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Abstract

Field studies were carried out in 1989–1995 and 2006–2012 on plantations of sugar beet (*Beta vulgaris* L. subsp. *vulgaris*). During this period, 542 phytosociological relevés were made using the Braun-Blanquet method. In total, 46 weed species were found. In 1989–1995, the occurrence of 36 segetal species was reported. The highest cover indices were determined for *Chenopodium album* and *Amaranthus retroflexus*. *Gallium aparine*, *Echinochloa crus-galli*, and *Elymus repens* were the dominant species, as well. Analysis of the frequency of occurrence revealed one constant species (*Chenopodium album*), two frequent species (*Amaranthus retroflexus* and *Gallium aparine*), and two medium-frequent species (*Echinochloa crus-galli* and *Matricaria maritima* ssp. *inodora*).

In 2006–2012, the occurrence of 40 weed species on the sugar beet plantations was recorded. The plantations were clearly dominated by *Chenopodium album*, accompanied by *Polygonum persicaria* and *Polygonum lapathifolium* ssp. *lapathi-foliolum*. Other dominant species comprised *Setaria viridis*, *Galinsoga parviflora*, *Brassica napus* ssp. *napus*, and *Fallopia convolvulus*. The *Chenopodium album* was a constant component of the sugar beet plantations. In turn, no frequent species were observed and six medium-frequent species were found (*Setaria viridis*, *Galinsoga parviflora*, *Brassica napus* ssp. *napus*, *Echinochloa crus-galli*, *Amaranthus retroflexus*, and *Capsella bursa-pastoris*).

Noteworthy, the presence of previously unreported species, e.g., *Abutilon theophrasti*, *Hyoscyamus niger*, or *Artemisia vulgaris*, was revealed. These species are rare components in sugar beet crops. A reverse phenomenon, i.e., the disappearance of some species such as *Euphorbia helioscopia*, *Malva neglecta*, *Rumex acetosella*, *Sinapis arvensis*, or *Sisymbrium officinale*, was also observed.

Keywords

*Beta vulgaris* L. ssp. *vulgaris*; weeds; changes in weed infestation; communities

Introduction

The sugar beet (*Beta vulgaris* L. subsp. *vulgaris*) is highly susceptible to weed infestation, which is related to the cultivation of this species with wide row spacing and a low growth rate in the initial growth period. Over the last 30–40 years, cultivation technology and weed control of sugar beet have undergone evolution. In the 1970’s and mid-1980’s, multigerm seeds of sugar beets were applied and plantations were weeded mainly mechanically. Herbicides were occasionally used, usually in the form...
of single treatments before germination of the crop plant [1]. From the mid-1980’s, herbicide treatments with lower doses in very early growth stages of weeds were introduced into farming practice [2–4]. Another step in the development of beet protection was the idea of treatment with the so-called microdoses, i.e., application of appropriately selected herbicide mixtures whose components were used at 50–67% lower doses [5–8]. Obviously, besides the changes occurring over the recent years in the technology of sugar beet cultivation, changes in weed infestation of this plant have become evident [9–11]. In the 1970’s and mid-1980’s perennial weeds, such as Elymus repens or Circium arvense, were a considerable problem. Herbicide application resulted in a reduction in their occurrence in the next years. However, the number of annual weeds, i.e., Amaranthus retroflexus, Chenopodium album, Echinocloa crus-galli, and Galium aparine, increased [12]. The successive changes consisted in the penetration of segetal communities by ruderal species, mainly Aethusa cynapium, Descurainia sophia, and Artemisia vulgaris [13,14]. As regards climate change, in the last several years thermophilic weed species such as Hyoscyamus niger and Solanum nigrum have occurred more frequently in sugar beet fields or new alien species, like Abutilon theophrasti, have been observed [15].

The aim of the study was to compare the rate of weed infestation of a sugar beet plantation in Lower Silesia in 1989–1995 and 2006–2012.

### Material and methods

The field study was conducted in 1989–1995 and 2006–2012. The observations were carried out on large-area intensive commercial plantations of sugar beet (Beta vulgaris ssp. vulgaris) cultivated on black soils near Wroclaw. Weed infestation was assessed in herbicide-untreated areas of the analyzed fields. In total, 542 phytosociological relevés were made using the Braun-Blanquet method, including 255 relevés from the first analysis period and 287 from the other period. The relevés were the basis for making a list of weed species infesting the sugar beet plantations in the analyzed periods, and phytosociological constancy (S) as well as the cover index (Wp) were determined for the observed species [16].

The nomenclature of names of weeds described in this paper was given according to Flowering plants and pteridophytes of Poland – a checklist [17].

The statistical analysis of the results was based on one-way analysis of variance (ANOVA). Given the high variation of the cover indices expressed in percent, these values were transformed for calculations using the following formula: \( y = \arcsin \sqrt{x} \), where: \( x \) – values of the cover indices expressed in percent; \( y \) – values for statistical calculations.

### Table 1


<table>
<thead>
<tr>
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<tbody>
<tr>
<td>Chenopodium album</td>
<td>4417 a</td>
<td>3449 a</td>
<td></td>
</tr>
<tr>
<td>Amaranthus retroflexus</td>
<td>1117 b</td>
<td>112 a</td>
<td></td>
</tr>
<tr>
<td>Galium aparine</td>
<td>649 b</td>
<td>166 a</td>
<td></td>
</tr>
<tr>
<td>Echinochloa crus-galli</td>
<td>321 a</td>
<td>141 a</td>
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<tr>
<td>Elymus repens</td>
<td>240 a</td>
<td>84 a</td>
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<tr>
<td>Polygonum persicaria</td>
<td>170 a</td>
<td>858 b</td>
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</tr>
<tr>
<td>Matricaria maritima ssp. inodora</td>
<td>125 a</td>
<td>102 a</td>
<td></td>
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<tr>
<td>Brassica napus ssp. napus</td>
<td>111 a</td>
<td>366 a</td>
<td></td>
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<tr>
<td>Thlaspi arvense</td>
<td>103 a</td>
<td>138 a</td>
<td></td>
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<tr>
<td>Myosotis arvensis</td>
<td>87 a</td>
<td>51 a</td>
<td></td>
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<tr>
<td>Anthemis arvensis</td>
<td>78 a</td>
<td>58 a</td>
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<td>Polygonum aviculare</td>
<td>59 a</td>
<td>55 a</td>
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<tr>
<td>Capsella bursa-pastoris</td>
<td>54 a</td>
<td>82 a</td>
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<tr>
<td>Melandrium album</td>
<td>51 a</td>
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<td>Solanum nigrum</td>
<td>34 a</td>
<td>63 a</td>
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<tr>
<td>Aethusa cynapium</td>
<td>32 a</td>
<td>64 a</td>
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<td>Polygonum amphibium</td>
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<td>Stelaria media</td>
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<tr>
<td>Sinapis arvensis</td>
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<tr>
<td>Fallopia convolvulus</td>
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<td>250 a</td>
<td></td>
</tr>
<tr>
<td>Polygonum lapathifolium ssp. lapathifolium</td>
<td>14 a</td>
<td>705 b</td>
<td></td>
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<tr>
<td>Viola arvensis</td>
<td>12 a</td>
<td>154 a</td>
<td></td>
</tr>
<tr>
<td>Sisymbrium officinale</td>
<td>12 a</td>
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<tr>
<td>Lamium purpureum</td>
<td>10 a</td>
<td>58 a</td>
<td></td>
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<tr>
<td>Euphorbia helioscopia</td>
<td>10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Malva neglecta</td>
<td>10</td>
<td></td>
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</tr>
<tr>
<td>Rumex acetosella</td>
<td>10</td>
<td></td>
<td></td>
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<tr>
<td>Veronica hederifolia</td>
<td>9 a</td>
<td>35 a</td>
<td></td>
</tr>
<tr>
<td>Daucus carota</td>
<td>8 a</td>
<td>2 a</td>
<td></td>
</tr>
<tr>
<td>Galinsoga parviflora</td>
<td>4 a</td>
<td>368 b</td>
<td></td>
</tr>
<tr>
<td>Fumaria officinalis</td>
<td>4 a</td>
<td>19 a</td>
<td></td>
</tr>
<tr>
<td>Sonchus arvensis</td>
<td>4 a</td>
<td>16 a</td>
<td></td>
</tr>
<tr>
<td>Anagallis arvensis</td>
<td>4 a</td>
<td>5 a</td>
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</tr>
</tbody>
</table>
--- | --- | --- | ---
Cirsium arvense | - | 2 a | 73 a
Veronica persica | - | 2 a | 41 a
Descurainia sophia | - | 2 a | 17 a
Setaria viridis | - | - | 440
Convolvulus arvensis | - | - | 179
Setaria pumila | - | - | 144
Avena fatua | - | - | 79
Papaver rhoeas | - | - | 51
Artemisia vulgaris | - | - | 27
Hyoscyamus niger | - | - | 23
Oxalis acetosella | - | - | 21
Abutilon theophrasti | - | - | 10
Geranium pusillum | - | - | 4

Values marked with the same letter do not differ significantly between study periods.

### Tab. 2

--- | --- | --- | ---
Constant | V | V | V
Chenopodium album | III | III | III
Echinochloa crus-galli | II | II | II
Polygonum persicaria | II | II | II
Myosotis arvensis | II | II | II
Aethusa cynapium | I | I | I
Anagallis arvensis | I | I | I
Daucus carota | I | I | I
Descurainia sophia | I | I | I
Elymus repens | I | I | I
Fumaria officinalis | I | I | I
Melandrium album | I | I | I
Polygonum aviculare | I | I | I
Sonchus arvensis | I | I | I

### Results

The phytosociological relevés taken in 1989–1995 and 2006–2012 on the plantations of sugar beet (Beta vulgaris ssp. vulgaris) revealed 46 weed species in total. In the first period, 36 taxa were noted and 40 taxa were found in the second period (Tab. 1, Tab. 2). Chenopodium album was the dominant species throughout both study periods. Although the cover index for this species decreased from 4417 to 3449, the change was not statistically confirmed. Additionally, Amaranthus retroflexus (Wp = 1117) and Galium aparine (Wp = 649) were found as the dominant species on the sugar beet plantations in 1989–1995. In the second period (2006–2012), the frequency of Amaranthus retroflexus and Galium declined and their cover indices decreased to 112 and 166, respectively. The next high values of the cover index in 1989–1995 were found for Echinochloa crus-galli (Wp = 321) and Elymus repens (Wp = 240). The other assessment of their frequency revealed a slight decline in their cover indices to 141 and 84, respectively, but the significance of this change was not statistically confirmed. Another four species, Polygonum persicaria, Matricaria maritima ssp. inodora, Brassica napus ssp. napus, and Thlaspi arvense, were characterized by cover indices in the range from 103 to 170. The evaluation performed in 2006–2012 showed a statistically significant increase in the frequency of Polygonum persicaria, with a cover index of 858, and an increase in this parameter for Brassica napus ssp. napus (Wp = 366), which was however not confirmed statistically. The cover indices for the other 27 taxa observed in 1989–1995 were low and ranged from 2 to 87. The second evaluation of the weed infestation rate carried out in 2006–2012 revealed that the values of the cover indices significantly increased only for Polygonum lapathifolium ssp. lapathifolium and Galinsoga parviflora to 705 and 368, respectively. In the case of Fallopia convolvulus and Viola arvensis, an over 10-fold increase in the cover index value was recorded, but it was not confirmed statistically. Six species, i.e., Polygonum amphibium, Sinapis arvensis, Sisymbrium officinale, Euphorbia helioscopia, Malva neglecta, and Rumex acetosella, were not found during the second period of assessment. The analyses of weed infestation carried out in 2006–2012 showed the occurrence of 10 taxa that had not been noted before, i.e., Setaria viridis, Convolvulus arvensis, Setaria pumila, Avena fatua, Papaver rhoeas, Artemisia vulgaris, Hyoscyamus niger, Oxalis acetosella, Abutilon theophrasti, and Geranium pusillum. The first one was characterized by a relatively high cover index of 440. The next two, i.e., Convolvulus arvensis and Setaria pumila, reached cover index values of 179 and 144, respectively. The cover indices in the case of the other species did not differ considerably (Wp = 4–79) – see Tab. 1.
The assessment of the changes in weed phytosociological constancy (S) occurring in 1989–1995 and 2006–2012 demonstrates that there was only one constant weed component of the sugar beet plantations (S = V), i.e., Chenopodium album. In 1989–1995, two species (Amaranthus retroflexus and Galium aparine) that are frequent components of agrocoesenes (S = IV) were recorded. In the next period (2006–2012), the constancy of these species was lower, i.e., III and II, respectively, and no other taxon reached such a constancy (Tab. 2, Fig. 1). The share of medium-frequent species (S = III) increased from 2 in the first study period to 6 in the other one. This was similar to the case of taxa that are infrequent components of the community (S = II), as their number increased from 6 in 1989–1995 to 13 in 2006–2012. The number of sporadic components (S = I) decreased from 25 to 20 (Fig. 1).

The analysis of the changes in weed frequency on the sugar beet plantations occurring over the study period demonstrated that 15 taxa had not changed its occurrence frequency in the examined communities. Besides the dominant Chenopodium album, these were Echinochloa crus-galli, Polygonum persicaria, Myosotis arvensis, Aethusa cynapium, Anagallis arvensis, Daucus carota, Descrurainia sophia, Elymus repens, Fumaria officinalis, Melandrium album, Polygonum aviculare, Sonchus arvensis, Veronica hederifolia, and Veronica persica (Tab. 2). Progressive species, which increased their frequency, constituted the most numerous group. Besides the 10 species observed during the two investigation periods, such as Brassica napus ssp. napus, Capsella bursa-pastoris, Galinsoga parviflora, Cirsium arvense, Fallopia convolvulus, Lamium purpureum, Polygonum lapathifolium ssp. lapathifolium, Solanum nigrum, Stellaria media, and Viola arvensis, there were also taxa that had not been recorded earlier (Tab. 2). The group of disappearing species comprised 11 taxa, including five (Amaranthus retroflexus, Galium aparine, Matricaria maritima ssp. inodora, Anthemis arvensis, and Thlaspi arvense) that exhibited a lower frequency in the agrocoesenes and six that disappeared completely.

**Discussion**

A comparison of the results of the floristic analyses carried out during the study periods on the sugar beet (Beta vulgaris ssp. vulgaris) plantations demonstrated both quantitative and qualitative changes in the weed infestation rate. In general, there was a slight increase in the number of weed species from 36 to 40. As reported by Rola [18], the causes of the weed infestation increase is due to the simplification of agricultural technology, untimely weed control treatments or abandonment thereof, and
Phytosociological constancy (S): V – constant components; IV – frequent components; III – medium-frequent components; II – infrequent components; I – rare or sporadic components.

The evaluation conducted in 1989–1995 in Lower Silesia revealed the highest cover indices for Chenopodium album and Amaranthus retroflexus. Moreover, Galium aparine, Echinochloa crus-galli, and Elymus repens were found to be the dominant species. In terms of frequency of occurrence, one constant weed species (Chenopodium album), two frequent species (Amaranthus retroflexus and Galium aparine), and two medium-frequent species (Echinochloa crus-galli and Matricaria maritima ssp. inodora) were distinguished. The observations carried out in 2006–2012 revealed some changes. Chenopodium album was still a dominant weed, but it was accompanied by Polygonum persicaria and Polygonum lapathifolium ssp. lapathifolium. The next species on the dominant species lists were Setaria viridis, Galinsoga parviflora, Brassica napus ssp. napus, and Fallopia convolvulus. The analysis of the frequency of the individual taxa in the sugar beet plantations indicated that Chenopodium album was a constant component, there were no frequent species, and six medium-frequent taxa were distinguished, i.e., Setaria viridis, Galinsoga parviflora, Brassica napus ssp. napus, Echinochloa crus-galli, Amaranthus retroflexus, and Capsella bursa-pastoris. These species were highly competitive and restricted the growth and development of the sugar beet. Chenopodium album and the majority of the aforementioned weed taxa pose a threat to beet cultivation also in other regions of the country. This has been confirmed by investigations conducted in the regions of Wielkopolska [25], Opolszczyna [26], Mazowsze [27], Mazury [28], and Podlasie [29].

It should be emphasized that several thermophilic species were found in the analyzed communities throughout the study period. Besides the frequent components of the phytocoenoses such as Echinocloa crus-galli or Amaranthus retroflexus, there were also sporadic taxa, Aethusa cynapium and Solanum nigrum. These taxa were also found in the communities of root crops in the regions of Ziemia Łódzka [11], Podlasie [10], and Lubelszczyzna [30]. Moreover, in 2006–2012 two new species with high thermal requirements, i.e., Hyoscyamus niger and Abutilon theophrasti, were reported.

The Abutilon theophrasti, deserves particular attention. The first reports of its occurrence in Poland can be found in the paper by Rostański and Sowa [31], who cited (after other researchers) its localities in Wielkopolska and Opolszczyna as well as in the cities of Kraków, Łódź, and Siemianowice Śląskie. However, this information concerns ruderal rather than segetal habitats. In the crop fields of Lower Silesia, Abutilon

![Changes in the phytosociological constancy of weeds between 1989–1995 and 2006–2012.](image-url)
Abutilon theophrasti was reported for the first time in 2001 [15]. Since then, the species has been expanding its occurrence range and, although currently it constitutes a rare component of phytocoenoses and reaches minimum cover indices, it can be assumed to become a noxious weed in the future, as is the case in other countries [32–37]. It should also be expected that climate change might contribute to the enrichment of the floristic lists of field plants with new thermophilic species [38].

Conclusions

- Quantitative and qualitative changes in the weed infestation rate of sugar beet (Beta vulgaris L. ssp. vulgaris) plantations between the periods of 1989–1995 and 2006–2012 have been demonstrated.
- In both study periods, Chenopodium album was the dominant weed species and a constant component of the sugar beet plantations.
- In 1989–1995, the dominant weed species additionally comprised Galium aparine, Echinochloa crus-galli, and Elymus repens. In 2006–2012, the dominant Chenopodium album was accompanied by Polygonum persicaria, Polygonum lapathifolium ssp. lapathifolium, Setaria viridis, Galinsoga parviflora, Brassica napus ssp. napus, and Fallopia convolvulus.
- The disappearance of some weed taxa, e.g., Euphorbia helioscopia, Malva neglecta, Rumex acetosella, Sinapis arvensis, or Sisymbrium officinale, was revealed. However, some species that had not been reported earlier, e.g., Abutilon theophrasti, Hyoscyamus niger, or Artemisia vulgaris, were recorded among the rare weed components of the sugar beet plantations.

References


Streszczenie


Na uwagę zasługuje fakt, że w agrofitocenozach buraka cukrowego wśród składników rzadkich zaczęły pojawiać się nowe, wcześniej nie obserwowane gatunki, takie jak *Abutilon theophrasti*, *Hyoscymus niger* czy *Artemisia vulgaris*. Obserwowano również zjawisko odwrotne, ustępowanie niektórych taksonów, takich jak *Euphorbia helioscopia*, *Malva neglecta*, *Rumex acetosella*, *Sina pis arvensis* czy *Sisymbrium officinale*. 