Annales Universitatis Paedagogicae Cracoviensis
Studia Naturae, 7: 23–39, 2022, ISSN 2543–8832
DOI: 10.24917/25438832.7.2

Alina Stachurska-Swakoń*, Rakowska Rita, Sabina Klich

Department of Plant Ecology, Institute of Botany, Jagiellonian University, Gronostajowa 3, 30–387 Kraków, Poland, *alina.stachurska-swakon@uj.edu.pl

Weed communities of Jerusalem artichoke (*Helianthus tuberosus* L.) cultivation

Introduction

The European initiative "Clean energy for all Europeans" facilitates the transition from fossil fuels toward cleaner energy. The changed directive from December 2018 points to 32% energy consumption from renewable sources (*EU Directive*, 2018/2001). It causes demand to search for various sources to gain the EU target. One of the sources of clean energy is organic matter and the interest in plants as the source of renewable energy has increased in the last twenty years. The plants could be used in two ways in the context of renewable energy: the plant biomass can be burned to produce electricity from the heat or can be transformed and converted into liquid fuels (e.g. Tuck et al., 2006; Tilman et al., 2009; Araújo et al., 2017). To achieve high yields from biomass production, the use of additional water, fertilisers, and pesticides are usually needed. Additionally, the competition for land between food and fuel uses was recently recognised (Haberl, 2015).

The choice of cultivated plant species for energy crops depends mainly on purpose; however, the environmental conditions are also taken into consideration. To the group of species for biomass combustion belong among others: *Miscantus ×giganteus* J.M. Greef & Deuter ex Hodk. & Renvoize, *Reynoutria sachalinensis* (F. Schmidt) Nakai, *Rosa multiflora* Thunb., *Salix viminalis* L., and *Sida hermaphrodita* (L.) Rusby (e.g. Anioł-Kwiatkowska et al., 2009; Wróbel et al., 2011; Tokarska-Guzik et al., 2012). Plant species used to receive liquid fuels are corn, and sugar beet (Rossini et al., 2019). Jerusalem artichoke (JA) (*Helianthus tuberosus* L.) can be used both for above-ground biomass for burning and undergrowth tubers for ethanol production (Swanton et al., 1992; Rossini et al., 2019).

There are several characteristics that make JA worthy of cultivation for an energy crop: rapid growth, a high carbohydrates content, high dry mass (Monti et al., 2005; Baldini et al., 2006; Rossini et al., 2019), pathogen tolerance, minimal external production costs (Monti et al., 2005), ability to grow in marginal lands (Kays, Nottingham, 2007). Total dry matter production ranges from 6 to 9 t/ha under limiting conditions and from 20 to 30 t/ha under favourable conditions, or even to 35 t/ha in the case of some genetic lineages (Denoroy, 1996; Kays, Nottingham, 2007; Liu et al., 2011). Environmental conditions influence the biomass allocation strategy (Swanton et al., 1992; Gao et al., 2011), and assimilation activities also vary between developmental stages and genotypic lines (Swanton, Cavers, 1989; Kocsis et al., 2007; Gao et al., 2011). The species is tolerant to drought, frost, and salinity; it can easily grow in different types of soil (Kosaric et al., 1984; Swanton et al., 1992; Denoroy, 1996; Baldini et al., 2006).

The JA is a perennial plant native to central North America (Swanton et al., 1992). The original use of this plant was for food for humans and livestock. The North American Indians appreciated JA as a readily available source of food. The species was introduced to Europe as early as the beginning of the XVII century (Balogh, 2008). It has escaped cultivation and started to invade natural plant communities. In Poland, it was recorded for the first time in 1872 (Sudnik-Wójcikowska, 1987). Its spread into natural and semi-natural habitat began in 1960, today it could be found along rivers, ponds and at the edges of forests (Tokarska-Guzik, 2005; Towpasz, Stachurska-Swakoń, 2011, 2018; Popiela et al., 2015; Zając, Zając, 2015; Jarek, Stachurska-Swakoń, 2016). Nowadays, the species has the status of invasive in Europe: Poland, Austria, Italy, Germany, France, and Hungary (Wittenberg, 2005; Balogh, 2008; Tokarska-Guzik et al., 2012; Filep et al., 2018).

H. tuberosus belongs to the Asteraceae family and is one of the sixty-six species of the genus *Helianthus* L. native to America (Balogh, 2008). It creates coarse stems reaching above 3 m with numerous ovate leaves up to 25 cm long (Swanton et al., 1992; Kays, Nottingam, 2007). It produces yellow inflorescences (capitula) that are 5–10 cm in diameter (Fig. 1 – Appendix 1). The plant reproduces by seed and spreads by tuber-bearing rhizomes. The species is known to be highly polymorphous (Kays, Nottingham, 2007).

The cultivation of energy crops is still a little researched subject in terms of their impact on biodiversity. The energy crops are a specific type of plantation, the crops are harvested usually in the autumn. In syntaxonomy, weed communities constitute a separate group of ecosystems that arise spontaneously under conditions of a specific, but extreme anthropopressure. The aim of the research was to study the weed species that could occur in the plantation of the *H. tuberosus*. We hypothesize that in the JA plantations develop communities from the *Polygono-Chenopodietalia* (R. Tx. et Lohm. 1950) J. Tx. 1961 order, as the JA has long development during the vegetation season and the crops are harvested in autumn.

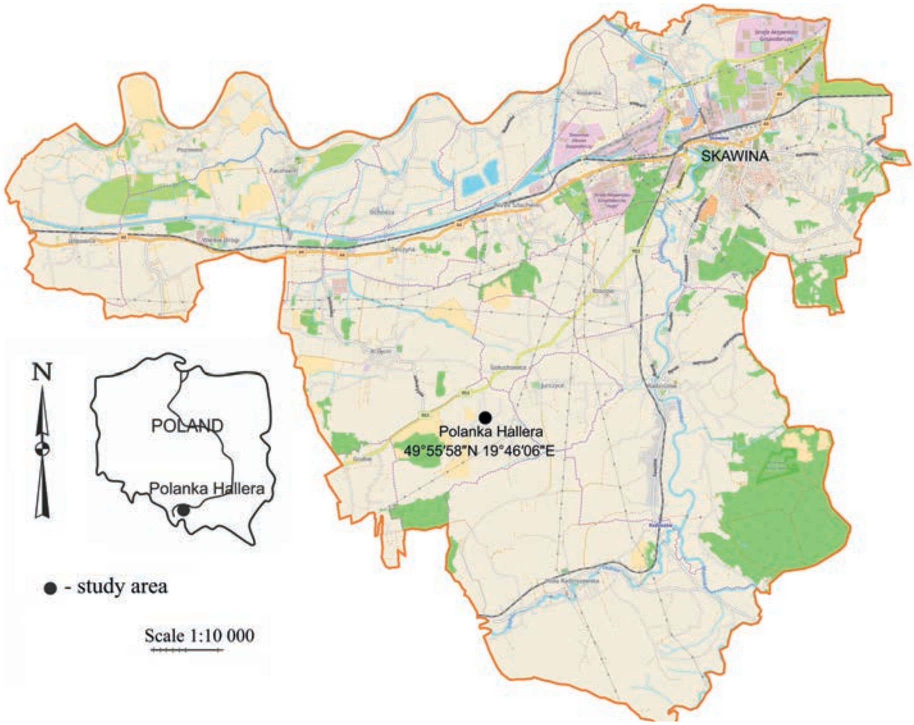

Fig. 2. The locality of the Polanka Haller (Wielickie Foothills, Western Carpathians) (https://pl.m.wikibooks.org/wiki/map.png, modified)

Study area, data collection, and data analyses

The research was carried out in the Wielickie Foothills (West Carpathians, S Poland) in the experimental plantation in the area of "Polanka Haller" belonging to the Jagiellonian University (Fig. 2). The experimental farm is located in an area with a mean annual temperature of 7.8 °C. The gray-brown podzolic soils dominated here. The detailed characteristic of the area is given by Drużkowski (1998).

The phytosociological relevés were made in the first year of plantation of *Helianthus tuberosus* – (JA) using the Braun-Blanquet (1964) approach, in 2007. The time of August and September was chosen as the best to make relevés in the plantation according to the developmental stage of JA. The area of 100 m^2 was chosen as the appropriate for the aim of the study and the seventeen stands were chosen as representative of the plantation area in accordance with the JA cover. The whole area of the JA plantation on the Jagiellonian University farm was 3.25 ha at that time. Additionally, soil pH was measured in the field in each plot using the Hellige colorimetric method.

The phytosociological table was prepared based on the results of UPGMA with the Ruzicka coefficient (MVSP package). The syntaxonomical affinity of the species follows Matuszkiewicz (2005). The names of vascular plants follow Mirek et al. (2002). The correlations between plant cover were examined using the Kendall coefficient (Statistica 13.0 software).

Habitat characteristics were performed using the phytoindication method with indicator values according to Ellenberg (Ellenberg et al., 1992). Weighted average values of indicators were calculated for all relevés: light – L, soil moisture – F, soil acidity – R, and nitrogen – N, taking into account the number of species. The Mann-Whitney nonparametric test was used to check the influence of soil requirement of weeds (Statistica 13.0 software).

Results

The cover of *Helianthus tuberosus* (JA), as a crop plant, was differentiated in the study area and the relevés were made in representative plots with its cover between 35 and 100%. The average cover of the plants in the relevés was 83%. Vascular plants were noticed in every plot, however, their number and cover varied between plots. The cover of the plants was highly correlated with the abundance of JA and ranged between 5 and 70% with a mean of 30%. In plots with the cover of 100% JA cover, weeds covered 3–20% of the plot area (Tab. 1 – Appendix 2).

A total of 82 species of vascular plants were noticed in *H. tuberosus* with the range of 5 to 36 in one relevé with the area of 100 m^2 (Tab. 1 – Appendix 2). More than half of them (45 species, 55%) were noticed only sporadically. The group of plants that achieved the IV degree of constancy included: *Agrostis stolonifera*, *Cirsium arvense*, *Elymus repens,* and *Rumex obtusifolius*. The listed species were also more numerous: they occurred with a cover-abundance value between 1 and 3. They represent the ruderal communities of the *Artemisietea* class and all of them are perennial plants.

Field weeds belonging to the *Stellarietea mediae* class were represented by the largest group and consisted of 26 species (31.7% of all species); however, only 17 occurred in more than 20% of plots. Furthermore, the group was not homogenous and contained the characteristic species of both weed crop types: cereal of the order *Centauretalia cyani* (9) and root crops of the order *Polygono-Chenopodietalia* (8). The most common species in the data set, reaching the III degree of constancy, were: *Apera spica-venti*, *Matricaria maritima* subsp. *inodora*, and *Vicia tetrasperma* characteristic of *Centauretalia cyani* and *Chenopodium album,* and *Sonchus oleraceus* characteristic of *Polygono-Bidentetalia*.

The group of meadow species that occurred in the plots with JA consisted of 24 species (29.3%); however, only 8 species were abundant in more than 20% of the plots. They represent *Molinio-Arrhenatheretea* class, plants with a wide ecological spectrum. Additionally, a few sporadic species were moisture preferred like *Mentha longifolia* and *Scirpus sylvaticus.* Meadow species were often noted in the plots.

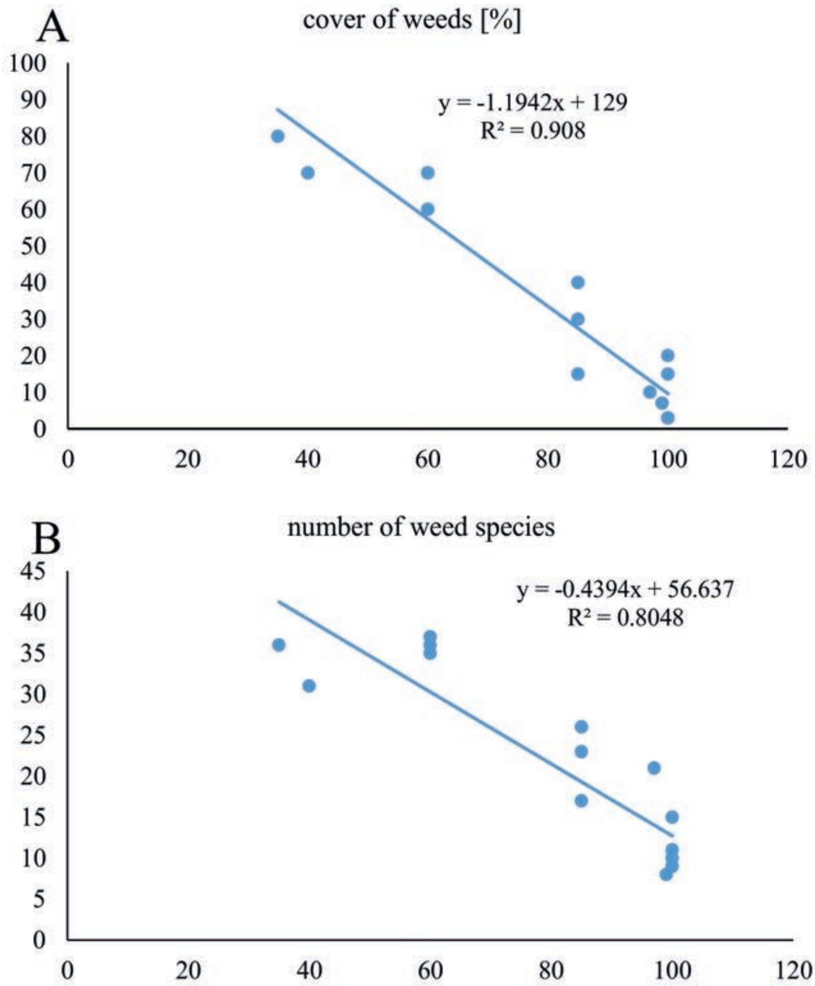

Fig. 3. Coverage of weed species (A) and a number of weed species (B) in relation to Jerusalem artichoke cover in Jerusalem artichoke plantations ($p < 0.005$)

A mean number of 20 vascular plant species was observed in one relevé. This number differentiated between plots and ranged between 8 and 36. The number of weed species was significantly negatively correlated with the cover of JA (Fig. 3; y=-1.19x+ 129, R2=0.91; p<0.0001), the high land cover of JA resulted in a smaller number of vascular plants that cooccurred with the crop-plant. Similarly, a negative correlation between the cover of JA and the cover of other vascular plants was noticed (Fig. 3; y=-0.44x+56.67, R2=0.8; p<0.0001).

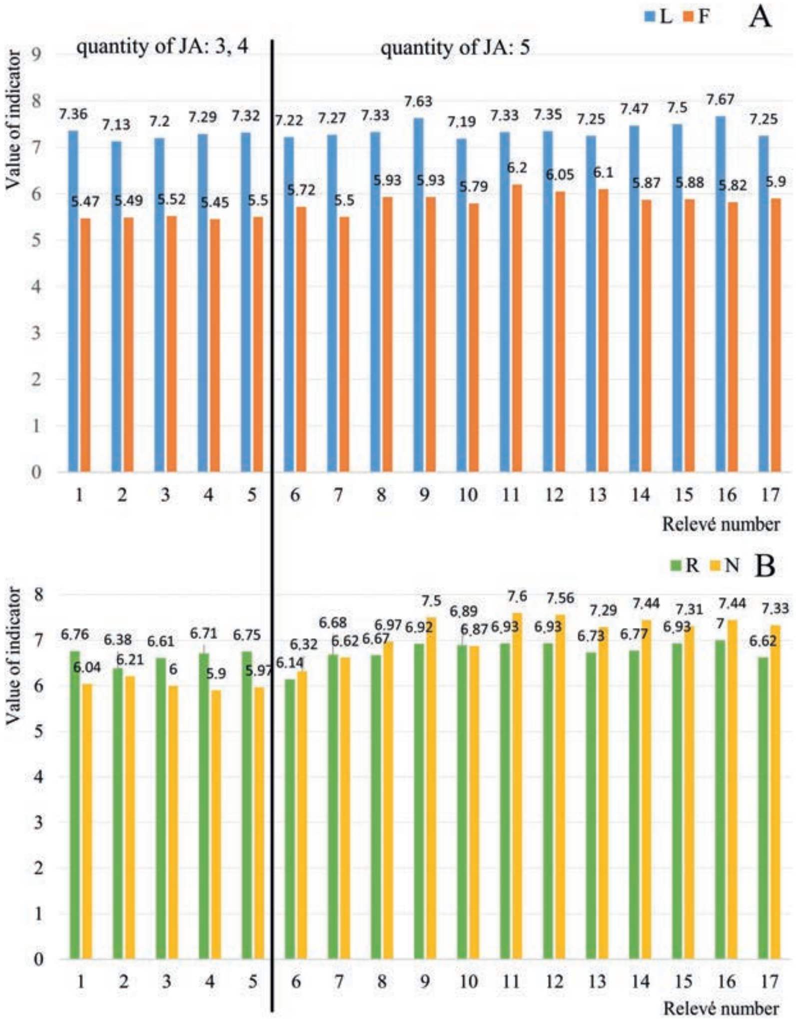

Fig. 4. Mean weighted values of the Ellenberg's indicators for L – light, F – soil moisture (A) and R – acidity, N – soil nitrogen content (B), calculated for all relevés with Jerusalem artichoke; sequence of phytosociological relevés according to Tab. 1 – Appendix 2

Most of the plants accompanying JA cultivation are perennial, mainly hemicryptophytes (42 species, 51.2%) with a smaller number of geophytes (14 species, 17%). Therophytes were represented by 21 species (25.6%). Considering the plant origin, 12 species were archaeophytes (14.6%), while 7 species (8.5%) represented kenophytes such as *Solidago canadensis, Erigeron annuus, E. canadensis*.

The species richness and composition were connected with the JA cover, which was also reflected in the mean Ellenberg values. The statistical significance (U Mann-Whitney test) difference of indicators between stands with relatively low (3–4) and high (5) JA cover was detected for the moisture and nitrogen indicator (Fig. 4). The moisture indicator was higher with the closed canopy of JA (respectively 5.48 for JA=3–4 and 5.89 for JA=5, $p < 0.001$). The nitrogen indicator was also lower, with an average value of 6.0 when the JA cover was lower and 7.19 for JA cover 5 ($p<0.001$).

Discussion

The impact on the biodiversity of perennial crops intended for energy purposes is poorly understood, as it is a relatively new direction of production introduced on agricultural land. Some authors emphasize the need for the monitoring of energy crops in terms of their impact on biodiversity at various levels (e.g. Rowe et al., 2007; Feledyn-Szewczyk et al., 2011; Klima et al., 2019). Usually, energy plantations are less intensively managed and less disturbed than arable fields. In this aspect, some benefits for local biodiversity could be perceived when we compare them with arable fields (Rowe et al., 2007; Dauber et al., 2010; Stanley, Stout, 2013) and a general decline in European agriculture landscapes.

The presented research contributes to the understanding of biocenotic and floristic relationships in energy crops, since the studies on the infestation of energy crops are carried out rarely. The energy crops are usually composed with the alien species to the local habitat, and the weed composition is not yet stable. From the syntaxonomical point, the affinity of the weed composition in energy crops to the syntaxonomical classification could be interesting. In the literature, most attention is paid to weed infestation in willow plantations, as this species is cultivated more often.

Our research indicates that the weeds in the Jerusalem artichoke (JA) plantation do not create a stable composition. The occurred species represent various communities, the spontaneous vegetation consists of species that are characteristic for arable fields, ruderal, and meadow habitats. Most species appeared sporadically with low importance for species composition. As JA plantation could persist for a few years, perennial cultivation promotes the appearance of perennial species, the appearance of troublesome weeds, and the presence of meadow species.

The difficulties to identify weed communities were also indicated by other studies on weed infestation in energy crops (Korniak, 2007; Rola et al., 2007; Sekutowski, Badowski, 2007; Trąba et al., 2009; Anioł-Kwiatkowska et al., 2009). As in the case of our studies, the composition of species representing different syntaxonomical units: forest, meadow, ruderal, and segetal plants were reported. The authors indicate that the species richness of the energy crops depends on the age of cultivation and the previous state of the habitat.

Plantations established in meadow habitats should be more diverse in weed composition than those established on former agricultural lands. Koncekova et al. (2014) assumed an influence by both the impact of prior land use and the impact of crops from the surrounding arable fields. In their studies on spontaneous vegetation of *Miscanthus* plantation, they found a higher share of species included in the group of species occurring in root crops and cereals. In the third year of their observation, the share of perennial species increased. The authors explained it with little land disturbance that creates good conditions for perennial species. The life form and some morphological traits of the cultivated species could also influence the weed community. Sobisz and Ratuszniak (2009), comparing species of weed companions in willow, rose, and JA plantations, indicated that the smallest number of weeds was recorded in *Helianthus* cultivation, under dense and shadow conditions, on the other side the highest in *Salix* cultivation. In his study, there were no species with high degrees of constancy in *Helianthus* cultivation, and he did not find a group that would positively distinguish JA crops. Ziaja and Wnuk (2009) pointed to the impact of crop duration on the composition and diversity of herbaceous plants accompanied energy crops. Baum et al. (2012) found the highest similarity in plant composition of willow plantations with marginal grassland strips, grasslands, or even mixed forests. Janicka et al. (2020) indicated the significance of soil condition that influences the plant diversity in *Salix* crops. Similarly, the diversity of weed species in the *Miscanthus* crop was dependent on soil type (Feledyn-Szewczyk et al., 2011).

There is a group of species that we could consider generalist perennial weeds that occur in various energy crops. To this group, generalist energy crop weeds, belong: *Convolvulus arvensis*, *Elymus repens*, *Equisetum arvense*, *Ranunculus repens*, and *Rumex obtusifolius*.

We expected more species of archaeophytes in our plots, as JA crops were established in the formerly cultivated fields, and therefore seeds of field weeds could persist in the soil bank. The low number of archaeophytes recorded during the conducted research coincides with observations from other energy plantations (e.g. Anioł-Kwiatkowska et al., 2009). The decline of local flora in archaeophytes is often documented (e.g. Meyer et al., 2013; Stachurska-Swakoń, Trzcińska-Tacik, 2014; Towpasz and Stachurska-Swakoń, 2018). Introducing new crop plants may intensify this trend.

The low number and frequency of the accompanying plant species could be related to the allelopathic potential of JA. The published experiments showed that wild and cultivated decomposing JA residues, particularly leaves and stems, have a phytotoxic potential (Tesio et al., 2011). The allelopathic potential of this plant was studied for several crops and weeds. According to Vidotto et al. (2008), the species showed a varied sensitivity to aqueous extracts from JA. The species group including *Amaranthus retroflexus* and *Echinochloa crus-galli* belonged to the sensitive species, and *Chenopodium album*, the common weed species belonged to the group poorly sensitive. In another experiment, the germination rates of *Elymus repens*, *Solidago gigantea*, and *Trifolium vulgare* were not influenced by extracts of JA (Filep et al., 2016). The allelopathic potential is also known for the other species of the *Helianthus* genus (Kliszcz, 2018; Puła et al., 2019). In addition, invasive species often reveal the allelopathic potential for the germination process of accompanying species (e.g. Zandi et al., 2020).

According to Kompała-Bąba and Błońska (2008), JA creates its own communities with different species depending on place history and soil types. It grows together with dominants of nitrophilous communities of semi-shaded margins (*Aegopodium podagraria*) or perennials from the *Artemisietea* class such as *Urtica dioica*, *Artemisia vulgaris*, *Cirsium arvense*, *Equisetum arvense,* or with other alien species such as *Solidago canadensis* or *S. gigantea*. In his natural range, the species build communities along with a wide ecological tolerance species such as *Cirsium arvense* and *Elymus repens*. These two species were also noticed in our research.

Conclusions

The spontaneous vegetation of Jerusalem artichoke (JA) crops consists of varied groups of species, and we did not notice the repeatable composition of plants. The list contains species with low cover and low frequency across our dataset of relevés. In general, the associated vegetation of JA is similar to other perennial energy crops. It can be proposed the group of generalist energy crop weeds with *Convolvulus arvensis*, *Elymus repens*, *Equisetum arvense*, *Ranunculus repens*, and *Rumex obtusifolius*. The history of the plantation, the vicinity of plant associations, and the local habitat condition could be major drivers of the diversity of weeds in the plantations. As JA is also an invasive species and it is difficult to eradicate, in that case, the monitoring of JA plantation is needed.

Conflict of interest

The authors declare no conflict of interest related to this article.

References

Anioł-Kwiatkowska, J., Kącki, Z. Śliwiński, M. (2009). Porównanie kompozycji gatunkowej trzech upraw wierzby energetycznej. *Pamiętnik Puławski, 150*, 19–33. [In Polish]

Araújo, K., Mahajan, D., Kerr, R., Silva, M.D. (2017). Global Biofuels at the Crossroads: An Overview of Technical, Policy, and Investment Complexities in the Sustainability of Biofuel Development. *Agriculture*, *7*, 32. https://doi.org/10.3390/agriculture7040032

Baldini, M., Danuso, F., Monti, A., Amaducci, M.T., Stevanato, P., De Mastro, G. (2006). Chicory and Jerusalem artichoke productivity in different areas of Italy, in relation to water availability and time of harvest. *Italian Journal of Agronomy*, *1*, 291–307. https://doi.org/.4081/ija.2006.291

Balogh, L. (2008). Sunflower species (*Helianthus spp.*). In: Z. Botta-Dukat, L. Balogh (eds.), *The most invasive plants in Hungary*. Hungary: HAS Institute of Ecology and Botany, 227–255.

Baum, S., Weih, M., Bolte, A. (2012). Stand age characteristics and soil properties affect species composition of vascular plants in short rotation coppice plantations. *BioRisk*, *7*, 51–71. https://doi.org/10.3897/biorisk.7.2699.app

Braun-Blanquet, J. (1964). *Pflanzensoziologie: Grundzüge der Vegetationskunde*. Springer-Verlag, Wien-New York.

Dauber, J., Jones, M.B., Stout, J.C. (2010) .The impact of biomass crop cultivation on temperate biodiversity. *GCB Bioenergy*, *2(6)*, 289–309. https://doi.org/10.1111/j.1757–1707.2010.01058.x

Denoroy, P. (1996). The crop physiology of *Helianthus tuberosus* L.: A model orientated view. *Biomass and Bioenergy*, *11*, 11–32. https://doi.org/10.1016/0961–9534(96)00006–2

Drużkowski, M. (1998). *Współczesna dynamika, funkcjonowanie i przemiany krajobrazu Pogórza Karpackiego*. (Studium geoekologiczne w zlewni reprezentatywnej). Institute of Botany, Jagiellonian University, Kraków [In Polish]

Ellenberg, H., Weber, H., Dull, R., Wirth, V., Werner, W., Paulissen, D. powinno być: (1992). Zegerverte von Pflanzen in Mitteleuropa. *Scripta Geobotanica*, *18*, 1–258. [In German]

EU Directive, 2018/2001 http://data.europa.eu/eli/dir/2018/2001/o

Feledyn-Szewczyk, B., Matyka, M., Staniak, M. (2011). Diversity of weed flora, selected biometric characteristics and yielding of *Miscanthus* spp. cultivated on light and heavy soil. *Acta Agrobotanica*, *67(1)*, 67–76. https://doi.org/10.5586/aa.2014.005

Filep, R., Pál, R.W., Balázs, V.L., Mayer, M., Nagy, D.U., Cook, B.J., Farkas, Á. (2016). Can seasonal dynamics of allelochemicals play a role in plant invasions? A case study with *Helianthus tuberosus* L. *Plant Ecology*, *217(12)*, 1489–1501. https://doi.org/10.1007/s11258-016-0662-1

Filep R., Balogh L., Balázs V.L., Farkas Á., Pal R.W., Czigle S., Czégényi D. Papp N. (2018). *Helianthus tuberosus* L. agg. in the Carpathian Basin: a blessing or a curse? *Genetic Resources and Crop Evolution*, *65*, 865–879. https://doi.org/10.1007/s10722-017-0577-2

Gao, K., Zhu, T., Han, G., (2011). Water and nitrogen interactively increased the biomass production of Jerusalem artichoke (*Helianthus tuberosus* L.) in semi-arid area. *African Journal of Biotechnology*, *10(34)*, 6466–6472. https://doi.org/10.5897/AJB10.2317

Haberl, H. (2015). Competition for land: A sociometabolic perspective. *Ecological Economics*, *119*, 424–431. https://doi.org/10.1016/j.ecolecon.2014.10.002

Janicka M., Kutkowska, A., Paderewski, J. (2020). Diversity of vascular flora accompanying *Salix viminalis* L. crops depending on soil conditions. *Global Ecology and Conservation*, *23*, e01068. https://doi.org/10.1016/j.gecco.2020.e01068

Jarek, S., Stachurska-Swakoń, A. (2016). Flora okolic Tarnowa (Kotlina Sandomierska) (The flora of the Tarnów area (Kotlina Sandomierska basin). *Fragmenta Floristica et Geobotanica Polonica*, *23(2)*, 243–254.

Kays, S.J., Nottingham, S.F. (2007). *Biology and Chemistry of Jerusalem Artichoke: Helianthus tuberosus L*. CRC London, UK: Press/Taylor & Francis Group.

Kocsis, L., Liebhard, P., Praznik, W. (2007). Effect of seasonal changes on content and profile of soluble carbohydrates in tubers of different varieties of Jerusalem artichoke (*Helianthus tuberosus* L.). *Journal of Agricultural* and *Food Chemistry*, *55(23)*, 9401–9408. https://doi.org/10.1021/jf0717485

Kliszcz, A. (2018). Allelopathic effect of hydrodistilate from aboveground parts of *Helianthus tuberosus* L. on germination of *Sinapis alba* L. 7th International Conference for Young Researchers "Multidirectional Research in Agriculture, Forestry and Technology," April 2018, https://doi.org/10.13140/RG.2.2.32828.54400

Klima,K., Puła, J., Synowiec, A., Kliszcz, A., Lepiarczyk, A. (2019). Biomass yield and calorific value of Multiflora Rose (*Rosa multiflora* Thunb.) irradiated with laser beams and estimation of CO2 equivalent emission during the extensive cultivation. *Journal of Biobased Materials and Bioenergy*, *13(3)*, 424–427, https://doi.org/10.1166/jbmb.2019.1860

Kompała-Bomba, A., Błońska, A. (2008). Plant communities with *Helianthus tuberosus* in towns of Upper Silesian industrial region (southern Poland). *Biodiversity, Research and Conservation*, *11/12*, 57–64.

Končeková, L., Fehér, A., Halmová, D. (2014). Ecological and Socioeconomic Evaluation of Weed Vegetation in Stands of Energy Grass *Miscanthus ×giganteus*. *Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis, 62(5)*, 985–990. https://doi.org/10.11118/actaun201462050985

Korniak, T. (2007). Zachwaszczenie upraw wierzby w północno-wschodniej części Polski. *Pamiętnik Puławski*, *145*, 141–149. [In Polish]

Korniak, T., Hołdyński, Cz., Wąsowicz, K. (2009). Przemiany flory chwastów upraw wierzby w północno-wschodniej Polsce. *Pamiętnik Puławski*, *150*, 159–170. [In Polish]

Kosaric, N., Cosentino, G.P., Wieczorek, A., Duvnjak, Z. (1984). The Jerusalem artichoke as an agricultural crop. *Biomass*, *5*, 1–36.

Liu, Z.X., Han, L.P., Yosef, S., Xie, G.H. (2011). Genetic Variation and Yield Performance of Jerusalem Artichoke Germplasm Collected in China. *Agricultural Sciences in China*, *10(5)*, 668–678. https://doi.org/10.1016/S1671-2927(11)60049–7

Matuszkiewicz, W. (2005). *Przewodnik do oznaczania zbiorowisk roślinnych Polski*. Warszawa: Wydawnictwo Naukowe PWN. [In Polish]

Meyer, S., Wesche, K., Krause, B., Leuschner, C. (2013). Dramatic losses of specialist arable plants in Central Germany since the 1950s/60s – a cross-regional analysis, *Diversity and Distributions*, *19(9)*, 1175–1187. https://doi.org/10.1111/ddi.12102

Mirek, Z., Piękoś-Mirkowa, H., Zając, A., Zając, M. (2002). Flowering plants and pteridophytes of Poland a checklist. Kraków: W. Szafer Institute of Botany PAN.

Monti, A., Amaducci, M.T., Venturi, G. (2005). Growth response, leaf gas exchange and fructans accumulation of Jerusalem artichoke (*Helianthus tuberosus* L.) as affected by different water regimes. *European Journal* of *Agronomy*, *23*, 136–145. https://doi.org/10.1016/j.eja.2004.11.001

Popiela, A., Łysko, A., Sotek, Z., Ziarnek, K. (2015). Preliminary results of studies on the distribution of invasive alien vascular plant species occurring in semi-natural and natural habitats in NW Poland. *Biodiversity Research and Conservation*, *37(1)*, 21–35. https://doi.org/10.1515/biorc-2015-0003

Puła, J., Zandi P., Stachurska-Swakoń, A., Barabasz-Krasny, B., Możdżeń, K., Wang, Y. (2020). Influence of alcoholic extracts from *Helianthus annnus* L. roots on the photosynthetic activity of *Sinapis alba* L. cv. Barka plants. *Acta Agriculturae Scandinavica*, *Section B – Soil & Plant Science*, *70(1),* 8–13. https://doi.org/ 10.1080/09064710.2019.1661509

Rola, J., Sekutowski, T., Rola H., Badowski M. (2007). Bioróżnorodność zbiorowisk chwastów na plantacjach wierzby krzewiastej (*Salix viminalis* L.) na terenie województwa dolnośląskiego i opolskiego. *Pamiętnik Puławski*, *145*, 165–175. [In Polish]

Rossini, F., Provenzano, M.E., Kuzmanovic, L., Ruggeri, R. (2019). Jerusalem Artichoke (*Helianthus tuberosus* L.): a versatile and sustainable crop for renewable energy production in Europe. *Agronomy*, *9(9)*, 528. https://doi.org/10.3390/agronomy9090528

Rowe, R.L., Street, N.R., Taylor, G. (2007). Identifying potential environmental impacts of large scale deployment of dedicated bioenergy crops in the UK. *Renewable and Sustainable Energy Reviews*, *13(1)*, 271–290 https://doi.org/10.1016/j.rser.2007.07.008

Sekutowski, T., Badowski, M. (2007). Zróżnicowanie zachwaszczenia plantacji *Salix viminalis* (L.) w zależności od warunków glebowych siedliska. *Progress in Plant Protection*, *47(4)*, 371–378. [In Polish]

Sobisz, Z., Ratuszniak, I.(2009). Vascular flora of *Salix viminalis* L., *Helianthus tuberosus* L. and *Rosa multiflora* Thunb. crops on Central Pomerania. *Pamiętnik Puławski*, *150*, 307–321.

Stachurska-Swakoń, A., Trzcińska-Tacik, H. (2014). Zanikanie roślin towarzyszących uprawom okopowym w Ojcowskim Parku Narodowymi jego otulinie. (Weed disappearance of root crop cultivation in the Ojców National Park and its protection zone). *Prądnik. Prace Muz. Szafera*, *24*, 47–64. [In Polish]

Stanley, D.A., Stout, J.C. (2013). Quantifying the impacts of bioenergy crops on pollinating insect abundance and diversity: a field-scale evaluation reveals taxon-specific responses. *Journal of Application Ecology*, *50*, 335–344. https://doi.org/10.1111/1365–2664.12060

Sudnik-Wójcikowska, B. (1987). *Flora miasta Warszawy i jej przemiany w ciągu XIX i XX wieku*. Warszawa: Wyd. Uniwersytetu Warszawskiego. [In Polish]

Swanton, C.J., Clements, D.R., Moore, M.J., Cavers, P.B. (1992). The biology of Canadian weeds. 101. *Helianthus tuberosus* L. *Canadian Journal of Plant Science*, *72(4)*, 1367–1382. https://doi.org/10.4141/cjps92-169

Tesio, F., Leslie, A. Weston, L.A., Ferrero, A. (2011). Allelochemicals identified from Jerusalem artichoke (*Helianthus tuberosus* L.) residues and their potential inhibitory activity in the field and laboratory. *Scientia horticulturae*, *129*, 361–368. https://doi.org/10.1016/j.scienta.2011.04.003

Tilman, D., Socolow, R., Foley, J.A., Hill, J., Larson, E., Lynd, L., Pacala, S., Reilly, J., Searchinger, T. Somerville, C., et al. (2009). biofuels: the food, energy, and environment. *Science*, *325*, 270–271. https://doi.org/10.1126/science.1177970

Tokarska-Guzik, B. (2005). *The Establishment and Spread of Alien Plant Species (Kenophytes) in the Flora of Poland*. Katowice: Wydawnictwo Uniwersytetu Śląskiego.

Tokarska-Guzik, B., Dajdok, Z., Zając, M., Zając, A., Urbisz, A., Danielewicz, W., Hołdyński, Cz. (2012). *Rośliny obcego pochodzenia w Polsce ze szczególnym uwzględnieniem gatunków inwazyjnych*. Warszawa: Generalna Dyrekcja Ochrony Środowiska [In Polish].

Towpasz, K., Stachurska-Swakoń, A. (2011). The analysis of the forest flora of the Strzyżowskie Foothills from the perspective of presence of anthropogenic species. *Acta Universitatis Lodziensis*, *Folia Biologica et Oecologica*, *7*, 99–110. https://doi.org/10.2478/v10107-009-0018-x

Towpasz, K., Stachurska-Swakoń, A. (2018). Occurrence of alien species in the agriculture landscape: a case of Proszowice Plateau (Southern Poland). *Annales Universitatis Paedagogicae Cracoviensis Studia Naturae*, *3*, 7–21. https://doi.org/10.24917/25438832.3.1

Trąba, C., Majda, J., Wolański, P. (2009). Zbiorowiska roślinne towarzyszące plantacjom *Salix viminalis* L. w województwie podkarpackim. *Pamiętnik Puławski*, *150*, 323–335. [In Polish]

Tuck, G., Glendining, M.J., Smith, P., House, J.I., Wattenbach, M. (2006). The potential distribution of bioenergy crops *Biomass and Bioenergy*, *30(3)*, 183–197. https://doi.org/10.1016/j.biombioe.2005.11.019

Vidotto, F., Tesio, F., Ferrero, A. (2008). Allelopathic effects of *Helianthus tuberosus* L. on germination and seedling growth of several crops and weeds. *Biological Agriculture* & *Horticulture, 26*, 55–68. https://doi.org/10.1080/01448765.2008.9755069

Wittenberg, R., Kenis, M., Blick, T., Hänggi, A., Gassmann, A., Weber, E. (2005). *An Inventory of Alien Species and Their Threat to Biodiversity and Economy in Switzerland*. CABI Bioscience Switzerland Centre report to the Swiss Agency for Environment, Forests and Landscape.

Wróbel, M., Wróbel, J., Gregorczyk, A. (2011). Floristic and community diversity of weed vegetation in willow short-rotation coppices in different soil-habitat conditions. *Polish Journal of Ecology*, *59(2)*, 289–296.

Zając, A., Zając, M. (eds) (2015). *Distribution of kenophytes in the Polish Carpathians and their foreland*. Krakow: Institute of Botany, Jagiellonian University.

Zandi, P., Barabasz-Krasny, B., Stachurska-Swakoń, A., Puła, J., Możdżeń, K. (2020). Allelopathic effect of invasive Canadian goldenrod (*Solidago canadensis* L.) on early growth of red clover (*Trifolium pratense* L.). *Notulae Botanicae Horti Agrobotanici Cluj-Napoca, 48(4)*, 2060–2071. https://doi.org/10.15835/48412081

Ziaja, M., Wnuk, Z. (2009). Zachwaszczenie upraw energetycznych w Leszczawie Dolnej w województwie podkarpackim. *Pamiętnik Puławski*, *150*, 367–375. [In Polish]

Appendix 1

Fig. 1. Jerusalem artichoke *Helianthus tuberosus* L.; capitulum-type inflorescences (A), compact aggregation of the study species (B) (Photo A. Stachurska-Swakoń)

Appendix 2

Tab. 1. *Helianthus tuberorus* L. crops on the Wielickie Foothills (Western Carpathians)

Successive number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	Constancy
Field number	18	20	21	22	23	25	26	27	28	29	30	31	32	57	59	61	63	
Date [2007 year]	3.08	3.08	3.08	3.08	3.08	4.08	4.08	7.08	7.08	7.08	7.08	7.08	7.08	14.09	14.09	14.09	14.09	
area [m^2]	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	
soil pH	7	6	6	5.5	7	6	7	7	6	6	7	6	6	6	6	6	6	
cover of *H. tuberosus* [%]	60	60	40	35	60	85	85	97	99	85	100	100	100	100	100	100	100	
cover of weeds [%]	70	60	70	80	70	40	30	10	7	15	15	15	20	3	3	3	3	
Exposure	-	-	-	S	N	S	N	-	SSE	SSE	-	-		NE	SE	S	-	
Slope [degree]	-	-	-	5	5	5	3	-	3	5	-	-	-	3	3	3	-	
Number of weed species	36	37	31	36	35	26	23	21	8	17	11	11	15	9	9	10	10	
Crop plant																		
Helianthus tuberosus	4	4	4	3	4	5	5	5	5	5	5	5	5	5	5	5	5	V
Weeds:																		
Agrostis stolonifera	3	3	3	3	3	2	1	1	+	1	.	.	1	.	.	+	.	IV
Cl: Artemisietea																		
Elymus repens	2	3	3	3	3	3	3	.	1	2	2	2	2	.	.	.	.	IV
Cirsium arvense	1	2	1	1	1	2	.	1	1	+	1	.	+	+	.	+	.	IV
Rumex obtusifolius	1	.	.	.	+	1	+	+	+	.	+	1	2	+	.	+	+	IV
Tanacetum vulgare	3	+	2	3	3	1	1	.	.	1	.	.	.	.	.	.	.	III
Artemisia vulgaris	1	.	1	2	.	.	+	+	.	.	+	.	.	.	.	+	.	II

Galeopsis pubescens	+	1	.	.	+	.	.	.	+	.	.	+	.	.	+	+	+	II
Urtica dioica		.	.	.	.	.	.	.	.	+	1	+	1	.	.	.	3	II
O: Centauretalia cyani																		
Matricaria maritima subsp. *inodorum*	2	1	2	2	2	2	1	+	.	1	.	+	.	.	.	.	.	III
Apera spica-venti	+	1	1	1	1	+	+	.	+	+	.	.	.	.	.	.	.	III
Vicia tetrasperma	+	+	1	1		2	1	+	.	+	.	.	.	.	.	.	.	III
Matricaria chamomilla	1	1	1	1	1	.	.	.	.	.	.	.	.	.	.	.	.	II
Papaver rhoeas	+	2	+	+	.	.	+	.	.	.	.	.	.	.	.	.	.	II
Vicia hirsuta	1	2	+	1	1	.	.	.	.	.	.	.	.	.	.	.	.	II
O: Polygono-Bidentetalia																		
Sonchus arvensis	3	+	3	2	2	.	1	+	.	.	.	+	.	.	+	.	+	III
Chenopodium album	1	1	.	1	1	+	+	.	.	.	.	.	+	+	.	.	.	III
Oxalis stricta	+	+	+	1	1	+	.	.	.	.	.	.	.	.	+	.	.	II
Capsella bursa-pastoris	1	1	+	+	+	.	.	.	.	.	.	.	.	+	.	+	.	II
Cl: Stellarietea mediae																		
Galeopsis tetrahit	.	2	2	1	1	.	+	.	.	.	.	.	.	.	+	+	.	II
Polygonum aviculare	+	.	+	.	.	.	.	.	+	.	.	.	.	.	.	.	+	II
Tussilago farfara	1	+	1	1	1	.	.	.	.	.	.	.	.	.	.	.	.	II
Viola arvensis	+	+	+	+	+	.	.	.	.	.	.	.	.	.	+	.	.	II
Cl: Molinio-Arrhenatheretea																		
Ranunculus repens	+	2	2	.	1	1	.	1	.	+	1	+	1	.	.	.	.	III
Stachys palustris	1	.	1	2	2	1	.	.	.	.	.	+	.	1	1	.	.	III

Achillea millefolium	2	2	.	2	.	.	+	.	.	.	.	.	.	.	.	.	.	II
Crepis capillaris	1	.	.	1	1	.	+	+	.	.	.	.	.	.	.	.	.	II
Daucus carota	2	.	2	2	3	.	1	.	.	.	.	.	.	.	.	.	.	II
Phleum pratense	.	.	.	+	.	.	.	+	.	.	.	.	1	.	.	+	.	II
Poa pratensis	.	.	.	.	.	+	.	+	.	+	+	+	+	.	.	.	.	II
Vicia cracca	+	1	.	+	+	.	.	.	.	.	.	.	.	.	.	.	.	II
Companions																		
Erigeron annuus	1	+	.	.	2	2	2	1	.	+	.	.	.	.	+	.	1	III
Erigeron canadensis	1	1	2	1	1	2	+	+	.	+	.	.	.	.	.	.	.	III
Equisetum arvense	.	+	+	.	+	2	+	+	.	+	.	.	.	.	.	.	.	III
Epilobium sp.	.	.	.	.	.	+	.	+	.	1	.	.	.	+	+	+	.	II
Mentha arvensis	1	+	.	.	1	.	+	+	.	.	+	.	.	.	.	.	.	II
Galeopsis bifida	1	+	.	+	.	.	.	.	.	.	.	.	+	.	.	.	.	II
Taraxacum officinale	.	+	+	.	+	.	+	.	.	.	.	.	.	.	.	.	.	II

Sporadic species: *Centauretalia cyani: Centaurea cyanus* 1, 2; *Polygonum tomentosum* 4, 5; *Polygono-Bidentetalia: Raphanus raphanistrum* 5, 14; *Rumex crispus* 1: 1, 2, 4; *Setaria pumila* 4; *Veronica persica* 3, 7; *Stellarietea mediae: Geranium robertianum* 3, 14; *Lactuca serriola* 5; *Myosotis arvensis* 3, 6; *Sinapis arvensis* 5; *Molinio-Arrhenatheretea: Cerastium holosteoides* 6; *Cirsium oleraceum* 11; *Deschampsia caespitosa* 13; *Festuca pratensis* 2; *Geranium palustre* 17: 1; *Heracleum sphondylium* 2: 2, 6; *Juncus effusus* 6; *Lysimachia nummularia* 10; *L. vulgaris* 4; *Mentha longifolia* 4; *Plantago major* 6; *Potentilla anserina* 2: 1, 13:1; *Scirpus sylvaticus* 13; *Trifolium hybridum* 1; *Trifolium pratense* 2; *Veronica chamaedrys* 17: 1; *Artemisietea: Chaerophyllum aromaticum* 11; *Cirsium vulgare* 8; *Torilis wjaponica* 6, 10: 1; *Vicia angustifolia* 2; *Vicia sepium* 3, 5; *Companions*: *Betula pendula* (c) 3: 1, 4; *Calamagrostis epigejos* 4, 7; *Carex brizoides* 17: 2; *Epilobium hirsutum* 1; *Geranium dissectum* 4; *Gnaphalium sylvaticum* 1, 6:1, 8; *G. uliginosum* 6; *Medicago lupulina* 5; *Myosoton aquaticum* 8, 12 13; *Plantago intermedia* 3: 1; *Rubus caesius* 8; *Solidago canadensis* 3, 4, 5; *Stellaria graminea* 2; *Veronica arvensis* 2.

Abstract

Jerusalem artichoke could be used as a source of renewable energy in the meaning of biomass combustion or liquid fuels production. The presented study concerned on the impact of JA plantation for biomass combustion on plant diversity. The spontaneous vegetation of JA crops studied on the basis of phytosociological methods consisted of varied groups of species that contain weeds (32%), meadow (29%), and ruderal (13%) species. Most of the species occurred sporadically (55%) with low frequency. Most of the plants accompanying JA cultivation were perennial, mainly hemicryptophytes (51%) with a smaller number of geophytes (17%). Therophytes constituted 25% of spontaneous flora of JA crops. It can be proposed the group of generalist energy crop weeds with *Convolvulus arvensis*, *Elymus repens*, *Equisetum arvense*, *Ranunculus repens*, *and Rumex obtusifolius*.

Keywords: energy crops, invasive species, renewable energy, topinambour, weeds

Received: [2022.02.16]

Accepted: [2022.05.18]

Zbiorowiska chwastów w uprawach topinamburu (*Helianthus tuberosus* L.)

Streszczenie

Uprawy roślin energetycznych stanowią wciąż mało zbadany obiekt pod kątem wpływu na różnorodność biologiczną. Celem prezentowanej pracy była charakterystyka spontanicznej roślinności towarzyszącej uprawie topinamburu (*Helianthus tuberosus* L.), jednego z gatunków uprawianych na cele bioenergetyczne wykorzystywanego, zarówno w postaci biomasy, jak i biopaliw. Gatunki współwystępujące z topinamburem nie tworzyły trwałych zbiorowisk chwastów polnych, reprezentowały różne grupy syntaksonomiczne: chwasty polne (32% gatunków), gatunki łąkowe (29%), ruderalne (13%). Terofity stanowiły 25% zanotowanych gatunków. Większość roślin (55% gatunków) występowała sporadycznie z niskim pokryciem. Zarówno liczba towarzyszących gatunków, jak i ogólne pokrycie roślin towarzyszących, były ujemnie skorelowane z pokryciem topinamburu. Do gatunków, które można uznać za pospolicie występujące w uprawach energetycznych zaliczono *Convolvulus arvensis*, *Elymus repens*, *Equisetum arvense*, *Ranunculus repens*, *Rumex obtusifolius.*

Słowa kluczowe: rośliny energetyczne, gatunki inwazyjne, energia odnawialna, topinambur, chwasty

Information on the authors

Alina Stachurska-Swakoń https://orcid.org/0000-0003-0381-4520

She is interested in the vegetation ecology, particularly in the mechanisms of plant communities changes and flora under natural and anthropogenic influence, plant ecology, and plant protection.

Rakowska Rita https://orcid.org/0000-0002-4255-4576

She is interested in beaver influence on vegetation, IAS, nature management and conservation.

Sabina Klich https://orcid.org/0000-0001-5412-8390

She is interested in the development of water and marsh vegetation within dam reservoirs, plant ecology, invasive species, vegetation in protected areas and habitats protection.