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THE ROLE OF WILLOWHERBS (*EPILOBIUM*) IN THE RECOVERY OF VEGETATION COVER A YEAR AFTER USE OF HERBICIDE: A CASE STUDY FROM CENTRAL LITHUANIA

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Abstract

Matulevičiūtė D., 2016: The role of willowherbs (*Epilobium*) in the recovery of vegetation cover a year after use of herbicide: a case study from Central Lithuania [Ožkarožių (*Epilobium*) vaidmuo atsikuriant augalijai praėjus metams po herbicido panaudojimo: tyrimas centrinėje Lietuvos dalyje]. – Bot. Lith., 22(2): 101–112.

Several species of willowherb (*Epilobium*) are considered as agricultural weeds and their prevalence has become an increasing problem in agriculture. The aim of this study was to investigate the role of willowherb plants in the initial stage of vegetation succession a year after the use of glyphosate. The study was based on the examination of thirteen willowherb specimens collected in the apple orchard of 0.2 ha area in August 2008, one month after glyphosate treatment, and vegetation field investigations in the same orchard in July 2009. The coverage of herb layer, the abundance and life stages of *Epilobium* plants in twenty plots of 1 m^2 in size were investigated. The specimens of willowherbs, which survived the glyphosate application in 2008, were identified as *Epilobium ciliatum* and *E. tetragonum*. A year after the glyphosate treatment, the willowherb plants prevailed in the vegetation. One alien (*E. ciliatum*) and three native (*E. hirsutum*, *E. parviflorum* and *E. tetragonum*) species of willowherb were found. *E. ciliatum* was the most abundant. This species was characterized by the highest number of reproductive and virginile plants. *E. parviflorum* and *E. tetragonum* plants were abundant with a very high proportion of reproductive plants. Only pre-reproductive plants of *E. hirsutum* occurred in the study plots. The reproductive plants represented more than one third of the total number of willowherb plants. The distribution patterns of willowherb species in the plots were very variable.

Keywords: glyphosate, herbicide resistance, life stages, *Onagraceae*, plant invasions, weed.

INTRODUCTION

The willowherbs (*Epilobium* spp.) belong to Onagraceae family. Twenty-four native and four alien species represent this genus in Europe (Raven, 1968). In the Baltic region, as in Lithuania, the species richness is considerably lower – eight native and one alien species are found (Fatare et al., 1996). Several species of *Epilobium* are considered as agricultural weeds and their spread has become an increasing problem in agriculture (Bailey et al., 1982; Randal, 2012). The most noxious weed from this genus is an alien species American willowherb (*Epilobium ciliatum* Raf.) originating from North America (Table 1). It was found for the first time in Europe in 1891 (Preston, 1988). Since that time, *E. ciliatum* has spread in 29 European countries and nowadays it has naturalized in 21 countries (Lambdon et al., 2008). In Czech Republic, invasive metapopulations of *E. ciliatum* have been registered in 30 habitat types (Pyšek et al., 2012). In Austria, this willowherb has been included in the list of invasive species (Essl et al., 2002). In Europe, *E. ciliatum* hybridise with many native willowherb species (Holub & Kmetova, 1988; Stace, 1991; Smejkal, 1997; Krahulec, 1999), which can be considered as a genetical threat limiting the diversity of native willowherb species. Daehler & Carino (2001) have asserted that over a long term, even large native populations can be threatened due to native-alien hybridization.

As a weed, American willowherb occurs in Europe in various agricultural and horticultural habitats (Table 1). Lipecki & Janisz (2000) have referred about the tendency of the increasing frequency of *E. ciliatum*, while Weber & Gut (2005) have informed about increasing spread of this agricultural weed in Central and Eastern Europe.

Square-stalked willowherb (*E. tetragonum* L.) is the most common weed between native willowherb species. It is found in horticultural crops, especially in orchards and vineyards of several Central and Western European countries (Table 1) and is regarded as one of most heavily eliminable weeds in wet soils of orchards in Western Mediterranean countries of Europe (Guillerm & Maillet, 1982). As an arable weed, this species is appointed in South European countries (Table 1).

Great willowherb (*E. hirsutum* L.) is included into a list of weeds increasingly spreading in Europe (Weber & Gut, 2005). It occurs both in arable fields and in orchards of Central and Southern Europe (Table 1).

The data on the occurrence of other native willowherb species in the weed flora of agricultural and horticultural areas are less abundant. Broad-leaved willowherb (*E. montanum* L.), hoary willowherb (*E. parviflorum* Schreb.), pale willowherb (*E. roseum* Schreb.) and marsh willowherb (*E. palustris* L.) are considered as weeds (Table 1). In the last decades of the past century, populations of the willowherbs resistant to various herbicides have been found in many countries (Table 1). The occurrence of weeds resistant to herbicides is regarded as an important factor in agricultural production and technology, and may become more serious economic problem (LeBaron & McFarland, 1990).

In Lithuania, willowherbs are not considered as a problem for agriculture. These plants have not been found during the investigations on agrophytocenosis (Stancevičius, 1959) or the studies on segetal flora under intensive farming conditions (Rašomavičius, 2001; Rašomavičius et al., 2008). However, the *Epilobium* plants were noticed on the boundary strips of arable fields (V. Rašomavičius, 2016, personal communication). Solitary *E. montanum* plants occurred only in segetal flora under organic farming (Boguzas et al., 2004). Weed flora of the orchards in Lithuania has not been studied in detail yet. Possibly due to this circumstance, the weed compendium of Lithuania (Čiuberkis & Vilkonis, 2013), consisting of 234 species, does not include the members of the *Epilobium* genus. Therefore, the frequency and distribution of

Table 1. Occurrence of willowherbs as weeds in agricultural habitats, and their herbicide-resistant populations detected in European countries

Habitat type	Resistance to herbicide	Country	Reference
Epilobium ciliatum			
		Belgium	Bulcke et al., 1986
Fruit plantations	Atrazine, simazine	Belgium	Bulcke et al., 1987
Maize fields	Atrazine, cyanazine		
Orchard	Atrazine, simazine		
Roadsides	Simazine		
Salsify fields			
Soft fruit plantations	Simazine		
Tree nurseries	Simazine		
Soft fruit plantations	Simazine	England	Greenfield, 1987
Fruit plantations	Atrazine, simazine	Belgium	Bulcke & Van Himme, 1989
Maize fields	Triazines		
Nurseries	Isoxaben, napropamide, simazine		
Orchards	Isoxaben, napropamide, triazines		
Roadsides	Simazine		
	Paraquat, triazines	England	Clay, 1989

Habitat type	Resistance to herbicide	Country	Reference
	Oxyfluorfen, paraquat, pyridate, triazines	England	Clay & Underwood, 1989
	Paraquat	Belgium	Itoh & Matsunaka, 1990
	Paraquat, triazine	United Kingdom	Moss & Kemp, 1989
Christmas tree plantations	Triazines	Denmark	Rubow, 1989
Maize fields, orchards, nurseries	Triazines	Netherlands	Van Oorschot, 1991
	Atrazine	Denmark	Andreasen & Jensen, 1994
Orchards	Paraquat, soil-applied triazines	Belgium	Bulcke & Callens, 1998
Orchard	Glyphosate	Poland	Rabcewizc & Wawrzyńczak, 2004
Green fallows, cereal crops		Czech Republic	Winkler & Zelená, 2004
Black currant plantations	Glyphosate	Poland	Lisek, 2005
Vegetable and ornamental plantations, orchards, vineyards		Central and Eastern Europe	Weber & Gut, 2005
Arable fields (winter cereals, potato, sunflower), sown fallow (grass-clover)		Germany	Albrecht, 2008
Strawberry plantations (herbicide fallow, tillage places), plantations localized near orchards		Poland	Lisek, 2012a
Orchards (boundary strips, herbicide fallow under trees)		Poland	Lisek, 2012b
Flower gardens		Lithuania	Matulevičiūtė, unpublished data
	E. hirsutum		
Orchards	Diuron	France	Guillerm & Maillet, 1982
Fields of cereals, grain legumes and root crops, other agricultural areas		Southern Europe	Weber & Gut, 2005
Arable fields		Croatia	Dujmović & Hulina, 2008
Orchards (boundary strips, drainage ditches, herbicide fallow under trees)		Poland	Lisek, 2012b
Rye field, flower gardens		Lithuania	Matulevičiūtė, unpublished data
	E. montanum		
Soft fruit plantations	Simazine	Ireland	Mac Giolla Ri, 1989
Orchards (boundary strips, herbicide fallow under trees)		Poland	Lisek, 2012b
	E. palustre		
Brassica napus fields		Russia	Mikhailova et al., 2015
	E. parviflorum		
Maize fields		Hungary	Bene & Radócz, 2005
Cultivated fields (summer crops)		Kosovo	Mehmeti et al., 2009
	E. roseum		
Orchards (boundary strips, herbicide fallow under trees)		Poland	Lisek, 2012b
	E. tetragonum		
Vineyards	Triazines	France	Rouas, 1981
Orchards	Diuron	France	Guillerm & Maillet, 1982
Horticultural crops	Triazines	Germany	Kees, 1988
Arable fields		Croatia	Dujmović & Hulina, 2008
Cultivated fields (winter crops)		Kosovo	Mehmeti et al., 2009
	Triazines	France	Gasquez & Darmency, 1989
Orchards (boundary strips, drainage ditches, herbicide fallow under trees)		Poland	Lisek, 2012b
Rye field, vegetable bed (fertile individuals)		Lithuania	Matulevičiūtė, unpublished data

willowherbs in Lithuania are considered fluctuating (Matulevičiūtė, 2007, 2010). The information about the survival of willowherb plants after herbicide application in the orchards (V. Rašomavičius, 2016; J. Sendžikaitė, 2008; personal communications), and the provided herbarium specimens of the willowherb plants (collected by J. Sendžikaitė) that survived herbicide treatment have raised several questions: which willowherb species can survive herbicide treatment?; what role will the plants of the *Epilobium* genus play in the initial stage of the succession of weed vegetation a year after herbicide application?; how does the use of herbicide affect the spread of willowherbs? In order to answer these questions, the study on weed flora was performed in the orchard, where herbicide-resistant willowherb plants were collected in the growing season a year after the herbicide treatment.

DESCRIPTION OF THE STUDY SITE

The study site was situated in the central part of Lithuania, Kėdainiai district, Ąžuolaičiai village (55°20' N, 23°50' E). The study area was in a private 0.2 ha sized apple orchard surrounded by arable fields. The soil in the study site was classified as *Endocalcaric Cambisols* (after IUSS Working Group WRB, 2006). The soil of this type covers 16.8% of the Lithuanian territory (Motuzas, 2009). The sum of precipitation at the site is the lowest in the territory of the country, reaching about 600 mm per year (WMS, 2016).

For the weed control in the orchard, the area between apple trees had been moved once per growing season until 2007. In the middle of July 2008, another weed control alternative was applied: the area between the trees was treated with glyphosate in accordance with the manufacturer's instructions. Other weed control measures that year were not used.

On 13 August 2008, the sparse herb layer in the studied area consisted only of willowherb individuals (*Epilobium* spp.) that survived after glyphosate application (J. Sendžikaitė, 2008; personal communication and provided herbarium specimens of 13 willowherb plants collected on 13 August 2008). The total number of willowherb plants in the orchard in 2008 was not counted. A year after the herbicide treatment, in the period of field investigations in midsummer, the coverage of herb layer at the study site made up 90%, bryophytes – 60%. The herb layer consisted of 18 vascular plant species. The most abundant plants (degree 2, after the Braun-Blanquet scale (Braun-Blanquet, 1964)) were: *Capsella bursa-pastoris*, *Chenopodium album*, *Epilobium ciliatum*, *E. parviflorum*, *Euphorbia helioscopia*, *Galinsoga parviflora*, *Lamium maculatum* and *Stellaria media*. Rather abundant (degree 1) were such as *Epilobium tetragonum*, *Galium aparine*, *Myosotis arvensis*, *Taraxacum officinale* and *Viola tricolor*. The plants of other species (*Epilobium hirsutum*, *Equisetum arvense*, *Hordeum vulgare*, *Raphanus raphanistrum*, *Senecio jacobea*) were solitary. The distribution patterns of the plants were different.

MATERIALS AND METHODS

The field investigations were performed on 13 July 2009. The vegetation relevé were recorded according to the traditional Braun-Blanquet method (Braun-Blanquet, 1964) in the area of 100 m^2. The structure of willowherb population was investigated in 20 plots, randomly selected within the borders of the relevé area. Each plot had an area of 1 m^2. The coverage of herb and bryophyte layers and the total coverage rates of willowherb (*Epilobium*) plants in each plot were evaluated. The number of individuals of each willowherb species was counted. The life stage of each willowherb plant was classified after Gatsuk et al. (1980). The stage of pre-reproductive plants was recognized according to the attributes presented in Table 2. The seedlings were not counted due to uncertainty of species identification in such stage. The plants of other pre-reproductive stages were identified by comparing with the samples collected in natural habitats during the observations of willowherb population age structure, and using morphological characteristics after Haussknecht (1884).

The descriptive statistics of the data set was made

Table 2. Characters used for recognition of life stage of pre-reproductive *Epilobium* plants

Life stages	Characters
Juvenile	Plants have two or three pairs of true leaves
Immature	Plants have more than three pairs of true leaves; all leaves are arranged oppositely
Virginile	Plants have more than four pairs of true leaves; the apical leaves are arranged alternately or sub-alternately

using software package *Microsoft Excel*. Univariate test for differences between willowherb species in plant number per 1 m^2 plot was performed applying the Mann-Whitney U test (Zar, 1999). It was carried out using software package *Statistica* (Anonymous, 1998).

RESULTS

I identified herbarium specimens of willowherbs that survived herbicide treatment in the investigated area as follows: *Epilobium ciliatum* – two plants, *E. tetragonum* – 11 plants. All collected *E. ciliatum* plants were reproductive, while ten of the *E. tetragonum* individuals were reproductive and one belonged to virginile life stage. All willowherb plants had several damages: a part of the leaves and buds were dead and brown coloured; a part of live leaves had some dead spots and damages similar to fungal diseases. Most fruits (about ¾) were well developed and contained seeds, while the minor part of fruits were crooked.

In 2009, the coverage of willowherb plants in the investigated plots varied from 30% to 85% with an average of 59.4 ± 17.5%. Plants of the *Epilobium* genus constituted a substantial part (79.4 ± 17.9%) of the total herb layer coverage. The total number of willowherb plants in the plots with the total area of 20 m^2 was 6400. The distribution patterns of willowherb plants were very uneven: the number of willowherb individuals in each of 1 m^2 plot varied from 140 to 733 (320.0 ± 164.2).

In 2009, during field studies in the orchard, I identified four willowherb species: alien *E. ciliatum* and three native species (*E. hirsutum*, *E parviflorum* and *E. tetragonum*). The total number of individuals of each species was variable. The most abundant was *E. ciliatum* (4648 individuals) in all plots, while the total number of *E. parviflorum* and *E. tetragonum* plants was considerably lower (949 and 793, respectively). *E. hirsutum* plants were sparse – I counted only 10 individuals of this species. The frequency and abundance of these species strongly varied between the plots. From two to four (2.9 ± 0.5) willowherb species occurred in each plot. I found plants of *E. ciliatum* and *E. parviflorum* in all plots, while *E. tetragonum* occurred in 90.0% of these. *E. hirsutum* was the rarest species – only in 10.0% of the plots.

The individual number of each species varied between the plots within a wide range (Fig. 1). American willowherb distinguished between other species both by extremely high number of individuals per plot (on average 232.4) and by high variability (from 70 to 606). The distribution patterns of *E. parviflorum* and *E. tetragonum* were similar: mean plant numbers were 47.4 and 39.7 with variation from 2 to 101 and from 0 to 133, respectively, while *E. hirsutum* differed from other species by low mean number (0.5) and by rather low variability (from 0 to 6) of individuals per plot.

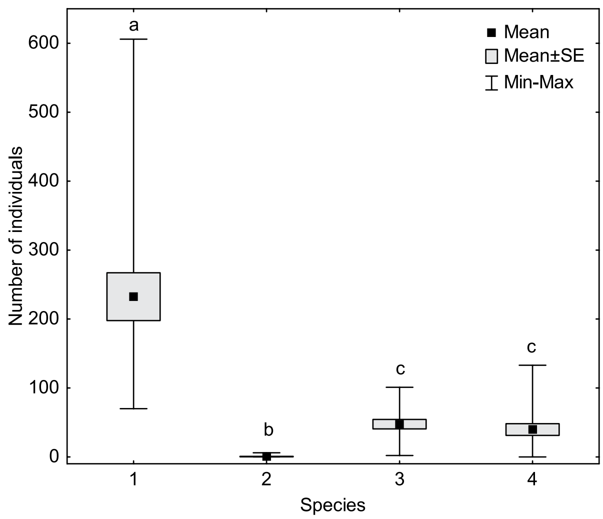

Fig. 1. Distribution patterns of willowherb plants in 1 m^2 sized plots. 1–4 – willowherb species: 1 – *E. ciliatum*, 2 – *E. hirsutum*, 3 – *E. parviflorum*, 4 – *E. tetragonum*. Bars with the same letter do not differ (Mann-Whitney U test, $p > 0.05$)

Regardless of high variance of the numbers of willowherb individuals in the plots, the prevalence of *E. ciliatum* plants was clear: the number of individuals of this species amounted on average to 68.4% of willowherb plants in a plot (Table 3). Participation of

Table 3. Representation of willowherb plant individuals of different species in the investigated plots (1 m^2) expressed as percentage values derived from absolute numbers of individuals

Epilobium species	Percentage of individuals in 1 m^2			
	Mean	SD	Max	Min
E. ciliatum	68.4	13.6	84.1	43.3
E. hirsutum	0.1	0.4	1.7	0
E. parviflorum	18.2	16.0	50.0	0.8
E. tetragonum	13.9	14.8	50.6	0

E. parviflorum and *E. tetragonum* was considerably lower, though in several cases plants of these species represented about a half of the total willowherb individuals in a plot.

The analysis of age structure revealed that in the middle of July, only 37.2% of all willowherb individuals were in a reproductive life stage. Of these, a major part (53.6%) of reproductive willowherb plants belonged to *E. ciliatum* species (Fig. 2). *E. parviflorum* plants made less than one-third (28.6%), while *E. tetragonum* – only 17.8% of the total number of reproductive willowherb plants. All *E. hirsutum* plants were in the pre-reproductive development stage.

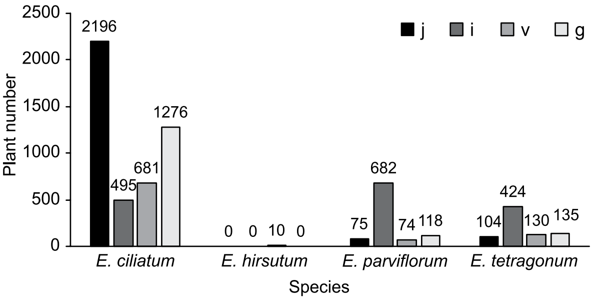

Fig. 2. Life stages of willowherb plants. Species: E. c. – *E. ciliatum*, E. h.– *E. hirsutum*, E. p. – *E. parviflorum*, E. t. – *E. tetragonum*; life stages: j – juvenile, i – immature, v – virginile, g – generative

The distribution patterns of willowherb plants belonging to different life stages were very variable as well (Table 4). In spite of great differences in the number of individuals per plot, *E. ciliatum* plants of all life stages occurred in all plots. In *E. parviflorum*, only reproductive plants occurred in all plots, while in *E. tetragonum*, none of the life stages was represented throughout all the plots. Only virginile plants were found for *E. hirsutum*.

E. ciliatum differed from other willowherb species by a prevalence of juvenile individuals both between all plants of this species and between juvenile plants of other species. Furthermore, American willowherb was characterized by very high mean number of juvenile individuals as well as by a very high variability of their distribution patterns (from 6 to 435) between the plots (Table 4). The individuals of other life stages of this species also exhibited high variability: the number of immature plants varied from 13 to 56 (24.7 ± 11.6), virginile – from 9 to 88 (34.0 ± 25.3) and generative – from 21 to 128 (63.8 ± 33.7). The individuals of generative life stage prevailed among

Table 4. Age structure of willowherb populations

Life stage	Total number of plants (in 20 plots)	Number of plants in 1 m^2 plot			
		Mean	SD	Max	Min
Epilobium ciliatum					
Juvenile	2196	109.8	127.5	435	6
Immature	495	24.7	11.6	56	13
Virginile	681	34.0	25.3	88	9
Generative	1276	63.8	33.7	128	21
Epilobium hirsutum					
Juvenile	0	0.0	0.0	0	0
Immature	0	0.0	0.0	0	0
Virginile	10	0.5	1.6	6	0
Generative	0	0.0	0.0	0	0
Epilobium parviflorum					
Juvenile	75	3.7	3.4	11	0
Immature	118	5.9	5.1	16	0
Virginile	74	3.7	3.1	12	0
Generative	682	34.1	24.9	78	1
Epilobium tetragonum					
Juvenile	104	5.2	8.3	28	0
Immature	135	6.7	7.9	31	0
Virginile	130	6.5	6.5	18	0
Generative	424	21.2	23.4	83	0

E. parviflorum and *E. tetragonum* plants. The distribution patterns among the plots of the individuals belonging to pre-reproductive life stages of *E. hirsutum*, *E. parviflorum*, and *E. tetragonum* showed lower variability compared to generative individuals of these species.

DISCUSSION

The fact that *E. ciliatum* and *E. tetragonum* plants survived the glyphosate treatment and produced seeds, while other plants disappeared completely, suggests the idea of the occurrence of glyphosate-resistant populations of the mentioned willowherb species in Lithuania. The resistance of American willowherb to glyphosate has been ascertained in neighbouring Poland as well (Rabcewizc & Wawrzyńczak, 2004; Lisek, 2005).

Weed resistance to herbicide develops by using it year after year, or as a consequence of repeated applications during the growing season (Bhowmik, 2010). Thus, treatment with glyphosate from time to time, which is discussed in our case, cannot be considered as an agent of the origin of genotypes resistant to this herbicide. However, it could play a role in the propagation of herbicide-resistant plants – in the current investigation, *E. ciliatum* and *E. tetragonum* plants not only survived the herbicide treatment, but also produced seeds.

The results show dominance of willowherb plants in the herb layer of the investigated territory (up to 98.7% of the herb layer coverage) and occurrence of several willowherb species (up to four species per 1 m^2) a year after the herbicide application. This can be determined by ruderal strategy (after MacArthur & Wilson, 1967) of the genus *Epilobium*. The life cycle length of willowherbs is short and they produce a large number of small (0.8–2.0 mm long, 0.3–0.5 mm width) and low weight (0.06–0.17 mg) seeds (Table 5), which can be transmitted by the wind, over long distances (Matulevičiūtė & Sprainaitytė, 2010). In the spread of these species, epizoochory and endozoochory (Couvreur et al., 2005) also take part. Thus, single plants can originate many populations distant from the primary population. Furthermore, willowherbs can be propagated through vegetative reproduction: plants produce overwintering organs such as rosette, epigeal or hypogeal stolons (Haussknecht, 1884) containing buds, which can spread through tillage or cultivation (Myerscough & Whitehead, 1967).

Moreover, willowherbs react positively to the disturbance of habitat (Biber et al., 2013). In the present study, the plant cover was destroyed by applying the herbicide. Thus, avoiding the competition of other weed species, willowherb plants grew in the investigated territory abundantly (up to 733 plants per m^2). The high proportion of the generative *Epilobium ciliatum*, *E. parviflorum* and *E. tetragonum* plants and their adaptation to anemochory (Haussknecht, 1884) suggests the accumulation of the abundant soil seed bank of these species in the investigated area and its surroundings. The occurrence of high number of virginile willowherbs, especially *E. ciliatum* plants in the study area can be considered as a potential input into the soil seed bank since the period between the

Table 5. Biological characteristics of willowherb species considered to be weeds. Information sources are given in the superscript

Willowherb species	Plant height (cm)	Life cycle length (weeks)	Seed number per plant	Seed length (mm)	Seed width (mm)	Seed weight (mg)
E. ciliatum	10–150[1,8]	9–10[7]	≤60,000[12]	0.8–1.0[1], 1.3[5], 1.1–1.3[9]	0.3–0.4[1], 0.5[5]	0.07[2], 0.06[5], 0.062[7]
E. hirsutum	50–200[1,4,8]	14–18[10]	≤70,000[11]	0.9–1.1[1], 1.0[5], 1.5[6], 0.8–1.1[9]	0.4–0.6[1], 0.5[5,6]	0.14[2], 0.05[5]
E. montanum	10–100[4]	11[7]		1.0–1.1[1], 1.0–1.3[9]	0.4–0.5[1]	0.12[2], 0.166[7]
E. palustre	5–80[4,8]			1.7–2.0[1], 1.8[5], 1.5–2[6], 1.3–2.1[9]	0.5–0.6[1], 0.5[5], 0.3–0.5[6]	0.04[5]
E. parviflorum	15–100[4]			0.9–1.1[1], 1.0[5,6], 0.8–1.0[9]	0.4–0.5[1], 0.5[5,6]	0.11[5]
E. roseum	15–100[4]			0.8–1.1[1], 1[6], 0.9–1.2[9]	0.4–0.51, 0.5[6]	0.0870[3]
E. tetragonum	15–110[8]			0.8–0.9[1], 1[6], 0.8–1.0[9]	c. 0.4[1], 0.3–0.5[6]	0.0676[3]

Information sources: 1 – Bojnanský & Fargašová (2007); 2 – Couvreur et al. (2005); 3 – Csontos et al. (2007); 4 – Fatare et al. (1996); 5 – Grime et al. (1988); 6 – Haussknecht (1884); 7 – Myerscough & Whitehead (1967); 8 – Raven (1968); 9 – Saxén (2011); 10 – Shamsi & Whitehead (1974); 11 – Shamsi & Whitehead (1977); 12 – Van Himme et al. (1986).

study date and the end of the growing season is adequate for maturity and seed production due to short life cycle of this species – *E. ciliatum* requires only 9 to 10 weeks for seed germination, maturity and production of another seed generation (Myerscough & Whitehead, 1967).

The composition of willowherb species and the number of individuals in the investigated area show the changing importance of particular species in the vegetation cover. Abundance of *E. ciliatum* in the territory and its predominance among other willowherb species is probably the result of high ecological plasticity of this species, which was ascertained under natural conditions of Lithuania (Matulevičiūtė, 2007).

Raven & Raven (1976) have highlighted the enormous seed production of American willowherb as a factor in the spread of this species in Europe and Australasia. In my opinion, another factor determining such wide and fast spread of this species is great adaptability. The occurrence of biotypes resistant to various herbicides (Bulcke et al., 1986, 1987; Clay, 1989; Rabcewizc & Wawrzyńczak, 2004) and the spread throughout many types of habitats (Pyšek et al., 2012) demonstrate such quality of *E. ciliatum.*

Inasmuch *E. ciliatum* penetrates into many types of natural habitats of Lithuania (Matulevičiūtė, 2007), large number of the seeds spreading from dense stands of American willowherb can become a serious threat to natural habitats of the country in general as well as to plant species diversity in particular. Whereas willowherb plants can reach heights of about 1 meter (Table 5), they can eliminate from the habitat minor and more susceptible to shading plant species.

The important role of the recovery of vegetation after the herbicide application in the study was demonstrated by *E. parviflorum* and *E. tetragonum* as well. High abundance and frequency of *E. parviflorum* plants contradict to the peculiarities of distribution of this species: it is not considered as frequent either in Lithuania (Fatare et al., 1996; Matulevičiūtė, 2010) or in neighbouring Latvia and Estonia (Fatare et al., 1996). The abundance of hoary willowherb in the study area was determined by favourable environmental conditions since this species is restricted to nutrient and carbonates rich, loamy or clayey soils and tolerates partial shade (Oberdorfer et al., 1994). The requirement of particular ecological conditions limits the establishment of *E. parviflorum* populations in many habitat types throughout large regions (e.g. those with nutrient- and carbonate-poor soils).

Interesting is the fact that five decades ago, *E. tetragonum* was sparse in the northern part of its distribution area (Meusel et al., 1965) and at the end of the 20th century this species was very rare in the Baltic countries (Fatare et al., 1996), though in the last decade it has become frequent, while not equally distributed in Lithuania (Matulevičiūtė, 2010). Based on my personal observations, I can affirm the changes in the frequency as well as in the abundance of this species and its spread over broad range of natural, seminatural and anthropogenic habitats of Lithuania. Such changes can be determined by multiple factors. However, dense population of *E. tetragonum* with high number of generative plants in the study area demonstrates a significant role of herbicide usage in the orchard for reproduction and possible spread of this species.

In the investigated area, *E. hirsutum* plants were solitary and could be attributed to pre-reproductive life stage. However, this species has been considered as increasingly spreading weed in Europe (Weber & Gut, 2005).

The current study is only the first and small contribution to the knowledge about the role of willowherb in weed vegetation of Lithuania. Nevertheless, it turns attention to potentially existing problems, and unexplored yet phenomena. It invites for detailed investigations on weed flora of orchards in Lithuania in order to evaluate the real role of willowherb species in weed vegetation under the influence of modern agricultural technologies and climate change.

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OŽKAROŽIŲ (*EPILOBIUM*) VAIDMUO ATSIKURIANT AUGALIJAI PRAĖJUS METAMS PO HERBICIDO PANAUDOJIMO: TYRIMAS CENTRINĖJE LIETUVOS DALYJE

Dalytė Matulevičiūtė

Santrauka

Kai kurios ožkarožių (*Epilobium*) rūšys laikomos piktžolėmis ir yra tapusios vis didėjančia žemės ūkio problema. Darbo tikslas buvo nustatyti, kokį vaidmenį atlieka ožkarožių augalai pradinėje augalijos vystymosi fazėje po purškimo glifosatu. Buvo tirti ožkarožių pavyzdžiai, surinkti 2008 metų rugpjūčio mėnesį 0,2 ha ploto obelų sode, praėjus mėnesiui po purškimo. Kitų metų liepos mėnesį tame pačiame sode buvo tirta augalija. Sodo augaliją reprezentuojančiame 100 m^2 plote buvo nustatyta rūšių sudėtis ir gausumas. Dvidešimtyje 1 m^2 laukelių vertintas žolių dangos projekcinis padengimas, ožkarožių augalų gausumas ir jų vystymosi stadijos.

Nustatyta, kad po purškimo išliko tik *Epilobium ciliatum* ir *E. tetragonum* augalai. Kitais metais tirto ploto augalinė danga buvo sudaryta iš 18 augalų rūšių, bet didžiausias projekcinis padengimas buvo *Epilobium* genties augalų. Buvo identifikuotos viena svetimžemė (*E. ciliatum*) ir trys vietinės floros (*E. hirsutum*, *E. parviflorum* ir *E. tetragonum*) rūšys. Gausiausi buvo *E. ciliatum* augalai. Ši rūšis pasižymėjo ir didžiausiu generatyvinių bei virgininio brandos amžiaus tarpsnio augalų skaičiumi. Didžiąją dalį *E. parviflorum* ir *E. tetragonum* augalų sudarė generatyviniai individai. Visi *E. hirsutum* augalai buvo priešgeneratyvinio brandos amžiaus periodo. Generatyviniai individai sudarė daugiau nei trečdalį visų ožkarožių augalų. Tyrimų laukeliai labai skyrėsi tiek ožkarožių rūšių ir jų individų skaičiumi, tiek augalų branda.