

Epilobium ciliatum Raf., a new plant invader in Slovenia and Croatia

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The North American invasive species *Epilobium ciliatum* Raf. was recently recorded for the first time in Slovenia and Croatia. The most reliable character with which to distinguish *E. ciliatum* from all native European *Epilobium* species is the presence of conspicuous longitudinal white stripes on the seed testa. If seeds are not available, *E. ciliatum* may easily be misidentified as *E. roseum*. With fieldwork and revision of herbarium material we ascertained that the invasion towards the territory discussed came from the north, which is in agreement with the north west to south east direction of the spread in Europe. At least in Eastern Slovenia *E. ciliatum* has already become an important member of ruderal plant communities. Rapid spreading and naturalization as in the case of *E. ciliatum* can give rise to concern that it will replace some indigenous species with a similar ecology or hybridise and so by introgression cause »genetic« pollution of native relatives' populations. Further spread to the south and east is expected.

Key words: *Epilobium ciliatum*, flora, plant invasion, Slovenia, Croatia

Introduction

Taxonomy and distribution

Epilobium ciliatum Raf. (syn. *E. adenocaulon* Hausskn.) is a perennial herb originating from North America (RAVEN 1980). It belongs to the section *Epilobium*, which comprises about 185 species of perennial herbs, mostly of moist places. The typical characters of this section are: actinomorphic flowers, pink, purple, white or creamy petals, floral tube present, 4-lobed or entire stigma, pollen shed in tetrads, distal walls with solid endexine and chromosome number $2n = 36$ (RAVEN 1976).

Epilobium ciliatum is a perennial, over-wintering with leafy rosettes (RAVEN 1980, SMEJKAL 1997). Stem is usually branched, 10–140 cm tall, with 4 elevated strigulose lines. Lower part of the stem is glabrous or with a few scattered simple (i.e. non-glandular) trichomes in rows, whereas its upper part and the inflorescence are densely glandular with few appressed simple trichomes. Leaves are lanceolate to narrowly ovate, 3–10 cm long and 1–3 cm wide, shortly petiolate (1.5–4 (5) mm), with rounded to cordate base, glabrous,

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ciliate only on the irregularly serrulate margins. Petals are purplish-pink or white and 2.5–6 mm long. Sepals (3–4 mm long) and ovary are densely glandular with erect glandular hairs and some appressed trichomes. Seeds are about 1 mm long, brown with conspicuous longitudinal white stripes, which are rows of laterally compressed and fused ridges of epidermal cells (SEAVEY et al. 1977). The flowering time of *E. ciliatum* is late summer.

Within the species *E. ciliatum* three subspecies can be distinguished by their morphology and distribution: *E. c.* subsp. *ciliatum*, *E. c.* subsp. *glandulosum* (Lehm.) Hoch et Raven and *E. c.* subsp. *watsonii* (Barbey) Hoch et Raven. But only the type subspecies is reported from temperate Europe (JÄGER 1986).

Epilobium ciliatum is native to North and South America with a distribution range from Alaska and North Canada to South Mexico (JÄGER 1986, MEUSEL et al. 1978), Chile, Argentina and the Falkland Islands (SOLOMON 1982). In view of the much higher intraspecific variability in North America, it is believed that the colonisation of South America happened relatively recently (SOLOMON 1982). In the 19th and 20th centuries *E. ciliatum* invaded several other parts of the World. In addition to Europe it is reported for East Asia, Hawaii, Australia, Tasmania and New Zealand (JÄGER 1986).

In Europe, *E. ciliatum* subsp. *ciliatum* has become naturalized in several countries. Its first records date back to 1889 in Great Britain, 1891 in Denmark, 1894 in Sweden, 1895 in Russia, 1910 in Finland, 1915 in Netherlands, 1917 in Poland, 1926 in Norway, 1927 in Germany, 1937 in Hungary and Romania, 1941 in the Slovak Republic, 1950 in Luxembourg (LAWALREE and REICHLING 1960), around 1950 in Austria (FISCHER and ADLER 1994), 1952 in Belgium (LAWALREE and REICHLING 1960) and in France (JÄGER 1986), 1956 in the Czech Republic (SMEJKAL 1982), 1968 in Switzerland (JÄGER 1986), 1995 in Slovenia (JOGAN 1996), 1998 in Italy (POLDINI et al. 2002), and 2001 in Ireland, (JÄGER, personal communication). In Flora Europaea (RAVEN 1980) its occurrence in the Baltic states and Ukraine is mentioned.

In addition to the type subspecies *E. ciliatum* subsp. *glandulosum* was found in Northern Europe, that is, in Central and South Scandinavia (Sweden from 1918 on), Denmark, the Baltic states (Estonia from 1928 on) and Poland (JÄGER 1986).

The spatial distribution pattern type for the European synanthropic part of the area of distribution of *E. ciliatum* is temp – (bo) · oz_(1–3) Eur, which means it occurs in temperate to boreal latitudes in highly to medium oceanic climate conditions (MEUSEL et al. 1978).

In the close neighbourhood of Slovenia and Croatia, *E. ciliatum* is known to occur in Southern Austria; the lowlands of Carinthia (HARTL et al. 1992), Styria, from 1971 on (MAURER 1996) and Northern Hungary, from 1937 on (HOLUB 1968, JÄGER 1986). In 1998 Hügün recorded the species also in North-Eastern Italy (POLDINI et al. 2002).

In Slovenia *E. ciliatum* was noticed for the first time in 1994 (JOGAN 1996), so it was included in »Mala flora Slovenije« with the comment »ephemeral occurrence on Kozjansko« (RAVNIK 1999). Until now, the species was not known for Croatia (DOMAC 1994, REGULA-BEVILACQUA 1997).

Ecology

The ecology of *E. ciliatum* reported from localities in Europe is very diverse. It has been observed in disturbed places, where it occurs as a pioneer species, especially on rich soils

(JÄGER 1986). According to the Ellenberg indices, *E. ciliatum* prefers well-lit places but occurs also in partial shade (L7). It is an indicator of warm conditions (T6), moist sites (F5w) and neutral soils (R7), which are rich to extremely rich in available nitrogen (N8) (ELLENBERG et al. 1991).

Habitat preferences of *E. ciliatum* are similar to some indigenous European taxa of the genus, namely *E. hirsutum*, *E. obscurum*, *E. parviflorum*, *E. roseum* and *E. lamyi*, so the co-occurrence of these taxa can be expected.

Hybridisation

Apparently all the species within the section *Epilobium* can hybridise (RAVEN 1976), so despite its remote origin many different hybrids with *E. ciliatum* are known from Europe too, where hybrids with the following species were recorded: *E. alpestre*, *E. ciliatum*, *E. collinum*, *E. hirsutum*, *E. lamyi*, *E. lanceolatum*, *E. montanum*, *E. obscurum*, *E. palustre*, *E. parviflorum*, *E. roseum* and *E. tetragonum*. (LAWALREE and REICHLING 1960, SMEJKAL 1982, HOLUB and KMETOVA 1988, STACE 1991, SMEJKAL 1997, KRAHULEC 1999)

Materials and methods

The aim of this study was a revision of herbarium material and systematic sampling in Slovenia and the neighbouring parts of Croatia to recognise the invasion dynamics and distribution pattern of *E. ciliatum*.

From each sampling locality up to 5 specimens of each species and/or hybrid taxon were taken for herbarium vouchers now deposited in University of Ljubljana Herbarium (LJU).

Herbarium material of *Epilobium* was revised in the LJU public herbarium collection (about 600 sheets), the working collection of ZRC SAZU (Scientific Research Centre of the Slovene Academy of Sciences and Arts) in Ljubljana and Tolmin and two private herbarium collections belonging to Nejc Jogan and Božo Frajman. Altogether over 700 herbarium sheets were revised and among them 50 turned out to be *E. ciliatum*.

Results and discussion

Problems with determination

The reliable determination of *Epilobium* species requires some experience with the group. Some of misidentifications of *E. ciliatum* can be attributed to biased or even incorrect keys. For example, in the determination key for *Epilobium* in Flora Hrvatske (DOMAC 1994) *E. ciliatum* is not included. Using this key trying to determine *E. ciliatum* material leads either to misidentification of the plant as *E. lamyi*, or to the point where none of the alternatives correspond. Further on, in Mala flora Slovenije (RAVNIK 1999) some important distinguishing characters are not used at all. Accordingly *E. ciliatum* can be identified as *E. tetragonum* or *E. roseum*, as well.

Many authors agree (HOLUB 1968, SMEJKAL 1997, STACE 1991) that *E. ciliatum* may easily be misidentified as *E. roseum*, because these two species do not differ in many distinguishing characters (Tab. 1).

The revision confirmed, that the reliable characters distinguishing *E. ciliatum* from *E. tetragonum* or *E. lamyi*, are glandular trichomes on the upper part of the stem, inflorescence, calyx and fruit which are present in *E. ciliatum*, but always absent in the other two species.

Tab. 1. Most important characters distinguishing the closely related species *Epilobium ciliatum* and *E. roseum*

	<i>E. ciliatum</i>	<i>E. roseum</i>
leaf shape	lanceolate to narrowly ovate with rounded or cordate base	ovate with cuneate to rounded base
leaf lamina (Fig. 2.)	non-glandular trichomes only on leaf margins, veins glabrous (Fig. 2b)	non-glandular trichomes on leaf margins and on veins (Fig. 2a)
petiole	short 1.5–4 (5) mm	longer (5) 10–15 (20) mm
seeds (Fig. 2.)	spindle shaped, with pellucide appendage, testa with conspicuous longitudinal white stripes (Fig. 2d)	rounded at ends, without pellucide appendage, testa with rounded papilae, not in distinct rows (Fig. 2c)

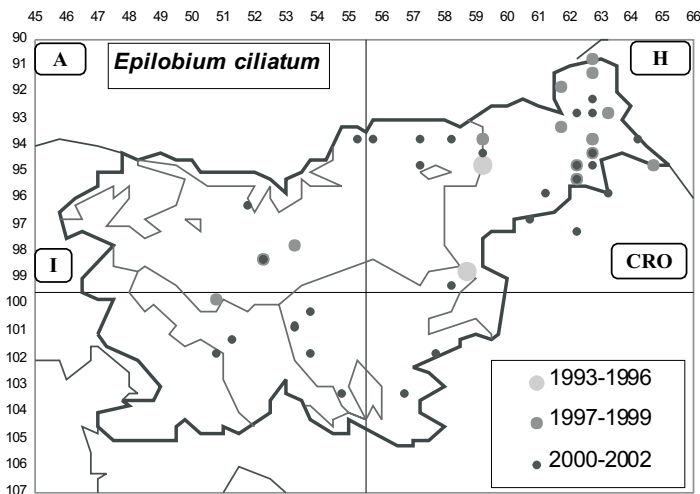


Fig. 1. Known distribution of *Epilobium ciliatum* in Slovenia and Croatia

Hybrids

In the three localities listed below hybrids with *E. ciliatum* have been found:

1. *Epilobium ciliatum* x *palustre*: 9853/2, Slovenia: Ljubljanska kotlina, Radomlje, Plastenka, brook bank, 330 m. Leg: N. Jogan et B. Trčak, 1.8.1999, Herbarium: Nejc Jogan
2. *Epilobium ciliatum* x *parviflorum*: 0054/3, Slovenia: Dolenjska, Radensko polje, Velika Račna, Mokrine, by the Zelenka brook, 250 m. Leg: S. Strgulc Krajšek, 26.7.2001, Herbarium: LJU

3. *Epilobium ciliatum* x *roseum*: 0254/4, Slovenia: Ribniško-Kočevska kotlina, Prigorica pri Ribnici, by the road through the village, 500 m. Leg: S. Strgulc Krajšek, 31.7.2001, Herbarium: LJU

Hybrids were present together with at least one of the parent taxa in all listed localities. They can be recognised by the not fully developed seeds with some irregular and often interrupted longitudinal white stripes on the testa. A hybrid stem is usually more branched, and the fruits are shorter. Most of the character states are intermediate between those of the parent species (SMEJKAL 1997).

These are the first data for *E. ciliatum* hybrids from the discussed area.

Distribution and ecology

Herbarium revision of genus *Epilobium* revealed the following localities of *E. ciliatum*. Records are listed in chronological order, each with all the available data from the label and MTB code at the first place (MTB = Messtischblatt, mapping unit used in Central Europe, each quarter covering about 35 km², i.e. 5' geographical longitude x 3' latitude).

1. 9559/2, Slovenia: Štajerska, Slivniški ribniki in Hočki gozd, near lower pond, 278 m. Leg: B. Frajman, 28.7.1993, Herbarium: Božo Frajman
2. 9959/1, Slovenia: Kozjansko, Vinogora, 500 m. Leg: N. Jogan, 2.8.1995, Herbarium LJU
3. 9463/1, Slovenia: Štajerska, Krapje, gravel-pit bank, 177 m. Leg: V. Babij, 24.7.1997, Herbarium SAZU Ljubljana
4. 9463/1, Slovenia: Prekmurje, Dokleževje, gravel-pit bank, 181 m. Leg: V. Babij, 24.7.1997, Herbarium SAZU Ljubljana
5. 9562/4, Slovenia: Slovenske Gorice, Ormož, 200 m. T. Bačič, 30.7.1997, Herbarium LJU
6. 9562/4, Slovenia: Štajerska, Velika Nedelja, Drakšl, orchard edge, 300 m. N. Jogan, 31.7.1997, LJU
7. 9565/1, Slovenia: Prekmurje, Benica, Murska Šuma, Muriša oxbow-lake, oxbow-lake bank, 152 m. Leg: V. Babij, 26.9.1997, Herbarium SAZU Ljubljana
8. 9562/2, Slovenia: Slovenske Gorice, Ivanjkovci, railway station, 220 m. Leg: A. Javorič, 26.6.1999, Herbarium LJU
9. 9463/3, Slovenia: Pomurje, Ljutomer, railway station, 180 m. Leg: A. Javorič, 26.6.1999, Herbarium LJU
10. 9459/2, Slovenia: Štajerska, Maribor, Studenci, railway station, 275 m. Leg: A. Javorič, 27.6.1999, Herbarium LJU
11. 9163/3, Slovenia: Goričko, Gornji Petrovci, 280 m. Leg: N. Jogan, 23.7.1999, Herbarium LJU
12. 9163/1, Slovenia: Goričko, Čepinci, 300 m. Leg: S. Strgulc, 24.7.1999, Herbarium LJU
13. 9363/2, Slovenia: Goričko, 300 m. Leg: S. Strgulc, 25.7.1999, Herbarium LJU
14. 9262/1, Slovenia: Goričko, Petroža, Motovilci, gutter, 230 m. Leg: N. Jogan, 26.7.1999, Herbarium LJU

15. 9852/4, Slovenia: Ljubljanska kotlina, Vojsko pri Skaručni, meadow, 300 m. Leg: S. Strgulc, 28.7.1999, Herbarium LJU
16. 9852/4, Slovenia: Ljubljanska kotlina, Vojsko pri Skaručni, near brook Gameljščica, brook bank, 300 m. Leg: S. Strgulc, 28.7.1999, Herbarium LJU
17. 9853/2, Slovenia: Ljubljanska kotlina, Radomlje, Plastenka, brook bank, 330 m. Leg: N. Jogan and B. Trčak, 1.8.1999, Herbarium Nejc Jogan
18. 0051/1, Slovenia: Rovtarsko hribovje, settlement Log, farm Petkovšek, brook bank, 530 m. Leg: B. Rozman, 8.8.1999, Herbarium LJU
19. 9362/3, Slovenia: Pomurje, Rihtarovci, swamp meadow, 200 m. Leg: N. Jogan, 9.8.1999, Herbarium Nejc Jogan
20. 9459/2, Slovenia: Štajerska, Maribor, central railway station, 275 m. Leg: A. Javorič, 7.9.1999, Herbarium LJU
21. 9459/4, Slovenia: Štajerska, Maribor, Tezno, railway station, railway bank, 275 m. Leg: I. Nekrep, 4.6.2000, Herbarium LJU
22. 9362/2, Slovenia: Prekmurje, Rankovci, near brook Dobel, meadow by the brook, 200 m. Leg: A. Šinko, 7.7.2000, Herbarium LJU
23. 9852/4, Slovenia: Ljubljanska kotlina, Tacen pod Šmarno goro, road margin in settlement, 300 m. Leg: S. Strgulc Krajšek, 10.7.2000, Herbarium LJU
24. 0151/4, Slovenia: Notranjska, Rakek, railway station, 520 m. Leg: B. Frajman, 13.7.2000, Herbarium: Božo Frajman
25. 0251/1, Slovenia: Notranjska, Postojna, railway station, 600 m. Leg: B. Frajman, 13.7.2000, Herbarium: Božo Frajman
26. 9852/4, Slovenia: Ljubljanska kotlina, Šmartno pod Šmarno goro, road margin in settlement, 300 m. Leg: S. Strgulc Krajšek, 17.7.2000, Herbarium LJU
27. 9458/2, Slovenia: Štajerska, Ruta, railway station, 300 m. Leg: B. Frajman, 23.7.2000, Herbarium: Božo Frajman
28. 9457/2, Slovenia: Kobansko, Vuhred, railway station, 300 m. Leg: B. Frajman, 23.7.2000, Herbarium: Božo Frajman
29. 9456/1, Slovenia: Koroška, Dravograd, railway station, 360 m. Leg: B. Frajman, 23.7.2000, Herbarium: Božo Frajman
30. 9562/4, Slovenia: Slovenski Gorice, Ormož, railway station, 200 m. Leg: B. Frajman, 23.7.2000, Herbarium: Božo Frajman
31. 9663/2, Slovenia: Štajerska, Središče ob Dravi, railway station, 180 m. Leg: B. Frajman, 23.7.2000, Herbarium: Božo Frajman
32. 9562/2, Slovenia: Slovenske Gorice, Ivanjkovci, railway station, 220 m. Leg: B. Frajman, 23.7.2000, Herbarium: Božo Frajman
33. 9557/2, Slovenia: Pohorje, Mislinja, around Založnik farm, near Mislinja, brook bank, 800 m. Leg: B. Frajman, 23.8.2000, Herbarium: Božo Frajman
34. 0357/3, Slovenia: Bela Krajina, Pusti Gradac, railway station, 160, B. Frajman, 17.9.2000, Herbarium: Božo Frajman
35. 9263/3, Slovenia: Prekmurje, Murska Sobota, 500 m SE of Dolina, shrubs. Leg: S. Žižek, 6.7.2001, Herbarium LJU
36. 9455/2, Slovenia: Koroška, Ravne, Zelenbreg, dike near the swamp, 500 m. Leg: S. Strgulc Krajšek and N. Jogan, 24.7.2001, Herbarium LJU

37. 0054/3, Slovenia: Radensko polje, Velika Račna, Mokrine, bank of brook Zelenka, brook bank, 250 m. Leg: S. Strgulc Krajšek, 26.7.2001, Herbarium LJU
38. 9563/1, Slovenia: Štajerska, Prlekija, 500 m W of Miklavž near Ljutomer, dry meadow dike, 235 m. Leg: T. Gregorc, 29.7.2001, Herbarium LJU
39. 9958/4, Slovenia: Dolenjska, Senovo, Reštanj, firing range, forest road, 450 m. Leg: S. Strgulc Krajšek and N. Jogan, 30.7.2001, Herbarium LJU
40. 9762/4, Croatia: Hrvatsko Zagorje, Ivanec, railway station. Leg: S. Strgulc Krajšek and N. Jogan, 30.7.2001, Herbarium LJU
41. 9761/1, Croatia, Hrvatsko Zagorje, Otok Virje, Vratno Otok, 1 km before border crossing at Ormož, cart track between fields. Leg: S. Strgulc Krajšek and N. Jogan, 30.7.2001, Herbarium LJU
42. 0355/3, Slovenia: Kočevsko, Kočevje, Rožni Studenec, forest path near a spring, 500 m. Leg: S. Strgulc Krajšek, 31.7.2001, Herbarium LJU
43. 0258/1, Slovenia: Gorjanci, Šentjernej, Javorovica, Strmec, beech forest. Leg: B. Trčak, 1.8.2001, Herbarium LJU
44. 0254/1, Slovenia: Dolenjska, Ribnica, Sušje, swamp meadow, 530, P. Vrh, 9.8.2001, Herbarium LJU
45. 9661/2, Slovenia: Haloze, Gradiški Hum. Leg: N. Jogan, 11.7.2002, Herbarium LJU
46. 9652/3, Slovenia: Slovenske Gorice, Tivolci, road margin. Leg: B. Frajman, 17.7.2002, Herbarium LJU
47. 0153/2, Slovenia: Turjak, around vilage Gradež, forest clearing, on rocks, 560 m. Leg: M. Sušnik, 25.7.2002, Herbarium LJU
48. 9464/2, Slovenia: Lendava, E of Sv. Trojica, shadow incline near the road, 320 m. Leg: D. Huzminec, 5.7.2002, Herbarium LJU
49. 9463/3, Slovenia: Ljutomer, Babinci, Babniška gramoznica, gravel-pit bank, 177 m. Leg: K. Karba, 1.8.2002, Herbarium LJU
50. 9363/1, Slovenia: Murska Sobota, NE of Rakičan near Ledava brook, meadow by a brook, 190 m. Leg: M. Plantan, 10.8.2002, Herbarium LJU

The distribution pattern of the known localities and temporal invasion dynamics are presented in Figure 1. In the period between 1993 and 1996 only few localities of *E. ciliatum* were known in the eastern-most i.e. sub-Pannonian phytogeographic region of Slovenia. In the years 1997–1999 a lot of new localities were found in the eastern part of Slovenia and the first three localities in the Central Slovenia. In the last three years (2000–2002) new localities in the southern parts of Slovenia and finally in Croatia were found.

All known localities of *E. ciliatum* in Slovenia and Croatia are scattered in the colline (rarely montane) belt, (150) 180–530 (800) m above sea level.

In the localities studied, *E. ciliatum* occurs in a wide spectrum of biotopes: ruderal habitats (road margin in urban areas, railway station, in gutter, cart-track between fields, orchard and garden edges), disturbed forest habitats (forest paths and roads, forest clearing, forest edge), moist sites (banks of fish pond, gravel-pit, oxbow-lake, brook, in gravel dike, swamp meadow, near spring), dry sites (rocks, dry meadow dike, meadow edge, shrubs).

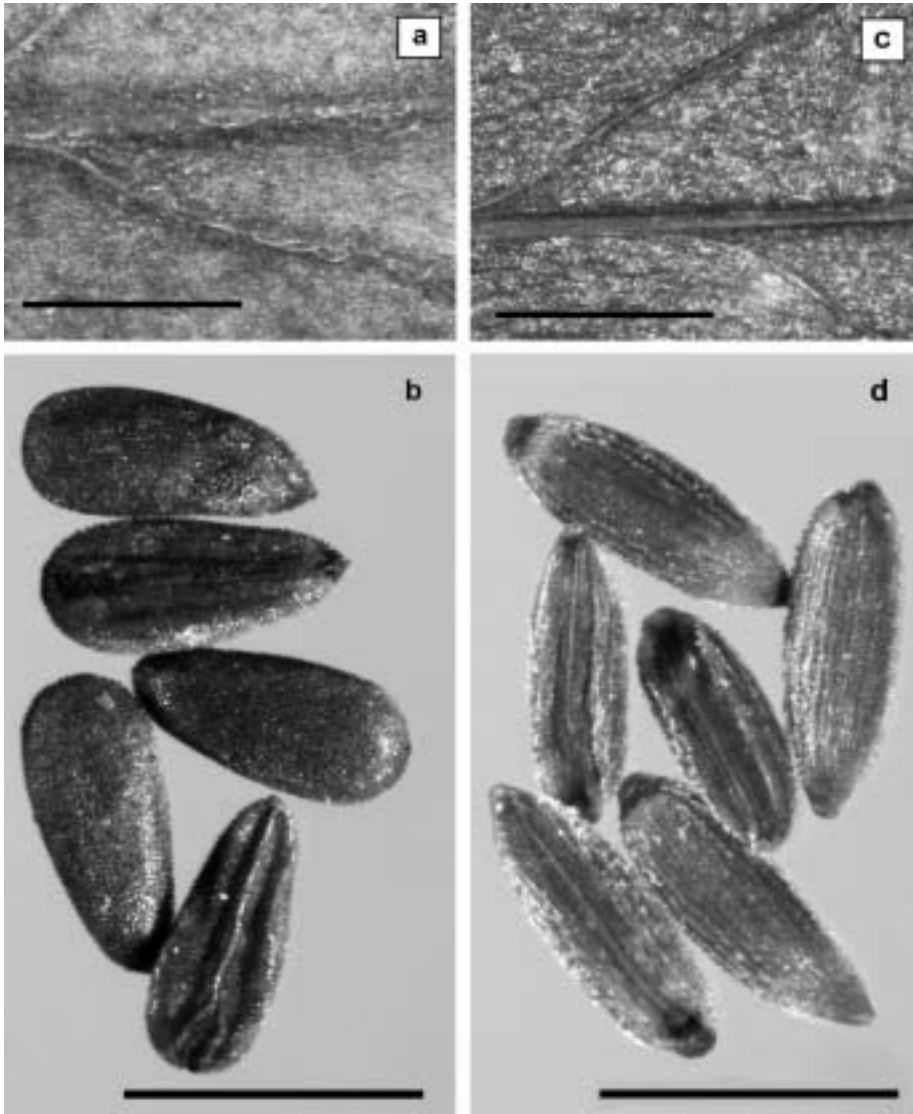


Fig. 2. Morphological details in *Epilobium roseum* (**a**-adaxial leaf blade, **b**-seeds) and *E. ciliatum* (**c**-adaxial leaf blade, **d**-seeds). Bars: 1 mm

All these observed habitats confirm the very high ecologic plasticity of *E. ciliatum* already reported by other authors (HOLUB 1968, JÄGER 1986, STACE 1991, SMEJKAL 1997).

Invasion of *Epilobium ciliatum*

We consider the most important factors of the successful invasion of *E. ciliatum* to be: 1) high seed production, 2) anemochory, 3) ecologic plasticity and 4) wide area of primary distribution.

The chorological data demonstrate that the invasion of the discussed territory came from the north, which is in agreement with the general spreading tendency of *E. ciliatum* in Europe: from northwest towards south and east (JÄGER 1986). The prognosis for the further spread of *E. ciliatum* in the discussed area is towards south and west Slovenia and north, east and south Croatia. To west Slovenia, *E. ciliatum* can also spread from northern Italy. In Croatia new localities in the northern part are expected, where *E. ciliatum* can spread from Hungary. Its current distribution in Hungary is almost certainly much wider now than reported in JÄGER (1986) and from Slovenia. Within Croatia, further spread to the south and east can be expected.

Whether the available field records really represent the spreading dynamics in the nature is not clear. However, we can be quite positive that *E. ciliatum* was not overlooked in Slovenia, since it has not been found in any of the herbarium sheets older than the year 1993. In Croatia, recent herbarium collections still have to be checked for the presence of this invader.

It is clear that at least in eastern Slovenia *E. ciliatum* has already become an important member of ruderal plant communities. From the natural-conservation point of view such a rapid spreading and naturalization as in the case of *E. ciliatum* can give rise to concern that it might replace some indigenous species with a similar ecology or that it might hybridise and so by introgression cause »genetic« pollution of native *Epilobium* populations.

There are also other potential invaders from the genus *Epilobium* that could spread to the territory discussed. Three New Zealand species have already been reported as fugitives in Europe: *E. komarovianum* was recorded in Bratislava (West Slovakia) and in Pardubice (East Bohemia), in both cases originating from botanical gardens. In the Western and Northern Europe *E. brunnescens* and *E. pedunculare* were also reported (HOLUB 1978).

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