Analysis and estimate of efficiency technological methods the destruction of Sosnowsky hogweed in the north-west region of Russia

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Abstract. The article explores a number of technological methods for the destruction of Sosnowsky hogweed (Heracleum sosnowskyi Manden) on agricultural lands. Graphical dependences of the degree of re-overgrowing by an invasive species of treated areas with working organs for its destruction were obtained. Based on the analysis of the obtained dependences, the most energy-efficient method of mechanical soil cultivation was revealed, which consists in high-quality pruning of the root system of weeds and the seeding of seeds with working bodies with a variable working width, which provides a significant decrease in the intensity of repeated overgrowing of the area with hogweed.

1. Introduction
Sosnowsky hogweed is a large perennial (up to 2-3 m) plant of the Umbrella family. The plant is monocarpic, that is, it blooms and bears fruit once in a lifetime, after which it dies. Hogweed seeds begin to germinate when the soil warms up in spring to 1-2°C. Mass shoots of weeds (up to several hundred pieces per 1 m²) appear even before the germination of any other vegetation.

The root system is pivotal, the bulk of the roots is located in a layer up to 30 cm, individual roots reach a depth of 2 m.

The hogweed has a high viability: seedlings tolerate frosts up to -10°C, under deep snow up to -35-45°C, and are also resistant to high temperatures up to 37°C [1].

The plant is characterized by rapid growth: 2-3 weeks after the beginning of spring regrowth, its height reaches 25-40 cm, and after 40-45 days - more than 1.5 m. The ability to grow with high density allows hogweed plants to displace other species in the agrophytocenosis. On one plant from 30 to 150 inflorescences are formed, on each 20-80 thousand seeds ripen [2].

The cow parsnip reproduces only by seeds and is not capable of vegetative propagation, but at the same time it is able to renew itself from underground buds (5-6 vegetative buds are formed at a depth of 7-15 cm), especially after mowing or mechanical damage. Seeds can be stored in the soil for more than 5 years [3-4].

Significant areas occupied by the Sosnowsky hogweed are agricultural land. Sosnowsky hogweed was cultivated as a fodder crop. To get rid of unwanted hogweed thickets, MTA and various mechanical, agro technical and chemical methods are used.

Mechanical methods include pruning or digging out plant rhizomes at a depth below the growth point (10-12 cm) in early spring, and repeated in mid-summer [4].
During agro technical measures, weeds are repeatedly mowed on agricultural lands, deep ploughing and disking are carried out, followed by sowing of replacement crops (cereals, legumes, potato cultivation) [5-6].

Ploughing the soil with a turnover restricts the possibility of preserving the viability of seeds by the Sosnowsky hogweed, since the average depth of seeds in the soil, favorable for the emergence of seedlings, is up to 5 cm. Thickened sowing of perennial grasses after deep ploughing only limits the germination of seedlings of hogweed, therefore, in the event of their appearance destruction by spot application of herbicides, weeding out or regular agricultural practices [5; 7].

It should be borne in mind that the destruction of hogweed on the basis of ploughing with subsequent disking (in those areas where there are conditions for the operation of the corresponding equipment) may be an economically more effective method than the use of herbicides.

Disking the soil as an independent method, it is necessary to carry out subject to repeated processing during the growing season or in a set of measures.

There are dormant buds in the upper part of the hogweed root. With a single disking, the process of cutting the roots into viable parts with buds occurs, which leads to the so-called artificial "grafting" of the invasive species [4].

The most effective is the chemical method of fighting hogweed using herbicides, the purpose of which is to destroy the vegetative mass and prevent fruiting of hogweed plants. The timing of the use of herbicides is from the beginning of regrowth of hogweed at a plant height of 15-35 cm and until the beginning of flowering. In other periods of the growth of the weed, the treatment will not give a significant effect, since monocarpic plants die off by themselves after flowering [4; 6].

After the introduction of herbicides, it is recommended to carry out ploughing in autumn or spring with the subsequent sowing of a replacement crop to slow down the process of recovery of the hogweed population.

When using covering shading materials, the surface of the area occupied by hogweed is covered with black polyethylene film or geotextile material (geotextile), which is used in combination with imported soil applied to its surface, followed by sowing cereal grasses [4].

On agricultural land, such control methods are not applicable due to the large areas. To reduce hogweed thickets, it is very important to carry out high-quality crop rotations and intensive land use, since it is the neglect of the fields for the last 25–30 years that has given this species an incredible chance to develop arable lands [6-7].

A brief analysis of the presented studies showed that to date, various methods of dealing with Sosnowsky hogweed have been developed and tested to varying degrees. Despite this, the territory of the secondary range of this species is increasing, since each of the methods considered has its own restrictions on application on lands for various purposes. On the territory of settlements, it is environmentally safe and effective to use covering shading materials. On agricultural lands - ploughing and disking of hogweed thickets with the subsequent planting of replacement crops. On vacant lots, territories adjacent to industrial facilities, along roads at a sufficient distance from settlements and residential areas, it is possible to use herbicides, provided that the regulations for their use are strictly observed [8-10].

Therefore, to date, most of the proposed methods of combating hogweed do not completely and effectively solve the problem of non-proliferation of invasion both in the territories of urban and rural municipalities and agricultural enterprises.

In this regard, a more specific assessment of the effectiveness of various technological methods for preventing the spread and destruction of Sosnowsky hogweed on agricultural lands is required.

2. Materials and methods
A field experiment on studying resource-saving soil cultivation systems to find the most environmentally-energy efficient solution to combat Sosnowsky Hogweed within the framework of agro technical measures was carried out at the beginning of June 2020 at the experimental production base of the IAEP.
The research conditions, as well as the physical and mechanical properties of the field in which the research was carried out, are presented in table 1.

**Table 1. Research conditions.**

| Indicator name                                      | Unit of measurement | Indicator value |
|-----------------------------------------------------|---------------------|-----------------|
| Ambient air temperature                             | °C                  | 19-22           |
| Total field area                                     | Hectare             | 2.4             |
| Field head length                                    | Meter               | 150             |
| Soil moisture absolute                               | %                   | 19-22           |
| Relative humidity                                    | %                   | 70-75           |
| Average wind speed                                   | m / s               | 2-3             |
| Direction of the wind                                | -                   | Western, southwestern |
| Soil type                                            | -                   | Medium loamy soddy-podzolic |
| Field relief                                         | -                   | 1-2°            |
| Field contamination with hogweed                    | pieces / m²         | 38              |
| Average height of one plant                          | Meter               | 0.30-0.33       |
| Soil hardness before processing in the layer:        |                     |                 |
| from 0 to 15 cm                                      | MPa                 | 1.31            |
| from 15 to 30 cm                                     |                     | 2.06            |

For research, the field was divided into 6 experimental plots with long-term (5-8 years) mass growth of Sosnowsky hogweed with a total area of 2.4 hectares on agricultural land within the boundaries of the Pushkin district of St. Petersburg.

The experimental scheme consisted of 6 methods of soil cultivation in the selected areas:

- 1 site - Traditional mouldboard ploughing of soil to a depth of 25-28 cm with a PLN-3-35 plow (control);
- Section 2 - Cutting the root system of weeds to a depth of 12-15 cm with pointed paws on spring stands;
- Section 3 - Cutting the root system of weeds to a depth of 15-18 cm using stubble tines with undercutting wings;
- Section 4 - Cutting the root system of weeds to a depth of 14-16 cm with staple paws (patent for invention of the Russian Federation No. 2453087) designed by IAEP;
- Section 5 - Cutting of the root system of weeds to a depth of 14-16 cm by working bodies with a variable width of capture (patent for invention of the Russian Federation No. 2702551) designed by the IAEP;
- Section 6 - Chemical treatment of the area contaminated with Sosnowsky hogweed with a sprayer OP-2000 using a continuous herbicide.

The appearance and brief description of the applied working bodies in the course of the experiments are presented in table 2.

As a machine for research on cutting the root system of the hogweed with various working bodies presented in table 2, we used the mounted universal combined unit UKPA-2.4 of the IAEP design with the MTZ-920 tractor. The average speed of the MTA was 7-8 km / h.

During the research, methods were used to study the physical laws that occur in the process of soil cultivation; plant growth and development; generalization and analysis of experimental data obtained on the basis of their own research and research of other scientists.
3. Results

Field experiments were carried out on specially designated areas of the same shape in order to establish the effectiveness of various technological methods for the destruction of Sosnowsky hogweed.

| No. | Type of the working body of the tillage machine | Type of the working body of the tillage unit | Appointment of the working body of the tillage unit | Working body width, cm | Processing depth, cm |
|-----|-----------------------------------------------|---------------------------------------------|---------------------------------------------------|------------------------|---------------------|
| 1.  | Plow body                                     | Reversal ploughing                          |                                                   | 35-40                  | 18-30               |
| 2.  | Pointed share (chisel) on a spring stand      | Undercutting weeds, loosening the soil, vibration effect as additional loosening |                                                   | 33                     | 15-22               |
| 3.  | Stubble cultivator tine with undercutting wings | Stubble cutting, soil loosening             |                                                   | 46                     | 15-25               |
| 4.  | Shackle loosening share                        | Loosening the soil, trimming weeds, crumbling effect due to the compression of the soil as it passes through the inner surface of the share |                                                   | 34                     | 10-25               |
| 5.  | Working body with variable working width      | Loosening the soil and cutting weeds, reducing drag due to the variable width of the trimmer wings |                                                   | 33                     | 12-15               |

Experimental site number 1. On the 1st site, mouldboard ploughing was carried out with a PLN-3.35 plow (figure 1).

The ploughing efficiency on average on the site was 96.2% per 1 m². The hogweed root stalk was turned over and laid on the bottom of the furrow, the seeds were plowed on average to a depth of 22-25 cm.

Experimental site number 2. On the second site, for cutting the root system of the Sosnowsky hogweed, daggers with spring struts were used, installed in two rows on the frame of the tillage unit (figure 2).
Figure 1. Agrophone of the experimental plot infested with Sosnowsky hogweed before ploughing (a) and view after processing (b).

Figure 2. Pruning of the Sosnowsky hogweed with lancet paws on spring racks: (a) - general view of the lancet paw, (b) - view of the agrophone after processing.

Undercutting efficiency on average on the site was 78.5% per m². Some of the roots of hogweed in the study area were not completely cut, in some cases, breaking, pulling out, moving and carrying the root to the soil surface occurred. Due to the different length of the hogweed root (5-10 cm) and, accordingly, the height of the plant, i.e. general heterogeneity of growth and development (vegetation) of plants, cutting at the set depth of the working organs of 12-15 cm did not occur. Some of the roots up to 10 cm long only rose during the process of loosening. Some of the large roots broke off above the hogweed growth point. The depth of processing (cutting) was not always maintained due to large hogweed rhizomes that came across. There was not significant clogging of the working organs with the stem part of the plants and leaves.

Experimental site number 3. At the third site, for cutting the root system of the Sosnowsky hogweed, stubble cultivator stands with cutting wings were used, installed in two rows on the frame of the tillage unit for continuous cutting (figure 3).

Undercutting efficiency on average on the site was 67.8% per 1 m². The roots of the hogweed up to 10-12 cm in length in the study area remained uncut, in some cases, as well as in the first site, there was an eversion of the root system of the hogweed, movement and removal of the root to the soil surface. A significant part of the large roots broke off above the growth point of the hogweed.

Due to the large area of the frontal projection of the paw (wide shaft), there was a partial clogging of the working bodies installed in the first row with a green mass.
Experimental site number 4. At the 4th site, for cutting the root system of the Sosnowsky hogweed, staple-shaped loosening paws developed in the IAEP were used, installed in two rows on the frame of the tillage unit for continuous cutting (figure 4).

Undercutting efficiency on average on the site was 68.4% per m$^2$. Large roots of 20 cm or more in length of the hogweed in the study area remained uncut; in some cases, the root system of the hogweed turned out to the surface of the soil. Some of the strong roots broke off above the growing point and were not cut.

Due to the design features of the working body, effective trimming took place only in the lower part of the staple share. During the movement of the unit, clogging of the working organs with plant remains of hogweed was noted, as well as periodic unloading of the soil by the working organs installed in the first and second rows.

Experimental site number 5. At the 5th site, for cutting the root system of the Sosnowsky hogweed, working bodies with a variable width of capture were used depending on the soil resistance, developed in the IAEP, installed in two rows on the frame of the tillage unit for continuous cutting (figure 5).
Figure 5. Pruning of Sosnowsky hogweed by working bodies with a variable working width: (a) - general view of the working body, (b) - type of agricultural background after processing.

Undercutting efficiency on average on the site was 92.4% per 1 m$^2$. Most of the roots have been completely cut.

The quality of undercutting when using this working body was achieved by a stepwise, that is, multidirectional impact on the soil layer, changing the angle of soil crumbling in the optimal range from 200 to 300, when soil resistance is minimal, and the minimum thickness of the undercutting (blades) of the paw wings. There was no soil loading; it should be noted that periodically insignificant collection of weeds and their roots in the place of transition from the chisel to the stand should be noted. The average length of the cut roots of the hogweed in the study area was from 8 to 16 cm (figure 6).

Figure 6. Cut roots of Sosnowsky hogweed by working bodies with variable working width.

Experimental plot number 6. On the 6th site, the hogweed was sprayed with the chemical "Tornado 500". It is a versatile, continuous herbicide for the control of a wide range of annual and perennial weeds on agricultural land. It penetrates into plants through leaves and other green parts and is transferred to all organs of weeds, reaching their root system, while the drug does not have a suppressive effect on seeds.

The first visible signs of leaf suppression after treatment with "Tornado 500" appeared after 15 - 17 days, stems - after 20 - 22 days. The complete death of weeds occurred 30-32 days after treatment (figure 7).
After the operations for the destruction of the Sosnowsky hogweed at each of the 6 sites, the growth of the number of plants per 1 m$^2$ was recorded, and phenological observations were also carried out. For this, plants were counted along the diagonal of each plot on fixed plots with an area of 1 m$^2$ (figure 1 a). The germination rate of new plants was determined every 10 days after the previous observation. A total of 6 counts were made. The accounting results are shown in figure 8.

Analyzing the degree of overgrowing with hogweed in the Sosnowsky experimental plots after the treatments carried out, it can be noted that the smallest number of plants was found in plot 1 (curve 1, figure 8) during ploughing. The rate of emergence of new sprouts averaged 2-3 sprouts per m$^2$ during each count. Phenological observations of the growth and development of weed stems have shown that the appearance of new shoots is, in the overwhelming majority, associated with their repeated germination from the root system, since the seeds of previous years that were originally on the surface (in a layer of up to 5 cm) of the soil were plowed to a depth of more than 22-25 cm.

Observations of plot 6 (curve 6, figure 8) after spraying with herbicides showed that in the first 30 days the invasive species was suppressed, and then a sharp increase in its number (up to 20 seedlings), the intensity of which began to decrease on day 60. This can be explained by the fact that the destruction of mature plants that shaded the soil surface from sunlight made it possible for the active germination of dormant seeds.

At the same time, from an environmental point of view, this technique is not safe, since it has a negative impact on the environment.
Analysis of areas 2 (curve 2), 3 (curve 3), 4 (curve 4), 5 (curve 5) (figure 8), on which the hogweed rhizomes were pruned with various types of working organs, indicates that among the operations performed the most effective technological method for the destruction of hogweed is its cutting by working bodies with a variable working width (curve 5). This is primarily due to their rational design parameters, such as minimal soil cutting resistance during processing, low crumbling angle of the working body when moving in the soil, the ability to automatically change the cutting angle when additional soil resistance occurs.

From a technological point of view, it was possible to cut the root system of the hogweed below its growth point, while part of the seeds was deepened by 10-12 cm, which affected the delay in their germination, while in the case of ploughing (curve 1) it is not possible to achieve such an effect. since moving and turning (ploughing) the roots after a certain time contributes to their re-germination. In addition, the energy intensity of the ploughing process is 30-35% higher in comparison with surface tillage.

The intensity of re-overgrowing in this area is on average 48% lower compared to area 2 when processing with lancet paws paws (curve 2) for the entire observation period, and compared to area 3 when cutting with stubble working bodies 50% (curve 3), in comparison with area 4 when using claw-type feet (curve 4) by 54%.

4. Conclusion

The studies carried out to study resource-saving soil cultivation systems in order to find the most effective solution in the fight against Sosnowsky hogweed suggest that one of the available, low-cost and environmentally effective methods of destruction is mechanical processing, in particular, cutting the root part of plants.

According to the results of the experiments, the efficiency of destruction of Sosnowsky hogweed on ploughing was 96.2%, when cutting with lancet paws - 78.5%; when pruning with stubble paws - 67.8%; staple paws - 68.4%; with paws with variable working width -92.4%. The most effective technological method for the destruction of hogweed is its cutting by working bodies with a variable working width.

At the same time, the intensity of re-overgrowing of the area on which the paws with variable width were used was reduced by 48% compared to the areas treated with lancet paws, by 50% with those treated with stubble paws, and by 54% with staple paws.

In the future, the proposed method in combination with replacement crops based on fast-growing and highly productive cereals, legumes, as well as oilseeds and row crops with their intensive cultivation in compliance with agro technical requirements will effectively combat such invasive species as Sosnowsky hogweed.

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