Influence of management on vegetative reproduction of invasive species of *Helianthus tuberosus* in Poodri PLA

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Abstract. In this article, the authors deal with the influence of management on vegetative reproduction of *Helianthus tuberosus*, which is an invasive plant in the Czech Republic and spreads uncontrollably in the Poodri PLA, where it displaces native plant species. We applied the proposed management (application of herbicides, mowing, engraving) on the study areas and then monitored the condition of the plant tubers.

1. Introduction

The Poodri Protected Landscape Area (PLA) is in the Czech Republic in the Moravian-Silesian Region close to the Ostrava agglomeration. Poodri PLA is created by the Odra River and its adjacent natural ecosystems with high biodiversity and the ability to stabilize the surrounding landscape affected by industry. There are biotopes closely related to water: floodplain forests, alluvial meadows and permanent or periodic pools. Also, system of ponds and drainage channels is typical for this area [1, 2].

The problem in Poodri PLA is the spread of the invasive plant species Jerusalem artichoke (*Helianthus tuberosus*), a perennial tuberous herb of the *Asteraceae* family, originally from North America [3]. *Helianthus tuberosus* is capable of rapid and successful reproduction, especially vegetative reproduction by tubers or rhizomes. It also reproduces generatively (seeds), but rarely in the Czech Republic [4, 5]. Plant populations of *Helianthus tuberosus* spread uncontrollably in the territory of the Poodri PLA and form large monodominant phytocoenosis, change local habitats and suppress native vegetation. It is successfully distributing along the watercourse of the Odra and Ondrejnice river and, due to the flow of rivers, also on the adjacent meadows, in floodplain forests and new forest plantings. In cooperation with experts of Nature Conservation Agency of the Czech Republic (NCA CR) experimental management on selected areas invaded by Jerusalem artichoke was suggested.

2. Materials and methods

In 2016, field studies were carried out in the Poodri PLA, cadastral territory Proskovice and Stara Ves nad Ondrejnici. We selected 10 experimental areas invaded by *Helianthus tuberosus* with an area about 50-100 m² (H1-H10). In 2017, a phytocoenological analysis was performed on each experimental area. Several methods of management were designed and applied for each area. No management was performed on the reference area H10, this area was intended for final comparison of the efficiency of chosen methods.

The following interventions were performed on experimental areas:

- The mowing - mechanical mowing of meadows twice per season, supplemented by manual mowing or brush cutting in places where regular mowing did not take place.
- Digging tubers up - removal of *Helianthus tuberosus* tubers by spade.
• Application of herbicides - spraying plants by herbicides (BOFIX, HERBISTOP). HERBISTOP is a total natural herbicide based on pelargonic acid, intended for the disposal of monocotyledonous and dicotyledonous weeds. Pelargonic acid is a naturally occurring fatty acid that leaves no residue and is environmentally friendly [6]. BOFIX is a selective herbicide able to kill resistant dicotyledonous weeds in lawns. The active substances are clopyralid, fluroxypyr and MCPA [7].

• Management combinations - mowing + digging up, mowing + spraying, spraying and digging up, mowing, spraying and digging up.

3. Results and discussion
In 2017, we have performed management interventions on 10 monitoring areas (H1-H9) invaded by Helianthus tuberosus. Monitoring area H10 was chosen as reference area and no management was performed here. Mechanical mowing of meadows ran in June and August, application of herbicides in July and digging tubers up in October. Results of phytocoenological analysis and selected growth characteristics from a representative square (1m²) before/after management are summarized in Table 1.

Table 1. Results of phytosociological analysis and growth characteristics of Helianthus tuberosus on selected monitoring areas applying management methods in 2017 (before and after intervention).

| Area | Biotope | Management | Vegetation Unit | Cover % | Number of stems (m²) | Height of stems (m) | Number of stems (pcs) | Weight (kg) |
|------|---------|------------|----------------|---------|----------------------|-------------------|------------------------|-------------|
| H1   | Meadow (Sunny) | M<sup>a</sup> | Arrhenatherion | 60/80   | 208/116               | 2.5/0.3-0.4       | -116                   | 0.1/0.09   |
| H2   | River-bank vegetation (Penumbra) | M<sup>a</sup>+BOF<sup>b</sup> | Alnion | 65/3   | 61/6               | 1.5/0.3          | 25/0                   | 0.28/0     |
| H3   | River basin boundary (Sunny) | D<sup>c</sup> | Arrhenatherion | 60/0   | 119/0               | 1.5/0             | 62/0                   | 0.89/0     |
| H4   | River basin boundary (Sunny) | BOF<sup>b</sup>+D<sup>c</sup> | Arrhenatherion | 55/0   | 128/0               | 1.4/0             | 64/0                   | 0.15/0     |
| H5   | River basin boundary (Penumbra) | M<sup>a</sup>+HER<sup>d</sup> | Alnion | 50/30  | 136/not found       | 1.4/0.3           | 94/31                  | 1.02/0.08  |
| H6   | Alnion (Shade) | HER<sup>d</sup> | Alnion | 70/50  | 56/31               | 3/2.5             | 89/55                  | 0.92/0.03  |
| H7   | Alnion (Shade) | BOF<sup>b</sup> | Alnion | 65/15  | 71/15               | 2.5/2.3           | 82/34                  | 0.76/0.18  |
| H8   | River-bank vegetation (Shade) | M<sup>a</sup>+HER<sup>d</sup>+D<sup>c</sup> | Alnion | 40/25  | 24/10               | 1.0/0.2           | 31/1                   | 0.25/-     |
| H9   | River-bank vegetation (Penumbra) | M<sup>a</sup>+D<sup>c</sup> | Alnion | 65/0   | 376/0               | 1.8/0.6/0         | 146/0                  | 0.54/0     |
| H10  | River basin boundary (Penumbra) | - | Bidens tripartitae | 60/60  | 186/186             | 0.8/2.0           | 97/not found          | 1.21/not found |

<sup>a</sup>M- mowing, <sup>b</sup>BOF- BOFIX herbicide, <sup>c</sup>D- digging up, <sup>d</sup>HER- HERBISTOP herbicide
Management methods were applied on selected monitoring areas repeatedly in 2018. New monitoring area H11 was designed. Number of tubers dug up from a representative square (1m$^2$) before and after intervention in 2017 and 2018 are summarized in Table 2.

### Table 2. Number of tubers (Helianthus tuberosus) before and after intervention in 2017 and 2018.

| Area | Management method | Number of tubers before | Number of tubers after |
|------|-------------------|-------------------------|------------------------|
|      | 10/2016 | 4/2018 | 10/2017 | 10/2018 |
| H1   | M$^a$ | - | - | 116 | 99 |
| H2   | M$^a$+BOF$^b$ | 25 | - | 0 | 0 |
| H3   | D$^c$ | 62 | - | 0 | - |
| H4   | BOF$^b$+D$^c$ | 64 | - | 0 | 18 |
| H5   | M$^a$+HER$^d$ | 94 | - | 31 | 40 |
| H6   | HER$^d$ | 89 | - | 55 | 59 |
| H7   | BOF$^b$ | 82 | - | 34 | 22 |
| H8   | M$^a$+HER$^d$+D$^c$ | 31 | - | 1 | 10 |
| H9   | M$^a$+D$^c$ | 146 | - | 0 | - |
| H10  | - | 97 | 297 | - | - |
| H11  | M$^a$+BOF$^b$ | - | 174 | - | 0 |

$^a$ M- mowing, $^b$ BOF- BOFIX herbicide, $^c$ D- digging up, $^d$ HER- HERBISTOP herbicide

Mowing. Area H1. It was not possible to determine the number of tubers before the intervention, as the meadow is regularly mowed every year as part of the management plan of PLA Poodri. However, mowing is exhaustive for the plant, which is evident on the less developed root system, and especially on the size of tubers, which are very small compared to the reference area without management. After mowing of Helianthus tuberosus, tuber and individual loss was not determined. Mowing has a negative effect also on the height of the plant, which does not exceed 30 - 40 cm on area H1. Flowering and generative reproduction was prevented by mowing Jerusalem artichoke, although it reproduces predominantly vegetatively. We can observe that after two years of management Helianthus tuberosus does not spread to the meadow outside the monitoring area H3. Repeated mowing as a mechanical method for the removal of Jerusalem artichokes is also recommended by the authors [8]. The plants do not produce tubers after removal of the growing tops. This claim was not confirmed after mowing twice a year on the area H1, in Poodri PLA. Regular mowing of invasive plants may limit the development of their stands, but this is a long-term process and it is necessary to mow regularly for several years [9]. Švehláková et al. (2019) recommend to sow areas with grass mixture after mowing [10].

Digging up, mowing, digging up. Areas H3, H9. When combining mowing and digging tubers up, plants should first be weakened to eliminate the source of vegetative distribution. On the area H9 with this management set, mowing was performed only in 2017 and in autumn of the same year, Jerusalem artichoke tubers were manually engraved from part of the area. Massive rejuvenation occurred after mowing and the plants reached a height of 60 cm in September 2017 on this area. Tubers were engraved on the area H3 in autumn, which seems to be effective as it eliminates the source of vegetative distribution. However, manual digging of entire research areas is very demanding and hardly feasible in the future, therefore the methods of manual digging were excluded from the project.

Application of herbicides. Areas H6 (HERBISTOP), H4, H7 (BOFIX). Application of HERBISTOP on the area H6 in 2017 was not easy due to the high growth of Jerusalem artichokes. It was not possible to reach all individuals in the upper part of the shoots. After application of the herbicide, the assimilation organs were damaged in the plants (browning, drying, withering). The lower individuals were destroyed
completely, without flowering. Higher individuals (over 2.5 m) showed leaf damage to 2/3 of the height, the tops remained intact. Some of them flowered. Even on the day of the herbicide application, dark spots were visible on the plants where the herbicide was applied. However, most plants were able to resist the herbicide and regenerate. Jerusalem artichoke populations continued to develop on the area H6, but at a slower rate than the populations of control areas and were unable to flower. Digging tubers up from a representative square at the end of the growing season proved that many tubers remained intact from which the new growing individuals grew up in the following growing season. The application of HERBISTOP as part of a chemical method shows very low efficiency and therefore the separate use of HERBISTOP is excluded from the research. We will continue to use HERBISTOP in combination with mowing. The application of BOFIX on the areas H4 and H7 was relatively successful. In most plants, the assimilation organs were heavily damaged (browning, wilting, withering), the growth tops were deformed and without flowers even on individuals over 2.5 m. After the herbicide application, the plants were able to produce tubers, but they were relatively smaller, wrinkled, spherical with deformations. In the following vegetation season in 2018, only a few individuals grew up on areas H4 and H7. The BOFIX herbicide was applied again. In 2017 the method of applying the BOFIX herbicide was chosen for the area H4, followed by the digging tubers up, which is, as already mentioned, difficult to implement. Engraving was carried out only on a part of this area in 2017, where deformed tubers were found again. In 2018, only chemical management (BOFIX) was chosen for area H4. In vegetation season 2019, the situation on area H4 and H7 is also monitored and we expect areas without Jerusalem artichokes.

Mowing and herbicide application. Areas H2, H11 (BOFIX), H5, H8 (HERBISTOP). The area A2 was cut with a brush cutter in 2017. The rejuvenating individuals were treated with BOFIX herbicide (August) and then mowed again as part of the management of the surrounding meadow. Inspection of the area in September 2017 showed that the area is completely free of rejuvenating Jerusalem artichokes and tubers. In the following vegetation season 2018, the area was again completely free of Jerusalem artichokes and was mowed only once in the management of the surrounding meadow, without the application of herbicide. In order to confirm the effectiveness of this management method, a new research area H11 was established in 2018 with the same management chosen as on the area H2. The control autumn engraving showed the effectiveness of this method (mowing + BOFIX) as no tubers were found on the area H11. The areas H5 and H8 were mowed manually once in 2017 and HERBISTOP was applied on the rejuvenated individuals. After the herbicide application the plants seemed to die, but in September the plants were growing again. As a result of the opening of the H5 habitat to sunlight, Colchicum autumnale, which has so far been represented only by assimilation organs, has started to flower. In addition, the digging up of survived individuals was performed on the area H8 in September. Small tubers were engraved on both areas H5 and H8 in autumn. In the next growing season, new Jerusalem artichokes were found on both areas H5 and H8, but in a smaller number than before the management intervention. Mowing and application of HERBISTOP on both areas were performed also in 2018 and the number and size of tubers after the next intervention is similar as in 2017. Another approved method of Jerusalem artichoke disposal is the use of an herbicide containing glyphosate [8, 11]. The application of glyphosate on Jerusalem artichoke in the Poodri PLA was used in the past but was stopped due to its toxicity [12]. It is important to prevent the spread of Jerusalem artichokes by careful maintenance of the affected parcels, because they are not spreading on permanently cultivated parcels. Regular mowing of the stand several times a season is recommended. It leads to a reduction and a gradual death of Jerusalem artichokes [13]. The disposal of Jerusalem artichokes due to the large number of root tubers in the soil is very demanding. Authors ČERNÝ et. AL. (1998) recommend a combination of mechanical and chemical processes-regular mowing and spraying with herbicides [14].

4. Conclusion
The article focuses on the effectiveness of various landscape management methods for the removal of invasive species Helianthus tuberosus from the alluvial communities of Poodri PLA. We have applied mechanical management methods, chemical management methods and their combinations. We can say that the most effective management method leading to Helianthus tuberosus elimination from alluvial
meadows of Poodří PLA is a combination of manual mowing-application of a suitable herbicide (BOFIX) -mechanical mowing (area H2, H11). This intervention resulted in complete death of Jerusalem artichoke without rejuvenation. Applying HERBISTOP does not have a required effect on the disposal of the selected species. HERBISTOP is based on a natural base, its active ingredient is pelargonic acid, which is commonly found in nature. The management of *Helianthus tuberosus* in the Poodří PLA will be carried out on selected and newly established areas until 2020 at least. Currently other herbicides are also being tested.

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