Türkiye is given in Table 1. The stems of the species are either horizontal or erect and can grow up to 120 cm in length. Considering the stem length, it is the second species with the longest stem structure after *C. dendroides*, which can grow up to 200 cm in length.

Table 1. Diagnostic characteristics of *Caroxylon* species from Türkiye (Boissier 1875, Il'in 1936, Brenan 1954, Aellen & Hillcoat 1964, Tutin *et al*. 1964, Zohary 1966, Tackholm 1974, Castroviejo 1990, Hedge 1997, Boulos 1999, Freitag 2000).

Species► Characteristics▼	*C. vermiculatum*	*C. ericoides*	*C. dendroides*	*C. laricinum*	*C. nodulosum*
Stem length	40-120 cm	Up to 30 cm	75-200 cm	Up to 75 cm	10-30 cm
Vegetative shoots	Present	Absent	Absent	Absent	Absent
Leaves shape and length	Linear or triangular, 5-12 mm	Ericoid, 3-12 mm	Linear, up to 10 mm	Linear, up to 20 mm	Ovate-triangular, up to 3 mm
Leaves hair type	Short crisped and long pilose hairs	Branched hairs	Glabrous	Pubescent or glabrous	Pubescent or glabrous
Perianth length	1.7-2.5 mm	1.0-2.0 mm	1.0-2.0 mm	1.25-2.25 mm	1.5-3.0 mm
Anther appendages shape	Short-obtuse	Rectangular to trapezoid	Short-obtuse	Short-obtuse	Oblong-ovate. elliptic-oblong, acute
Stigma shape	Subulate, papillate	Long papillate	Ribbon-shaped,	Thread-like papillate	Subulate, glabrescent
Style type and length	Long, 0.6-1.2 mm	Short, 0.2-0.4 mm	Long, 0.25-0.65 mm	Sessile or up to 0.25 mm	Short, 0.20-0.60 mm
Fruit diameter	8.0-13.0 mm	5-10 mm	3.75-10.50 mm	4-7.0 mm	4-9 mm
Fruit colors	Variable	Variable	Concolorous	Concolorous	Variable
Seed size (⌀)	1.7-3.0 mm	1.5-1.8 mm	1.10-1.75 mm	1.25-2.20 mm	1.50-2.50 mm

Regarding the habit of the species, it was determined that it has both many-stemmed flowering shoots from the base and many short vegetative shoots. When this condition was compared with other woody *Caroxylon* taxa distributed in Türkiye, it was determined that only *C. vermiculatum* has short vegetative shoots.

Among the perennial taxa of the genus, *Caroxylon ericoides* has the most distinct leaves of 3.0-12.0 mm long, ericoid, succulent and glabrous. In other species, the leaves are variable, linear, ovate, ovate-triangular, not succulent, hairy or glabrous and their length varies between 3.0-20 mm. The smallest leaf belongs to *C. nodulosum* with a length of 3.0 mm. In *C. vermiculatum*, the leaves are 5-12 mm long, linear, needle-like or triangular in shape and covered with both short crisped and long pilose hairs.

Caroxylon vermiculatum has the largest fruits (8.0-13.0 mm in diameter) among other representatives of *Caroxylon*in Türkiye. The fruits are 3.5-10.5 mm in diameter in *C. dendroides*, 5.0-10.0 mm in *C. ericoides*, 4.0-7.0 mm in *C. laricinum* and 4.0-9.0 mm in *C. nodulosum*. The fruits of *C. dendroides* and *C. laricinum* are dirty-white, white or yellowish-gray in the early period (immature). In the remaining perennial taxa, fruit color is variable and is yellow, orange, pink, maroon or red. In all taxa of the genus, ripe fruits are dark or light brown. Fruit color variability (yellow, orange, pink, red, burgundy) is also observed in annual taxa of the genus.

The seeds in all taxa of the genus are horizontal, disc-like, more or less rounded and the embryo is spiral. According to seed size, the largest seed belongs to *C. vermiculatum* with seed diameter varying between 1.7-3.0 mm.

Conclusion

As a result of this study, *Caroxylon vermiculatum* was recorded for the first time from Türkiye. Thus, one more species was added to the flora of Türkiye, contributing to our knowledge of plant biodiversity. The number of species of the genus *Caroxylon* in Türkiye increased to nine.

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Data Sharing Statement: The authors confirm that the data supporting the findings of this study are available within the supplementary material of the article.

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Conflict of Interest: The authors have no conflicts of interest to declare.

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