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ORIGINAL RESEARCH PAPER

Calystegia sepium – an expansive weed of maize fields near Krakow

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Abstract

The aim of the present study was to assess the degree of colonization of maize fields by the greater or hedge bindweed, *Calystegia sepium* L. in the vicinity of Krakow, and to investigate the habitat preferences of this weed. On the basis of field trips, carried out in 88 fields of maize, we found that *C. sepium* had colonized approximately 30% of the fields investigated. On average, it covered 17.5% of the field area. Multivariate analyses (PCA and RDA) showed that the presence of this species was correlated with that of sandy soils as well as the proximity of streams. Analysis of the morphological features revealed that *C. sepium* specimens growing both in fields and in natural stands share similar morphological characteristics.

Keywords

greater or hedge bindweed; colonization; multivariate analysis; natural stand

Introduction

Greater or hedge bindweed (*Calystegia sepium* L.) is a twining perennial belonging to the family Convolvulaceae. In Poland, the typical habitat of this species, which prefers growing in riverine shrubs [1], is called a "veil community". *Calystegia sepium* is closely related to field bindweed (*Convolvulus arvensis* L.), which is considered to be one of the world's most aggressive weeds [2]. In some European countries, *C. sepium* is also considered a troublesome weed [3,4], especially as it affects perennial crops and orchards [3]. European farmers have recently reported that *C. sepium* has become an increasingly important weed of maize fields [5]. *Calystegia sepium* poses a significant threat to maize crops throughout France and the Netherlands (widespread and regular populations of *C. sepium*), though less widespread and more sporadic populations of this species occur in southwestern Germany, and regional or rare populations in southern Poland [6,7]. Interestingly, *C. sepium* affects maize irrespective of the prevailing soil tillage system, whether it is chisel, disk harrowing, or moldboard plough [8].

Calystegia sepium significantly impedes mechanical harvesting [3]. Furthermore, it is a source of biological threat to crops, being a host for herbivorous insect pests and viruses that cause plant diseases [9].

Mechanical and chemical management of *C. sepium* is difficult, due to its massive regenerative potential [5]. Moreover, efforts to destroy this weed by tilling may result in the spreading of its rhizomes throughout the field, resulting in both vegetative reproduction and dispersal [4]. For chemical control of *C. sepium*, both selective and non-selective herbicides are applied, e.g., 2,4-D, dicamba, glyphosate, imazapyr, but these do not eradicate the plants. Instead, they merely reduce the growth and number of shoots and roots produced [9]. Recently, several pieces of research have been carried out on the biological control of *C. sepium* using pathogenic fungi [3,4,9,10].

An increase in the area used for growing maize in Poland [11] has necessitated an evaluation of the problems caused by *C. sepium* [7]. Polish scientific literature lacks information about the frequency of *C. sepium* in maize fields, even on a regional scale. Having considered the previously mentioned threats posed by *C. sepium*, this work focuses on: (***i***) the assessment of *C. sepium* colonization of maize fields near Krakow, (***ii***) the recognition of the habitat preferences of this weed, and (***iii***) comparison of selected morphological traits of *C. sepium* collected from maize fields and from adjacent natural stands.

Material and methods

Twelve field trips were performed in the fall of 2010–2013 in five physico-geographical mesoregions in the vicinity of Krakow City, namely: Tenczynek Prominence, Skawiński Trench, Olkuska Bernese, Wieliczka Foothills, and Proszowicki Plateau (Fig. 1). In total, 88 maize fields were surveyed, and in each case the following characteristics were determined: (***i***) field area (ha), (***ii***) field slope (degrees), (***iii***) presence of streams, and (***iv***) the use of herbicides. Streams were considered to be present in the vicinity of a field if they were located no further than 50 m from the field margin. The effect of herbicide was recorded based on its effect on the degree of colonization by *C. sepium* and the symptoms caused by applying it to this weed.

Where present in a field, the quantity of *C. sepium* was determined using the Braun-Blanquet scale [12], and the results were later expressed as the average percentage area cover. At each location for *C. sepium*, soil samples were collected from five different sites per field at a depth of 30 cm using a soil auger. Soil samples were also collected from selected fields where no *C. sepium* was observed for comparison of soil conditions between stands.

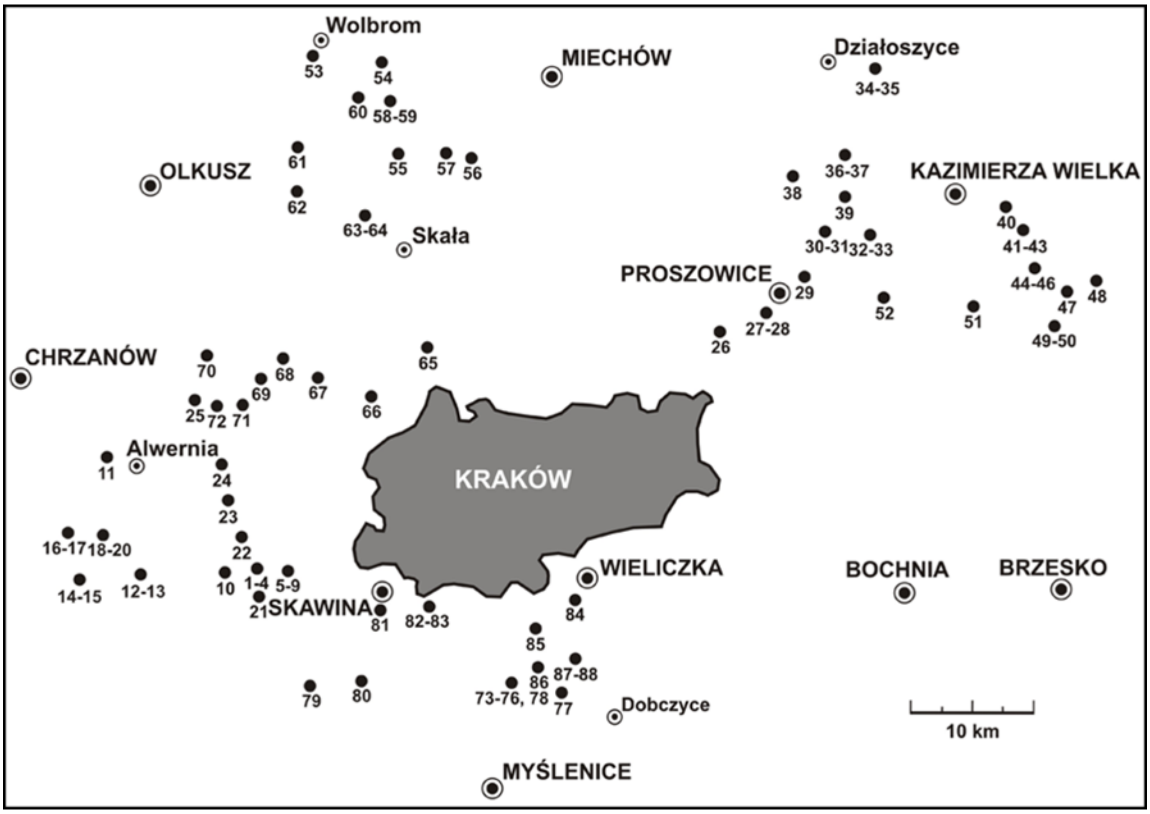

Fig. 1 Location of investigated maize fields in the vicinity of Krakow.

The soil samples were dried at room temperature and then sieved using a 2 mm mesh sieve. The prepared soil material was further used to determine soil texture by the aerometric method (according to Polish standard PN-R-04032 [13]) and soil pH in 1 M solution of KCl [14].

The above data were subjected to multivariate analysis in order to correlate the presence of *C. sepium* with selected habitat characteristics. The principal component analysis (PCA) was performed for all 27 stands where *C. sepium* was noted using PQ Stat ver. 1.6 (PQStat Software, Poznań, Poland). A Kaiser–Meyer–Olkin (KMO) coefficient was calculated using Canoco for Windows ver. 4.51 (Biometrcis Plant Research International, Wageningen University and Research, the Netherlands), indicating the correlation of the primary variables. A redundancy analysis (RDA) was conducted for both stands with and without *C. sepium*.

For sampling from each of the four locations, two specimens of *C. sepium* were collected from a maize field and an adjacent natural stand. Plants were collected with rhizomes. For each specimen, the following morphological features were measured: number and length of shoots (cm), number of seeds per capsule, length (cm), and diameter of rhizomes (mm). The results of morphological measurements were analyzed statistically using one-way ANOVA with STATISTICA PL ver. 10.0.

Results

In the studied area, *Calystegia sepium* was present in 27 of the 88 fields containing maize, which represented less than 30% (Tab. 1). The most frequent occurrence was recorded for the Skawiński Trench (nine locations), especially where maize fields were located close to the Vistula River, ditches, or local streams. *Calystegia sepium* appeared least frequently in maize fields of the Proszowice Plateau (two locations). Most probably, the difference in *C. sepium* frequency between these two regions is due to differences in the management regimes of agricultural land. In the Skawiński Trench, fields are rather small and herbicides are used less frequently compared with the Proszowice Plateau. Furthermore, the soil here is good and the crops grown are mostly vegetables.

The average percentage area occupied by *C. sepium* ranged from 0.5% to 87.5%, but mainly this was approx. 17.5%, which corresponds to a value of "2" on the Braun-Blanquet scale (Tab. 1). Frequently, *C. sepium* was found on clayey silt and silt loam having a wide range of pH values ranging from 4.2 to 7.3. The lowest pH values were observed in the Skawiński Trench soils (Tab. 1).

PCA analysis of the basic features of habitats inhabited by *C. sepium* explained 50.54% of the total variance, the KMO coefficient value being 0.39. Fig. 2 shows the variables responsible for the presence of *C. sepium* in maize fields. According to PCA analysis, the presence of sand in the soil of maize fields was particularly important for colonization by *C. sepium*. Conversely, RDA analysis explained 80% of the total variance and also confirmed that the sand fraction played a significant role relative to the presence of *C. sepium*. Furthermore, it revealed a positive correlation between the presence of the weed and the proximity of a stream as well as herbicide application (Fig. 3). Interestingly, RDA analysis showed that the presence of *C. sepium* was positively correlated with a particular soil texture, namely, clayey silt, even though each soil fraction (silt and clay) analyzed separately was not correlated with the presence of *C. sepium* in the field (Fig. 3).

RDA analysis revealed that the application of herbicide increased the frequency of *C. sepium* in maize fields (Fig. 3). It was also observed that regenerated *C. sepium* plants had a broader possibility to colonize maize if other weed species were destroyed by herbicide treatment, but this requires further, more detailed investigation.

Analysis of variance carried out for the selected morphological traits of *C. sepium* plants collected from maize fields and from adjacent natural stands showed that the plants do not differ statistically in terms of morphology (p = 0.3–0.7; Tab. 2). The analyzed plants had, on average, more than four shoots, each approx. 200 cm in length. The average length of rhizomes was 40 cm, and their diameter ca. 6 mm. The number of capsules per shoot was 0–5, each containing ca. 3 seeds (Tab. 2).

Tab. 1 Characteristics of maize fields where observations were made, and the frequencies of *C. sepium* based on the Braun-Blanquet (B-B) [12] scale for each field.

Field No.	Locality	Field area (ha)	Herbicides	B-B frequency	Field slope (°)	Streamside	Soil texture (PTG 2009)*	pH (KCl)
1	Czernichów	0.4	Yes	0	0	No	Clay loam	5.5
2	Czernichów	0.15	No	1	2	No	Clayey silt	6.2
3	Czernichów	4	Yes	3	0	Yes	Silt loam	4.2
4	Czernichów	3	Yes	0	0	No	Silt loam	4.6
5	Wołowice	3	Yes	0	0	No	Silty clay loam	4.7
6	Wołowice	1	Yes	1	0	Yes	Loam	5.9
7	Wołowice	3	Yes	5	0	No	Silt loam	4.5
8	Wołowice	1	No	0	0	Yes	Silt loam	4.1
9	Wołowice	0.2	Yes	2	0	Yes	Silt loam	5.1
10	Kłokoczyn	0.25	Yes	0	0	No	Sandy loam	4.6
11	Kwaczała	3	Yes	0	2	No	Sandy loam	6.4
12	Ryczów	4	Yes	0	0	No	Silt loam	6.3
13	Ryczów	2	No	0	2	No	Clayey silt	4.8
14	Palczowice	0.15	No	0	0	No	Loam	6.2
15	Palczowice	0.8	Yes	0	0	No	Silt loam	5.0
16	Smolice	1	Yes	0	0	Yes	Silt loam	3.8
17	Smolice	1	Yes	+	0	Yes	Clayey silt	5.7
18	Miejsce	0.2	No	0	0	Yes	Silt loam	3.4
19	Miejsce	0.8	No	2	0	No	Silt loam	4.2
20	Miejsce	0.15	No	0	1	No	Silt loam	4.3
21	Czernichów	0.3	No	0	0	No	Silty clay loam	3.7
22	Przeginia Narodowa	0.04	No	0	0	Yes	Sand	4.2
23	Rybna	0.4	Yes	0	1	No	Silt loam	5.3
24	Sanka	1	Yes	1	0	No	Silt loam	5.0
25	Tenczynek	1	Yes	2	0	Yes	Silt loam	6.1
26	Posądza	0.2	Yes	0	1	No	Clayey silt	5.0
27	Szklana	0.5	Yes	0	2	No		
28	Szklana	1	Yes	+	2	No	Clayey silt	5.8
29	Szreniawa	2	Yes	0	1	No		
30	Klimontów	1	Yes	0	0	No	Silt loam	5.3
31	Klimontów	0.5	Yes	0	0	No	-	-
32	Ostrów	0.4	Yes	0	0	No	Clayey silt	5.4
33	Ostrów	0.2	Yes	0	0	No	-	-

Tab. 1 Continued

Field No.	Locality	Field area (ha)	Herbicides	B-B frequency	Field slope (°)	Streamside	Soil texture (PTG 2009)*	pH (KCl)
34	Kwaszyn	0.5	Yes	0	0.5	No	Clayey silt	6.7
35	Kwaszyn	0.25	Yes	0	0	No	-	-
36	Baranów	1.5	Yes	0	2	No	Silt loam	5.3
37	Baranów	0.2	Yes	0	1	No	-	-
38	Pamięcice	2	Yes	0	1	No	-	-
39	Czuszów	3	Yes	0	0	Yes	Silt	6.8
40	Kazimierza Mała	0.03	No	0	0.5	No	-	-
41	Cło	0.15	Yes	0	0	No	-	-
42	Cło	0.5	Yes	0	2	No	-	-
43	Cło	3	Yes	0	0	No	Clayey silt	6.5
44	Bejsce	5	Yes	0	1	No	-	-
45	Bejsce	0.5	Yes	0	0	Yes	Sandy loam	5.8
46	Bejsce	20	Yes	0	0	Yes	-	-
47	Piotrkowice	2	Yes	0	1	No	Clayey silt	6.6
48	Wyszogród	1	Yes	0	0	No	-	-
49	Przemyków	1	Yes	0	2	No	Silt loam	6.1
50	Przemyków	2	Yes	0	2	No	-	-
51	Biskupice	3	Yes	0	0	Yes	-	-
52	Piekary	1	Yes	2	0.5	Yes	Silt loam	6.3
53	Wolbrom	5	No	0	0	No	-	-
54	Lgota Wielka	4	No	0	5	No	-	-
55	Ibramowice	2	Yes	0	0	Yes	-	-
56	Żarnowica	2	No	0	0	Yes	-	-
57	Ulina Wielka	2	Yes	0	0	No	-	-
58	Mostek	4	No	0	0	Yes	-	-
59	Mostek	3	No	0	2	No	-	-
60	Budzyń	3	No	0	0	No	-	-
61	Jangrot	2	No	2	0	Yes	Clayey silt	4.8
62	Sułoszowa	1	No	2	2	No	Clayey silt	6.5
63	Wielmoża	20	Yes	0	0	No	-	-
64	Wielmoża	0.5	Yes	2	5	No	Clayey silt	4.5
65	Giebułtów	20	No	2	0	No	Clayey silt	7.1
66	Zabierzów	30	Yes	2	0	Yes	Clayey silt	7.3
67	Brzezinka	20	No	2	0	No	Clayey silt	6.4
68	Dubie	1	Yes	2	0	No	Clayey silt	6.8

Tab. 1 Continued

Field No.	Locality	Field area (ha)	Herbicides	B-B frequency	Field slope (°)	Streamside	Soil texture (PTG 2009)*	pH (KCl)
69	Siedlec	0.5	No	2	0	No	Clayey silt	7.0
70	Krzeszowice	2	Yes	0	0	No	-	-
71	Łany	4	No	0	5	No	-	-
72	Nawojowa Góra	3	No	0	2	No	-	-
73	Siepraw	0.01	No	1	0	Yes	Silt loam	3.6
74	Siepraw	1	No	2	0	Yes	Clayey silt	5.0
75	Siepraw	3	Yes	0	10	Yes	-	-
76	Siepraw	2	No	0	5	No	-	-
77	Czechówka	0.03	No	0	0	Yes	-	-
78	Siepraw	0.5	No	1	0	No	Silt loam	5.7
79	Leńcze	0.5	No	+	0	No	Clayey silt	5.4
80	Wola Radziszowska	1	No	0	0	No	-	-
81	Skawina	0.2	No	+	0	No	Sandy loam	6.4
82	Libertów	2	No	0	5	No	-	-
83	Libertów	1	No	0	5	Yes	-	-
84	Siercza	4	Yes	0	15	No	-	-
85	Janowice	5	Yes	0	15	No	-	-
86	Byszyce	2	Yes	+	0	No	Clayey silt	6.4
87	Gorzków	4	Yes	2	5	No	Silt loam	5.7
88	Gorzków	3	Yes	+	5	No	Clayey silt	6.3

* Soil texture according to [18].

Discussion

Knežević et al. [8] as well as Burger et al. [15] point to *C. sepium* as one of the species that will very soon gain regional importance as a weed of maize fields, next to *Setaria viridis*, *Echinochloa crus-galli*, *Chenopodium album*, and *Ambrosia artemisiifolia*. Maize is also the most frequently listed crop which *C. sepium* may potentially infest, both in Europe [5,6,8] and in Poland [7,16]. In our study, *C. sepium* was observed in approximately 30% of the fields investigated.

Calystegia sepium usually colonized fields from the border, extending gradually further into the field. If the field was adjacent to a stream, it was usually that part of the field which formed the initial site of penetration by *C. sepium*. We did not check the origins of maize fields, but the researched areas are typical agricultural land, which suggests that they have been under cultivation for at least 10 years. Based on the observed entries of *C. sepium* into the fields, we hypothesize that this weed colonizes the area used as a maize field for many years, treating this crop as a good supporting plant.

In our study, RDA analysis showed that the presence of *C. sepium* was positively correlated with the presence of sand in the soil and of clayey silt, even though each soil fraction (silt and clay) analyzed separately was not correlated with the presence of *C.*

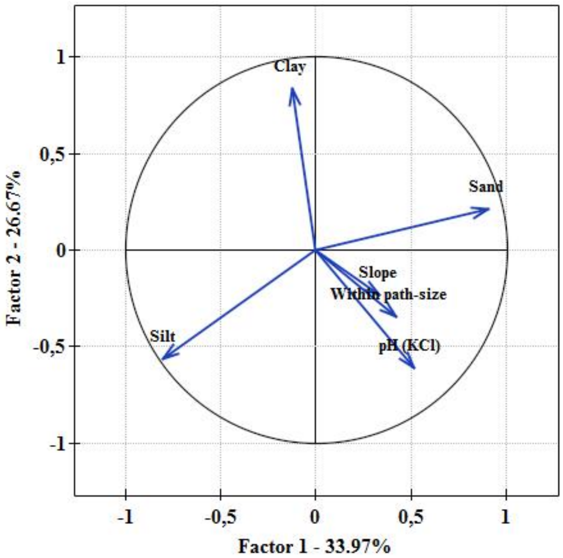

Fig. 2 PCA diagram displaying the main variables that determine the presence of *Calystegia sepium* amongst maize crops near Krakow. The upper right quadrant shows the most important variables. The importance of variables diminishes clockwise. Variance explained by Factors 1 and 2 is presented on the graph.

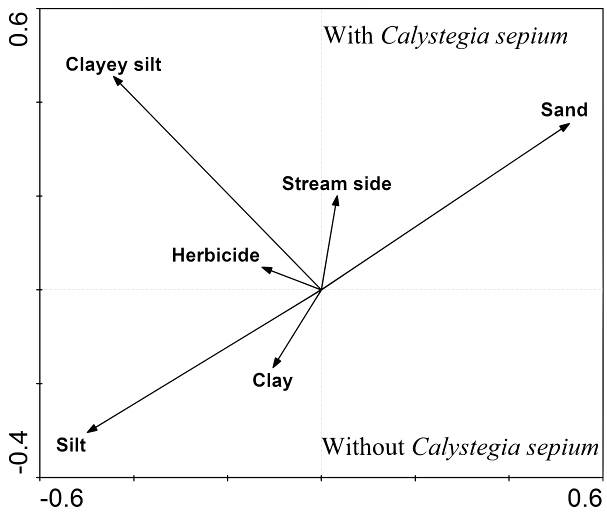

Fig. 3 RDA diagram presenting the main variables that determine the presence of *Calystegia sepium* in maize fields. The upper quadrants represent the variables positively correlated with the presence of *C. sepium*, whereas the lower quadrants show the important variables associated with the absence of *C. sepium* in a field. Variance explained = 80%; *F*-ratio = 101.1; *p* = 0.002.

Tab. 2 Selected morphological features of *Calystegia sepium* plants collected from four natural stands and four adjacent maize fields (mean value ±*SE*)

Morphological feature	Natural stand	Maize field	*F*-value	*p*-value
Number of shoots	4.25 ±0.31	4.56 ±0.68	0.18	0.7
Length of shoots (cm)	208 ±23.5	191 ±43.2	0.13	0.7
Number of seeds per capsule	3.25 ±1.08	3.75 ±0.84	0.13	0.7
Length of rhizome (cm)	43.9 ±6.16	40.5 ±10.3	0.08	0.8
Diameter of rhizome (mm)	0.68 ±0.02	0.62 ±0.06	0.99	0.3

Number of replications = 8; degrees of freedom = 1; degrees of freedom of error = 14.

sepium in the field. Ivanova et al. [17] noted the presence of *C. sepium* in the sandy and saline soils of Pomorie in Bulgaria. Pfirter [9] also confirmed that *C. sepium* prefers moist soils. Contrary, farming magazines state that moist habitats rich in nutrients and clay are typical habitats for *C. sepium* [16]. All these data may indicate quite broad soil preferences of *C. sepium*, under one condition – high moisture content.

The same analysis also revealed that the application of herbicide increased the frequency of *C. sepium* in maize fields. Many authors [3,4,8,10] have reported that *C. sepium* is difficult to manage using herbicides. This is due to its deep-growing rhizomes which are difficult to destroy with chemicals and which are a source of new regenerating plants.

Analysis of variance carried out for the selected morphological traits of *C. sepium* plants collected from maize fields and from adjacent natural stands showed that the plants do not differ statistically in terms of morphology. This lack of morphological differences between plants obtained both from their natural habitat and the maize field habitat indicates that this species is highly adaptable to new conditions.

Currently, *C. sepium* poses a local threat to maize fields [6,7,16], but owing to the increasing popularity of maize growing in Poland, this species may soon become a pernicious weed. Rask and Andreasen [3] listed *C. sepium* as a troublesome weed that is as expansive as *C. arvensis*. A systematic survey of maize fields in order to assess the capacity of *C. sepium* as a weed in other regions of Poland is certainly recommended.

Summing up, we found that *Calystegia sepium* had colonized approximately 30% of the fields investigated. Mostly, the weed was found on rather small fields, on clayey silt and silt loam, regardless of soil pH, where herbicide control was less frequent. On average, *C. sepium* covered 17.5% of the field area. Multivariate analyses (PCA and RDA) showed that the presence of this species is correlated with that of sandy soils as well as the proximity of streams. Analysis of the morphological features revealed that *C. sepium* specimens growing both in fields and natural stands share similar morphological characteristics, which might suggest a good adaptability of *C. sepium* to the conditions of maize crops.

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Calystegia sepium – ekspansywny chwast na polach z kukurydzą w okolicach Krakowa

Streszczenie

Celem pracy było określenie stopnia kolonizacji upraw kukurydzy w okolicach Krakowa przez kielisznik zaroślowy (*Calystegia sepium* L.) oraz zbadanie preferencji siedliskowych tego gatunku. Posługując się metodą marszrutową zlustrowano łącznie 88 pól z kukurydzą. Występowanie kielisznika zaroślowego stwierdzono w 30% badanych upraw. Gatunek pokrywał średnio 17.5% powierzchni pola. Analizy wielowymiarowe (PCA i RDA) wykazały, że obecność kielisznika zaroślowego na polach z kukurydzą powiązana jest z występowaniem frakcji piasku w glebie i z bliskością cieków wodnych. Rośliny kielisznika zaroślowego występujące na polach z kukurydzą oraz w pobliskich siedliskach naturalnych mają zbliżone parametry morfologiczne.