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Invasion, distribution and habitat affiliation of *Cyperus esculentus*, a new weed in Slovenia

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Key words: alien plant, agriculture, plant communities, yellow nutsedge, vegetation.

Ključne besede: tujerodna rastlina, kmetijstvo, rastlinske združbe, užitna ostrica, vegetacija.

Abstract

Cyperus esculentus (yellow nutsedge) is an alien species that started to spread in arable fields in Slovenia and has already become a noxious weed. In this study we present the spatio-temporal pattern of this invasion in Slovenia. Species was first recorded in 1980 and currently two hotspots are evident (Ljubljana Basin and Posočje). Habitat preferences of *Cyperus esculentus* and the floristic compostion of invaded plant communities were studied. These communites were compared to similar communities in Slovenia and to so far described vegetation types with dominating *Cyperus esculentus* in Europe. Based on these analyses we described new weed association, namely *Digitario sanguinalis-Cyperetum esculenti*.

Izvleček

Cyperus esculentus (užitna ostrica) je tuejrodna vrsta, ki se v Sloveniji širi na obdelanih tleh in je že postala škodljiv plevel. V raziskavi predstavljamo prostorsko-časovni vzorec razširjanja v Sloveniji. Vrsto so prvič opazili leta 1980 in trenutno sta očitni dve vroči točki pojavljana (Ljubljanska kotlina in Posočje). Preučili smo rastiščne značilnosti in vrstno sestavo rastlinskih združb, v katerih se pojavlja vrsta *Cyperus esculentus.* Te združbe smo primerjali s podobnimi v Sloveniji in z dosedaj opisanimi vegetacijskimi tipi, v katerih prevladuje *Cyperus esculentus* v Evropi. Na osnovi teh analiz smo opisali novo plevelno asociacijo *Digitario sanguinalis-Cyperetum esculenti*.

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Introduction

Many alien plants are expanding their areal and are invading arable land (Weber & Gut 2005). Alien plants are particularly successful and several have already become invasive and noxious weeds with significant ecological impact and economic damage (Pimentel et al. 2001).

For understanding the invasion pattern of an invasive alien plants it is important to know the spatio-temporal history of their invasion and which habitats are predominately colonized. Successful invasive alien plants can be part of many plant communities and can even change their habitat affiliation over time (Essl et al. 2009). Knowledge of these invasion processes is particularly important for preventing current spread of invasive alien plants and to develop strategies to predict and stop future invasions. Recently early warning systems were established to detect the occurrence of potential invasive alien species (Slovenian forestry institute 2016–2020) and the reconstruction of the historical spread of alien species can be a valuable assistance to such efforts (Essl et al. 2009).

Cyperus esculentus or yellow nutsedge, a species from the Cyperaceae family, is an invasive alien plant in most parts of Europe. It is a perennial weed that reproduces by seeds and underground tubers. Its origin is uncertain, but it originates most likely from the Mediterranean and Southwest Asia. Today, it is widely distributed in western and southern Europe as well as in parts of Central Europe (Follak et al. 2016). *Cyperus esculentus* has C4 photosynthetic pathway (Li et al. 1999) and this among other traits (high tuber production, allelopathy, vegetative reproduction) contributes to its competitiveness (Brown 1999, Follak et al. 2016).

Cyperus esculentus can cause up to 80% loss of yield in field crops or vegetables (Lešnik & Vajs 2017). It was listed as the 16th worst weed in the world (Holm et al. 1991). The management of *Cyperus esculentus* is very difficult and usually integrated methods (the combination of cultural, mechanical and chemical control options) are recommended (Bohren & Wirth 2013, Follak et al. 2016). Trials of herbicide efficacy show that the herbicides available on the Slovenian market cannot guarantee completely reliable chemical control on arable land (Lešnik & Vajs 2017). Yellow nutsedge is also common on arable land near water bodies and safeguard zones where only a narrow selection of herbicides is available (Lešnik & Vajs 2017).

Plant communities dominated by *Cyperus esculentus* were first described from riverbanks and gravel bars from several parts of Europe (Wisskirchen 1995, Felzines & Loiseau 2005, Lastrucci et al. 2012, Pellizzari 2020). Although *Cyperus esculentus* is known as a noxious weed on arable land for a long time, the vegetation with yellow nutsedge of invaded crop field has been rarely sampled so far (Fragner 2010) and as far as we know, it was never analysed on a large scale. Novel ecosystems have new combinations of species and arise through human action or environmental change (deliberate or inadvertent) (Hobbs et al. 2006). Arable vegetation could hardly qualify as novel ecosystem as it is intensively managed for centuries, but in recent decades we can observe drastic changes of weed vegetation species composition and abundance of neophytes due to changed agricultural practices (Richner et al. 2015).

The aims of our study were: 1) to present the current distribution of *Cyperus esculentus* in Slovenia, and 2) to analyse the habitats and plant communities it invaded in Slovenia and as well as in Europe.

Methods

For the analysis of the current distribution of *Cyperus esculentus* in Slovenia we used data of flora mapping (according to Ehrendorfer & Hamann 1965) that is stored in the Flovegsi database (Seliškar et al. 2003). Moreover, we collected all available distribution data from various sources (published and grey literature, unpublished data, internet). Specimens collected in the field are deposited in the herbarium of the Institute of Biology ZRC SAZU (LJS).

The vegetation in one hotspot of spread in Slovenia (Ljubljana basin) was sampled according to the Braun-Blanquet method (Braun-Blanquet 1964) between 2015 and 2020. Furthermore we collected all available relevés with dominant species *Cyperus esculentus* from Europe (Table 2) and stored them in the Turboveg database (Hennekens & Schaminée 2001).

We transformed the combined cover-abundance values into percentage and then log transformed it. For numerical comparisons we performed Non-metric multidimensional scaling (NMDS) ordinations. Statistical analyses were made using Juice (Tichý 2002) and R software (R Development Core Team 2012). Diagnostic species were determined by comparison of all relevés and phi fidelity index (Chytrý et al. 2002).

The nomenclature of species is according to Martinčič et al. (2007) except for species *Amaranthus emarginatus* Salzm. ex Uline & Bray and *Panicum laevifolium* Hack., and syntaxa according to Šilc & Čarni (2012) and Mucina et al. (2016). In the classification of species into phytosociological groups (groups of diagnostic species) we mainly refer to the EuroVegChecklist (Mucina et al. 2016).

Results

Distribution and spatio-temporal spread pattern in Slovenia

We gathered 99 records of *Cyperus esculentus* in Slovenia from 1980 to 2020 and this comprise 21 quadrants of the floristic mapping grid (Figure 1). Rapid increase in number of records and quadrants is evident after 2006 (Figure 2).

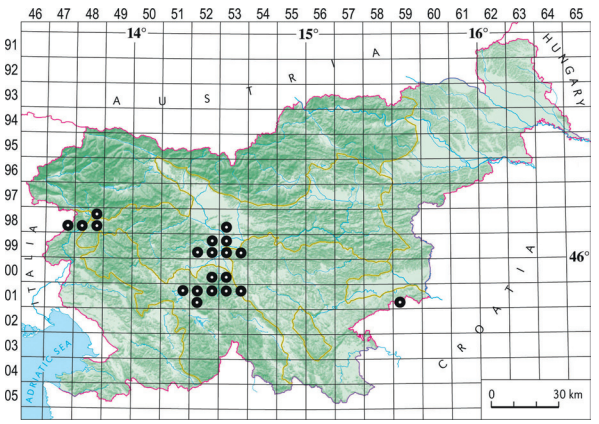


Figure 1: Distribution of *Cyperus esculentus* in Slovenia.
Slika 1: Razširjenost vrste *Cyperus esculentus* v Sloveniji.

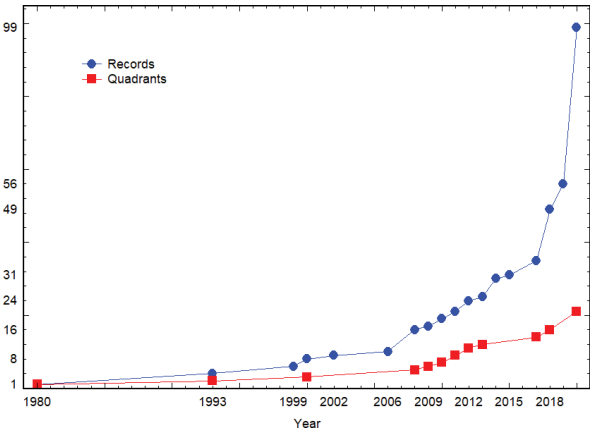


Figure 2: Cumulative number of occurrences and occupied quadrants of *Cyperus esculentus* since its introduction in Slovenia.
Slika 2: Kumulativno število pojavljanj in kvadrantov z vrsto *Cyperus esculentus* od prve zabeležbe v Sloveniji.

Currently there are two major »hotspots« of invasion: in the Posočje region and in central Slovenia, however there are also some individual locations scattered across eastern Slovenia (Figure 1).

Out of 99 records, 79 (80%) had habitat information. Most invaded habitats in Slovenia were arable fields (66%), followed by riverine vegetation (7%), while *Cyperus esculentus* is rare in ruderal sites (4%) and grasslands (3%). Among arable fields maize was most frequently invaded, but yellow nutsedge occurred also among potato, pumpkin, and cereals.

Phytosociologial affiliation and habitat preferences

In the Ljubljana Basin, that is one of the two hotspots of its spread in Slovenia vegetation on 24 mostly arable fields was sampled. The average number of species per plot was 14 (ranging from 6 to 26 species). *Cyperus esculentus* dominated vegetation is found mainly on maize fields that are the most common fields in Ljubljansko Barje. Stands were dominated by *Cyperus esculentus* and characteristic plant species of three classes of anthropogenic vegetation—i.e., *Digitario sanguinalis-Eragrostietea minoris*, *Papaveretea rhoeadis* and *Sisymbrietea,* prevail as accompanying species (Table 1). Their presence indicates weed character of this vegetation type.

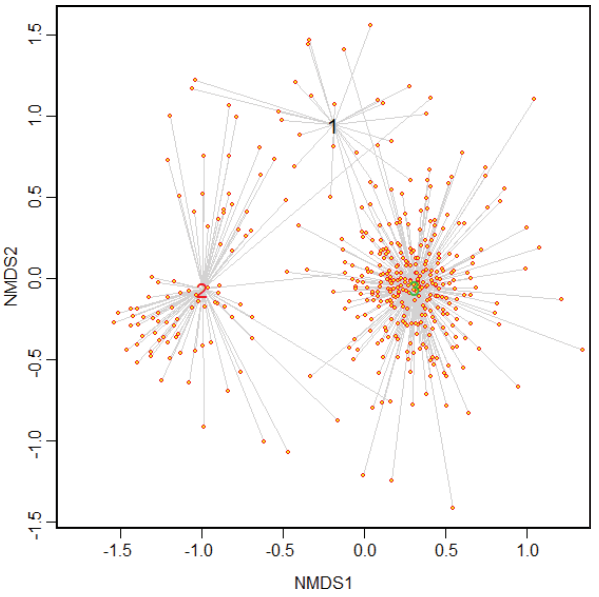
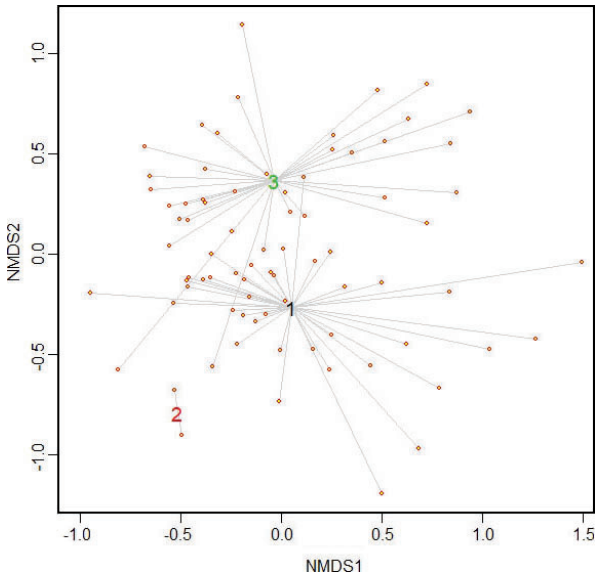


Figure 3: NMDS spiderplot of relevés of the three syntaxa from Slovenia. Numbers indicate centroids of particular vegetation cluster: 1 – *Digitario sanguinalis-Cyperetum esculenti*, 2 – *Bidentetea*, 3 – weed vegetation (only *Atriplici-Chenopodietalia* sensu Mucina (1993)).
Slika 3: NMDS graf popisov treh sintaksonov iz Slovenije. Številke predstavljajo centroide posameznih vegetacijskih klastrov: 1– *Digitario sanguinalis-Cyperetum esculenti*, 2 – *Bidentetea*, 3 – weed vegetation (samo *Atriplici-Chenopodietalia* v skladu z Mucina (1993)).

The comparison of the relevés from Slovenia, originally classified into the *Bidentetea* (seasonally flooded nutrient-rich alluvia, banks and heavily nutrient loaded anthropogenic habitats) and *Atriplici-Chenopodietalia* (arable crops, gardens and waste places), and the relevés

of plant communities dominated by *Cyperus esculentus* shows higher similarity with weed vegetation of cultivated land, although position in the graph is intermediate (Figure 3).



1 ***Digitario-Eragrostietea***
a. *Digitario-Cyperetum esculenti*, Slovenia (this paper)
b. weed vegetation, Austria (Fragner 2010)

2 ***Isoëto-Nanojuncetea***
c. *Cyperus eculentus-(Isoëto-Nanojuncetea),* Poland (Dajdok et al. 2007)

3 ***Bidentetea***
d. *Cyperetum esculenti*, Italy (Lastrucci et al. 2012)
e. *Cyperetum esculenti*, Italy (Otolini 2013)
f. *Cyperus eculentus* community, France (Felzines & Loiseau 2005)
g. *Cyperetum esculenti*, France (Wisskirchen 1995)
h. *Cyperetum esculenti*, France (Cornier 2002)
i. *Cyperetum esculenti*, France (SMEAG 2011)
j. *Cyperetum esculenti*, Italy (Pellizarri 2020)

Figure 4: NMDS spiderplot of relevés with dominant *Cyperus esculentus* from Europe. Classification of the syntaxa is according to original authors.
Slika 4: NMDS graf popisov s prevladujočo vrsto *Cyperus esculentus* iz Evrope. Uvrščenost sintaksonov se ujema z izvorno uvrstitvijo avtorjev.

We also compared *Cyperus esculentus* dominated plant communities from other parts of Europe (Table 2). NMDS analysis shows great similarity between stands (Figure 4). Stands with *Cyperus esculentus* from (1) arable land (a-b) and (2 and 3) on wet riverbanks and gravel (c, e-f) are floristically very similar. In both vegetation types plant species characteristic for *Digitario-Eragrostietea* and *Papaveretea* classes are present, but in stands from wet, natural habitats species of classes *Bidentetea* and *Phragmitetea* are more abundant.

Plant community on arable fields is negatively characterised by absence of species characteristic for *Bidentetea* class (e.g. *Bidens frondosa, B. cernua, Xantium italicum*). Weed stands are differentiated by typical weeds *Veronica persica, Setaria pumila* and *Digitaria sanguinalis* (Table 2).

Based on the floristic composition and particular habitat differences, we are of the opinion that *Cyperus esculentus* dominated plant community presents new plant association within *Digitario-Eragrostietea* class.

Syntaxonomical scheme of *Cyperus* dominated communities:

Bidentetea Tx. et al. ex von Rochow 1951
Bidentetalia Br.-Bl. et Tx. ex Klika et Hadač 1944
Chenopodion rubri (Tx. In Poli et J. Tx. 1960) Hilbig et Jäger 1972
Cyperetum esculenti Wisskirchen 1995
Characteristic species*: Cyperus esculentus*
Differential species: *Xanthium italicum, Amaranthus tuberculatus, Portulaca oleracea, Polygonum lapathifolium, Eragrostis pectinacea, Cyperus glomeratus, Bidens frondosus*

Digitario sanguinalis-Eragrostietea minoris Mucina, Lososová & Šilc 2018
Eragrostietalia J. Tx. ex Poli 1966
Eragrostion Tx. in Oberd. 1954
Digitario sanguinalis-Cyperetum esculenti ass. nova hoc loco
Holotypus: relevé 7 in Table 1.
Characteristic species*: Cyperus esculentus*
Differential species: *Equisetum palustre, Digitaria sanguinalis, Setaria pumila, Veronica persica, Galinsoga ciliata*

Discussion

Cyperus esculentus was first reported for Slovenia already in the 1980s by Gabrijel Seljak on maize fields near Kobarid (Dakskobler & Čušin 2002, Čušin 2006) and the first published locality was nearby in 1993 (Jogan & Podobnik 1995). The time of the first introduction in Slovenia is comparable to other western and southern countries (e.g. France, Italy) and Follak et al. (2016) erroneously indicated year 1999 as first occurrence in Slovenia due to reports published in local journals. In Europe, a rapid spread of species was observed since 2005 (Follak et al.

2015), while in Slovenia this was delayed for a few years (Figure 2). The reason for time lag can also be attributed to differences in sampling efforts. In Slovenia, records were from the Ljubljana basin, while the north-eastern part is less invaded. In addition, we can expect spread to NE Slovenia from the neighbouring Styria (Austria), which is one of the invasion hotspots in Central Europe (Follak et al. 2015).

The status of naturalisation of the species in Slovenia changed rapidly from casual to invasive species (sensu Richardson et al. 2000). In 2001, *Cyperus esculentus* was not mentioned even as rare based on a surey of arable fields (Lešnik 2001) and it was also (erroneously) listed on the Red List as a vulnerable species (Anonymous 2002). Few years later Lešnik (2009) mentioned it as present in smaller extent on arable land. In 2017, yellow nutsedge was already recognised as a species with the highest impact of noxious effects in agricultural production systems (Lešnik & Vajs 2017). The species is now listed on the black action list of Slovenia (Grudnik et al. 2015). In Europe, it is listed on the EPPO List of invasive alien plants (EPPO 2002), and on national black lists in other European countries (e.g. in Switzerland, INFOFLORA 2020).

Alien species initially first colonize disturbed habitats with low competition from other plant species, such as ruderal sites or riparian habitats (Jogan & Vreš 1998, Šilc 2002, Dakskobler & Vreš 2009, Dakskobler et al. 2019). Later they can invade also arable fields. Such pattern was observed in Slovenia with *Ambrosia artemisiifolia*. First, it was found in ruderal sites and along roads (Šilc 2002), later it occupied arable land where it became an economically important weed (Lešnik & Vajs 2017). In Slovenia, *Cyperus esculentus* invasion began with the colonization of arable land (maize fields), where the species is still most abundant. Other habitats, such as ruderal and riverine vegetation, are currently less invaded. In other parts of Europe, the invasion process was similar, pre-1990 records were mostly from arable land, and also recent records were from arable land (Follak et al. 2015). Other habitats, like riparian sites were by the opinion of Follak et al. (2015) colonized later from cultivated land. However, first reports of plant communities were from stands along water bodies (Wisskirchen 1995).

The pathways of introduction of *Cyperus esculentus* in Europe are very diverse and related to human activities. Soils transport, ploughing, and handling of crop waste are probably the main drivers for the species spread within and between fields (Follak et al. 2016). Lešnik (2009) pointed out that used growth substrate from nurseries that is used as compost, and cultivation in small gardens are one of the possible vectors of introduction and spread. As *Cyperus esculentus* is found mainly on maize fields in Central Slovenia, a possible reason could also be also uncertified maize seeds (Dancza et al. 2004), but this was not confirmed (Follak et al. 2016).

Plant communities with *Cyperus esculentus* in Europe were so far studied sporadically, and contrarily to prevailing floristic records in arable fields, they were sampled mostly along river banks and gravel bars. Riparian habitats were colonized by *Cyperus esculentus* mainly along the rivers Rhine and Elbe rivers (Wisskirchen 1995), Tiber (Lastrucci et al. 2012) and Po (Pelizzarri 2020). Stands were classified as *Cyperetum esculenti* (class *Bidentetea*). Relevés of weed vegetation with *Cyperus esculentus* are rare, only from Austria (Styria) (Fragner 2010) and Slovenia (this paper). In both cases habitats are very similar: disturbed, often wet, therefore both vegetation types are floristically very similar with many common weed pioneer species (e.g. *Echinochloa crus-galli*, *Setaria pumila*, *Polygonum lapathifolium*) and therefore are transitional between *Bidentetea* and *Digitario-Eragrostietea* classes. Floristic differences between *Bidentetea* and *Chenopodietalia albi* are very small, as many weed species have their natural origin on wet, periodically flooded river banks (Mucina 1993). Many relevés from Fragner (2010) with lower abundance of *Cyperus esculentus* are also transitional to other thermophilous weed communites like *Echinochloo-Setarietum*.

Character species of *Cyperetum eculenti* is almost with all authors only *Cyperus esculentus* (Wisskirchen 1995, Pelizzarri 2020). Wisskirchen (1995) mentions also *Polygonum lapathifolium* and *Echinochloa crus-galli* with higher constancy. *Xanthium italicum* also characterises riparian stands. On the other hand, arable stands of *Digitario sanguinalis-Cyperetum esculenti* also dominated by *Cyperus esculentus* as character species but are characterized also by typical weed species while pioneer river bank species are missing.

Rapid spread of *Cyperus esculentus* is expected also in the future in many European countries, particularly with global warming (Simpson 2011). Based on the Slovenian experience with *Cyperus esculentus* spread and taking into consideration the short time from establishment of the species to becoming noxious weed, we can also expect other alien Cyperaceae species to invade and colonize Central Europe (Lešnik 2009). Beside *Cyperus esculentus* also *C. rotundus* L., C. *iria* L. and *C. congestus* Vahl. can potentially spread (Lešnik & Vajs 2017), while in Slovenia *C. eragrostis* is already established in ruderal sites (Dakskobler & Vreš 2009).

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Table 1: Phytosociological table of *Digitario sanguinalis-Cyperetum esculenti*.
Tabela 1: Fitocenološka tabela asociacije *Digitario sanguinalis-Cyperetum esculenti*.

(Mucina et al. 2016)		Layer	1	2	3	4	5	6	7*	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	fr	%
	Altitude		290	290	290	291	290	289	289	289	289	290	290	290	305	350	316	307	306	288	288	288	288	288	288	288		
	Relevé area (m²)		9	20	3	32	22	35	25	25	9	50	20	50	25	100	25	25	25	25	100	400	10	25	25	25		
Class	Cover herb layer (%)		80	80	90	90	90	90	90	80	80	50	90	70	80	70	80	65	65	80	80	90	80	70	80	100		
CHE	*Cyperus esculentus*	C	3.2	4.5	3.4	5.5	3.4	5.5	4.5	5.5	3.4	3.4	5.5	4.4	4,5	4.5	1.1	2.1	4.4	2.1	5.5	4.5	3.4	2.1	2.4	1.1	24	100
	Digitario sanguinalis-Eragrostietea minoris																											
DIG	*Digitaria sanguinalis*	C	3.1		+			+	1.1	+	2.4	1.1	1.1	1.1		1.1	1.1	+		+				4.4			16	67
DIG, BID	*Echinochloa crus-galli*	C	2.2	+	2.2		2.2			1.1			+	+	1,1	+	2.1	3.1	2.4	1.1				+		1.1	14	58
DIG	*Panicum capillare* (incl. *P. barbipulvinatum*)	C		2.1		1.1	2.2	+	2.1	1.1							+			3.4			+	1.1		5.5	10	42
DIG	*Setaria pumila*	C		+					+				1.1	+	+	+	1.1	+	1.1								9	38
DIG	*Amaranthus lividus*	C												+										+	+		3	13
DIG, POL	*Polygonum aviculare*	C			+													+		+							3	13
DIG	*Portulaca oleracea*	C													+												1	4
DIG	*Panicum miliaceum* subsp. *agricola*	C															+										1	4
	Papaveretea rhoeadis																											
PAR	*Veronica persica*	C		+	1.1						1.1	1.1	+	+		+	+	2.1					3.4			+	11	46
PAR	*Galinsoga ciliata*	C	2.1								+			+			1.1	1.1	2.1	1.1			2.4				8	33
PAR, BID	*Chenopodium polyspermum*	C	+		+	1.1									2,1		+	+						+	+		8	33
PAR, SIS	*Cirsium arvense*	C	+					+	+			+				1.1	+										6	25
PAR	*Polygonum lapathifolium* subsp. *pallidum*	C				+												+	+	+	2.1	2.4					6	25
PAR, SIS	*Stellaria media*	C									+			+				+									3	13
PAR	*Capsella bursa-pastoris*	C	+														+	+									3	13
PAR	*Brassica napus*	C																			1.1	1.1		+			3	13
PAR, SIS	*Sonchus asper*	C							+						+												2	8
PAR	*Galinsoga parviflora*	C				+											+										2	8
PAR	*Lamium purpureum*	C	+															+									2	8
PAR, SIS	*Convolvulus arvensis*	C	+														+										2	8
PAR, SIS	*Matricaria perforata*	C													+		+										2	8
PAR	*Apera spica-venti*	C													+												1	4
PAR	*Sinapis alba*	C																				+					1	4
PAR	*Solanum nigrum*	C																						+			1	4
	Sisymbrietea																											
SIS	*Chenopodium album*	C		+	1.1						+	+		1.1	+		+	+					+	+			10	42
SIS	*Amaranthus retroflexus*	C	2.1														1.1	+							+		4	17
SIS	*Atriplex patula*	C		+																			+				2	8
SIS	*Conyza canadensis*	C							1.1																		1	4
SIS	*Geranium pusillum*	C															+										1	4

	Bidentetea																											
BID	*Polygonum lapathifolium* subsp. *lapathifolium*	C			2.4	2.1			1.1		1.1				+						+	1.1		+	+	+	10	42
BID, PAR	*Polygonum persicaria*	C												1.1			+			+			+	+			5	21
BID	*Polygonum mite*	C															+		1.1	+		1.1					4	17
BID	*Bidens tripartita*	C							+					+							+						3	13
BID	*Rorippa sylvestris*	C													+		+								+		3	13
BID	*Bidens frondosa*	C																			1.1	2.1			+		3	13
BID	*Rorippa palustris*	C							+																		1	4
BID	*Ranunculus sardous*	C																							+		1	4
	Epilobietea angustifolii																											
EPI, PHR	*Calystegia sepium*	C	+		+					+	1.1			+									+				6	25
EPI	*Myosoton aquaticum*	C	+									+														+	3	13
EPI	*Urtica dioica*	C	+		+																						2	8
EPI	*Solidago gigantea*	C												+													1	4
EPI	*Verbascum nigrum*	C							1.1																		1	4
EPI	*Echinocystis lobata*	C																						+			1	4
	Artemisietea vulgaris																											
ART, EPI	*Erigeron annuus* subsp. *annuus*	C							+		+						+		+								4	17
ART, GER	*Silene latifolia* subsp. *alba*	C									+			+			+			+							4	17
ART	*Elytrigia repens*	C										+														+	2	8
ART; MOL	*Rumex obtusifolius*	C															+						+				2	8
ART, SIS	*Equisetum arvense*	C										+															1	4
ART	*Medicago lupulina*	C																	+								1	4
ART	*Medicago sativa*	C																+									1	4
ART, MOL	*Plantago lanceolata*	C																	+								1	4
	Molinio-Arrhenatheretea																											
MOL	*Equisetum palustre*	C	1.1	1.1	2.1	1.1	2.2	2.1	1.1	1.1	1.1	1.1	1.1	1.1				1.1		2.1		2.1	+	+			17	71
MOL, ISO	*Plantago intermedia*	C							+		+		+	+	2,1		+	2.1	+				2.2	+	+		11	46
MOL	*Carex hirta*	C					2.2	1.1		+		+								+			+			+	7	29
MOL	*Lolium perenne*	C	+		+																				2.4		3	13
MOL	*Trifolium repens*	C			+				+								+	1.1	1.1	+					1.2		7	29
MOL	*Agrostis stolonifera*	C						1.2																			1	4
MOL	*Dactylis glomerata* s.str.	C										+													3.4		2	8
MOL	*Festuca pratensis*	C				+																			1.1		2	8
MOL	*Galium mollugo*	C							+									+							+		3	13
MOL	*Hypericum tetrapterum*	C							+																		1	4
MOL	*Leucanthemum ircutianum*	C							+																		1	4
MOL	*Lotus corniculatus*	C							+																+		2	8
MOL	*Poa pratensis*	C	+																								1	4
MOL	*Poa trivialis*	C										+								+		+	+			+	5	21

(Mucina et al. 2016)		Layer	1	2	3	4	5	6	7*	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	fr	%
MOL	*Potentilla reptans*	C			1.2																		+				2	8
MOL	*Ranunculus flammula*	C							+																		1	4
MOL	*Mentha verticillata*	C													+												1	4
MOL	*Trifolium pratense*	C													+			+	2.4						1.2		4	17
MOL	*Lolium multiflorum*	C																							2.2		1	4
MOL	*Lychnis flos-cuculi*	C																							+		1	4
MOL	*Phleum pratense*	C																							1.1		1	4
MOL	*Ranunculus repens*	C																+		+					1.2		3	13
MOL	*Rumex conglomeratus*	C																					+		+		2	8
MOL	*Rumex crispus*	C															+						+		+		3	13
MOL	*Taraxacum* sect. *Ruderalia*	C															+								+		2	8
MOL	*Trifolium hybridum*	C																	1.1								1	4
MOL	*Verbena officinalis*	C																					1.1				1	4
MOL, PHR	*Lysimachia vulgaris*	C																					+				1	4
MOL; PHR	*Stachys palustris*	C																					+				1	4
	Other species																											
PHR	*Lythrum salicaria*	C				1.1	+		2.1									+					+				5	21
POL	*Plantago major* s. str.	C															+	+					2.1		+		4	17
POP	*Rubus caesius*	C																					+			+	2	8
PHR	*Mentha aquatica*	C							+																		1	4
POL	*Poa annua*	C			+																						1	4
	Arctium sp.	C											+														1	4
	Geranium sp.	C												+													1	4
	Sonchus sp.	C									+																1	4
FRA	*Salix cinerea*	B						+																			1	4
ISO	*Veronica catenata*	C					+																				1	4
ISO, SCH	*Juncus articulatus*	C							+																		1	4
	Mentha sp.	C																					+				1	4
ISO	*Cyperus fuscus*	C																+									1	4
	Rumex x pratensis	C																					+				1	4
PHR	*Scutellaria galericulata*	C																					1.1				1	4
POP	*Scrophularia nodosa*	C																					+				1	4

Appendix to Table 1

Number of relevé; authors; date; locality; habitat description; altitude (m); coordinates (WGS84).

1: 20080709/08; Vreš B. & Čelik T.; 9.7.2008; Slovenija, Ljubljansko barje, Brest: along dirt road and ditch Peščenek ca. 700 m north from village; pumpkin field.; 290; 45.97924; 14.4888;

2: 20180709/16; Šilc U. & Vreš B.; 9.7.2018; Slovenija, Ljubljansko barje: Ig, ca. 1 km NE from village, left bank of river Ižica (Iščica); withinin and margin of maize field; 290; 45.96918; 14.53979;

3: 20150630/1; Šilc U. & Vreš B.; 30.6.2015; Slovenija, Ljubljansko barje: Ig, ca. 1 km NE from village in vicinity of bridge over river Ižica (Iščica); within and margin of maize field; 290; 45.96724; 14.53607;

4: 20180709/11; Šilc U. & Vreš B.; 9.7.2018; Slovenija, Ljubljansko barje: Ig, along the road Ig-Škofljica between streams Želimeljščica and Dremavščica, ca. 2 km NE from settlement; abandoned field, along the ditch; 291; 45.96508; 14.54596;

5: 20180709/01; Šilc U. & Vreš B.; 9.7.2018; Slovenija, Ljubljansko barje: Ig, east along Ižanska road, ca. 1 km N from Ig and ca. 700 m east from Iška Loka; along the ditch between maize fields; 290; 45.97203; 14.52572;

6: 20180709/02; Šilc U. & Vreš B.; 9.7.2018; Slovenija, Ljubljansko barje: Iška Loka, ca. 1.7 km north from village, along the road Iška Loka – Ižanka (Črna vas); margin and in the maize field; 289; 45.98541; 14.51765;

7: 20180709/03; Šilc U. & Vreš B.; 9.7.2018; Slovenija, Ljubljansko barje: Iška Loka, ca. 1.2 km north from the village, along the road Iška Loka – Ižanka (Črna vas); abandoned field; 289; 45.98454; 14.51696;

8: 20180709/04; Šilc U. & Vreš B.; 9.7.2018; Slovenija, Ljubljansko barje: Iška Loka, ca. 1 km north from the village, along the road Iška Loka – Ižanka (Črna vas); maize field; 289; 45.98404; 14.51625;

9: 20180709/05; Šilc U. & Vreš B.; 9.7.2018; Slovenija, Ljubljansko barje: Iška Loka, ca. 350 m north from the village, east along the road Iška Loka – Črna vas; maize field; 289; 45.97763; 14.5172;

10: 20180702/1; Šilc U. & Vreš B.; 2.7.2018; Slovenija, Ljubljansko barje, Brest: Nature Reserve Iški morost (Mali deli), along the dirt road and channel Peščenek ca. 1.3 km north from the village; maize field; 290; 45.98476; 14.48702;

11: 20180702/2; Šilc U. & Vreš B.; 2.7.2018; Slovenija, Ljubljansko barje, Brest: Gmajne, long dirt road ca. 850 m north from village; margin of maize field; 290; 45.98053; 14.48855;

12: 20180702/3; Šilc U. & Vreš B.; 2.7.2018; Slovenija, Ljubljansko barje, Brest: Gmajne, along the dirt road ca. 600 m north from the village; maize field, at the margin of the ditch; 290; 45.97865; 14.48922;

13: Šilc U. & Vreš B.; 31.7.2019; Slovenija, Loka pri Mengšu, millet field; 305; 46.14940; 14.55247;

14: 30.7.2020; Vreš B.; Slovenija, Gorenjska, Smlednik, maize field; 350; 456176, 5113930;

15: 10.9.2020; Vreš B.; Slovenija, Gorenjska, Zgornje Pirniče, buckwheat field; 316; 456375, 5110550;

16: 16.9.2020; Vreš B.; Slovenija, Gorenjska, Rača, abandoned field; 307; 473910, 5110130;

17: 16.9.2020; Vreš B.; Slovenija, Gorenjska, Rača, abandoned field; 306; 473725, 5110145;

18: 8.7.2020; Vreš B.; Slovenija, Ljubljansko barje, Črna vas, hemp field; 288; 460440, 5094950;

19: 8.7.2020; Vreš B.; Slovenija, Ljubljansko barje, Črna vas, wet depression on a rape field; 288; 461900, 5095550;

20: 8.7.2020; Vreš B.; Slovenija, Ljubljansko barje, Črna vas, abandoned rape field; 288; 461962, 5095440;

21: 6.7.2020; Vreš B.; Slovenija, Ljubljansko barje, Sinja Gorica, edge of soya field; 288; 448220, 5092208;

22: 6.7.2020; Vreš B.; Slovenija, Ljubljansko barje, Blatna Brezovica, wheat field; 288; 448310, 5091920;

23: 6.7.2020; Vreš B.; Slovenija, Ljubljansko barje, Blatna Brezovica, sown grassland; 288; 448308, 5091944;

24: 6.7.2020; Vreš B.; Slovenija, Ljubljansko barje, Blatna Brezovica, maize field; 288; 448288, 5091690.

Table 2: Synoptic table of plant communities dominated by *Cyperus esculentus*.
Tabela 2: Sinoptična tabela rastlinskih združb z vrsto *Cyperus esculentus*.

Column number		1	2	3	4	5	6	7	8	9	10
Number of relevés		24	20	2	2	2	1	11	4	2	14
CHE	*Cyperus esculentus*	100	100	2	2	2	1	100	100	2	100
DIG	***Digitario-Eragrostietea***										
	Panicum capillare	42	.	.	.	1	1	100	25	1	.
	Digitaria sanguinalis	58	25	.	.	1	1	18	75	.	7
	Setaria pumila	38	40	.	.	.	1	9	.	2	.
	Portulaca oleracea	4	.	.	.	2	1	36	.	.	86
	Chenopodium ambrosioides	.	.	.	.	.	1	36	.	.	.
	Amaranthus emarginatus	.	.	.	.	.	.	82	50	.	.
	Polygonum aviculare	13	.	.	.	.	.	.	25	.	.
	Panicum laevifolium	.	20	.	.	.	.	.	.	.	.
	Setaria viridis	.	.	.	.	2	.	.	.	.	.
	Panicum dichotomiflorum	.	.	.	.	2	.	.	.	.	29
	Setaria macrocarpa	.	10	.	.	.	.	.	.	.	.
	Amaranthus lividus	13	.	.	.	.	.	.	.	.	.
BID	***Bidentetea***										
BID, DIG	*Echinochloa crus-galli*	58	55	2	1	1	1	100	25	2	43
	Polygonum lapathifolium (incl. subsp. *lapatifolium*)	42	15	.	.	1	.	100	50	2	29
	Bidens frondosa	13	.	.	2	1	.	91	50	2	14
	Rorippa palustris	4	.	.	.	1	.	9	50	2	.
	Polygonum persicaria	21	5	.	.	.	.	64	.	1	7
	Polygonum hydropiper	.	.	2	.	2	.	18	75	.	.
	Bidens tripartita	13	.	1	.	.	.	9	.	.	.
	Xanthium italicum	.	.	.	2	2	.	91	.	.	93
	Rorippa sylvestris	.	.	.	.	.	.	82	75	.	.
	Bidens cernuus	.	.	.	.	.	.	.	75	1	.
	Chenopodium polyspermum	33	.	.	.	.	.	64	.	.	.
BID, SIS	*Xanthium strumarium*		.	.	.	.	.	.	.	2	.
	Pulicaria vulgaris		.	.	.	.	.	.	25	.	.
	Bidens radiatus		.	1	.	.	.	.	.	.	.
	Polygonum mite	17	.	.	.	.	.	9	.	.	.
	Polygonum dubium		.	.	.	1	.	.	.	.	.
	Chenopodium rubrum		.	.	.	.	.	.	50	.	.
	Solanum lycopersicum		.	.	.	.	.	18	.	.	.
	Polygonum lapathifolium subsp. *brittingeri*		.	.	.	.	.	9	.	.	.
	Rumex maritimus		.	1	.	.	.	.	.	.	.
	Corrigiola litoralis		.	.	.	.	.	.	25	.	.
	Other species										
ALN	*Lythrum salicaria*	21	.	.	1	.	.	27	50	2	.
ALN	*Lycopus europaeus*	.	.	.	1	.	.	9	25	1	7
ART	*Equisetum arvense*	4	.	.	1	.	.	9	.	1	.
EPI	*Calystegia sepium*	25	10	.	.	.	.	9	.	1	.
ISO	*Cyperus fuscus*	4	.	2	2	.	.	9	25	.	21
MOL	*Lysimachia vulgaris*	4	.	.	1	.	.	9	25	1	.
MOL	*Agrostis stolonifera*	4	.	2	1	.	.	.	50	.	.
SIS	*Chenopodium album*	42	20	.	.	1	.	9	.	.	.

1. *Digitario-Cyperetum esculenti*, Slovenia (this paper)
2. weed vegetation, Austria (Fragner 2010)
3. *Cyperus eculentus-(Isoëto-Nanojuncetea),* Poland (Dajdok et al. 2007)
4. *Cyperetum esculenti*, Italy (Lastrucci et al. 2012)
5. *Cyperetum esculenti*, Italy (Otolini 2013)
6. *Cyperus eculentus* community, France (Felzines & Loiseau 2005)
7. *Cyperetum esculenti*, France (Wisskirchen 1995)
8. *Cyperetum esculenti*, France (Cornier 2002)
9. *Cyperetum esculenti*, France (SMEAG 2011)
10. *Cyperetum esculenti*, Italy (Pellizzari 2020)