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NEXT Poland – Ukraine

RECOMMENDATIONS ON A COMMON METHODOLOGY FOR CONTROL OF HOGWEED POPULATIONS IN VARIOUS CROSS-BORDER LANDSCAPE AREAS OF UKRAINE AND POLAND

These recommendations were developed based on existing methods of controlling Sosnowsky's hogweed in Poland and Ukraine (part 1) and selected laboratory and field research methods planned in the ZeroHeracleum project (part 2) in the field of controlling the hogweed population in various landscape areas of the Polish-Ukrainian border as part of the international conference "Applied application of methods of influence on the hogweed population in order to restore the biodiversity of the transboundary territories of Ukraine and Poland", which was held on October 16-17, 2025 as part of the project " Protecting the biodiversity of cross-border territories of Ukraine and Poland from invasive hogweed (Heracleum) populations" no. PLUA.01.03-IP.01-0008/23, financed by the European Union under the Interreg NEXT Poland-Ukraine Programme 2021-2027.

PART 1. EXISTING METHODS FOR CONTROL OF HOGWEED IN POLAND AND UKRAINE – RECOMMENDATIONS FOR THE TARGET COMMUNES

1A. RECOMMENDATIONS FOR THE TARGET COMMUNES

Recommendations will be implemented from several stages, namely:

1. **Detection and mapping of hogweed (March 2026 – December 2026 / Jan 2027).**
   - **Tools and applications**: satellite images, mobile application, drones, GPS, experts who will monitor the state of the population of invasive plants.
   - **Actions**: Inspect all 1000 hectares in 9 target territorial communes in UA and in 7 municipalities in Poland (905 km^2) target territorial communes especially roadsides, river banks, forest belts.
   - **Create an interactive map** at the beginning of 2027, presenting the results of remote sensing analyses.

At the first stage, the main goal is the complete and detailed detection of Sosnovsky's hogweed population. The work begins with the preliminary collection of available data, including observations and information from local residents about the spread of the plant. For a systematic survey, the territory is divided into sections of several hectares, which allows you to carefully inspect each site.

Field surveys are carried out using drones for aerial photography of hard-to-reach places, GPS navigators for accurate geolocation, and satellite images to detect the early stages of plant flowering. Hogweed population in all types of habitats will be analysed.

During the survey, the population frequency, distribution and the stage of plant development are determined, from rosette to budding, flowering and seed maturation, which allows us to plan the optimal timing of further activities. All detected locations of hogweed are recorded on an interactive map using GIS technologies. A detailed database is being created that includes geocoordinates of contaminated areas, photos from drones, and notes on implementation of control methods of mechanical or chemical treatment.

Additionally, the hogweed population will be mapped using an interactive mobile application by local citizens, which will support the identification of the plant's presence in the monitored area. Based on the obtained data, an analysis of plant distribution and population characteristics will be conducted, taking into account the HS population condition and providing further recommendations for HS control. This will ensure the effective planning of subsequent stages of work.

Stage 2: Planning and preparation (April 2026 – November 2026)

Formation of a team at the commune enterprises of the territorial community.

- The mobile group consists of two people who have a tractor driver's license and tractor driving skills, as well as know how to work with an interactive map using GIS technologies.
- Workers should be familiar with methods for controlling invasive plants at different stages of growth, from rosette to flowering and seed maturation.
- The group ensures the efficiency of work in all contaminated areas

Procurement of tractors, equipment for tractors, manual equipment and protective equipment

- **Personal protective equipment:**
  - Protective suits — 9 pcs. per community;

- Spray guns for washing suits — 2 pcs. per community;
- Chemically resistant gloves — 9 pcs.;
- Special shoes — 9 pairs;
- Respirators and filters — 9 pcs. Each;
- Safety glasses and visors — 9 pcs. Each.

These products allow you to safely carry out mechanical and chemical treatment of plants, prevent contact of the skin and respiratory tract with toxic substances, as well as maintain cleanliness and disinfection after work.

Mechanization of work

· **Manual equipment:** professional gasoline lawn mowers — 2 pcs. per community, cordless sprayers — 2 pcs. per community. They are used to treat small and hard-to-reach areas.

· **Tractors:** 80-110 hp, all-wheel drive, operator's cab, open-type hydraulic system with at least three pairs of rear hydraulic outlets.

· **Additional equipment for tractors:** a plow with a skimmer for soil preparation and road mowers with a working width of 1.8 m, adjustable cutting height, floating structure and hydraulic tilt adjustment. Such equipment allows you to work on slopes, roadsides and at an angle of up to 60 degrees, providing effective plant control over large areas.

Staff training

· Employees of target territorial communes are trained in safety and methods of treating hogweed at different stages of growth possible in this period.

· The training includes the practical use of hand equipment and tractors, the proper use of protective equipment, and compliance with the rules for handling chemicals.

· Such training guarantees safe and efficient performance of work in all areas of the community.

3: Spring Treatment (April–May)

Mechanical struggle

· **Continuous mowing of young plants** is carried out up to three times per season and is used for plants up to 1.5 meters high to limit the development of weeds in the early stages of growth and reduce the risk of seed formation.

· **Root pruning** is most effective in April, when the plants have not yet reached their maximum development. The pruning depth should be 12-15 cm, which allows you to significantly weaken or completely destroy the plant, preventing it from growing back.

· **Plowing** is used mainly in autumn, but during spring work it can also be used to prepare the site and destroy the root system, with a depth of up to 25 cm. This approach will help reduce the density of the hogweed population for the next season.

· **Cutting of inflorescences** is carried out in the middle of the flowering period, which prevents the formation of seeds and reduces the spread of the plant to new territories.

Stage 4: Summer control (June-August)

Reprocessing

· **Mowing adult plants before flowering** is carried out to prevent seed formation, which significantly reduces the further spread of hogweed. Mowing is repeated as needed in areas with high plant density.

· **Re-spraying of new seedlings** with herbicides is carried out after the active growth of young plants. This allows you to control the next generation of hogweed and prevent its mass spread in infected areas.

1B. EXISTING METHODS FOR CONTROL OF HOGWEED IN POLAND AND UKRAINE (presented at the conference)

Chemical control

· **Spot spraying with herbicides** is carried out in the phase of active growth of hogweed using powerful cordless sprayers. This method allows you to act on individual plants as accurately as possible, minimizing the contact of chemicals with other crops and the environment.

Tank mixtures of herbicides for the control of Sosnovsky's hogweed

№	Herbicide mixture	Mechanism of action
1	Arylex + Clopyralid	For young and medium-sized plants; spot spraying.
2	Dicamba + Glyphosate	Systemic action; suitable for large plants, including the root system.
3	Metribuzin + Rimsulfurone	For processing rosette stages of hogweed; increases penetration through the leaves.
4	Flurochloridon + Dicamba	Contact + systemic; effectively prevents seed formation.
5	Clopyralid + Glyphosate	For point control and treatment of roadsides.

Tank mixtures of inorganic compounds

№	Compound mixture	Mechanism of action
1	KCl + Urea	Increases the penetration of herbicides into the leaves; stimulates the development of cultivated plants in the treatment area.
2	CAS32 (ammonium sulphur nitrate)	Added before spraying; improves the effectiveness of systemic herbicides.

3	$CuSO_4$ + ATS	Trace elements and herbicide absorption stimulator; increases processing efficiency.
4	KCl + ATS + Urea	Complex mixture for experimental treatments; improves the adhesion of the working solution.
5	KCl+CAS32	It is used to enhance the action of systemic herbicides and optimize nitrogen application.

The main herbicide mixtures that are allowed in the EU:

Glyphosate + Triclopyr (Triclopyr 10% + Glyphosate 50% SP) Common Name: Triclopyr + Glyphosate CAS No.: 55335-06-3, CAS No.: 1071-83-6 Molecular Formula: C7H4Cl3NO3, C3H8NO5P Agrochemical Type: Herbicide- This preparation is for the treatment of stems and leaves after germination with internal absorption and conductivity. It can be applied to control hogweed on uncultivated land.

Triclopyr + Fluroxypyr + Clopyralid- Specialized herbicide 3D works by penetrating through the strong outer shell of the leaves of sprouted weeds before moving through the plant to the roots. Once in the plant system, 3D stimulates it to outgrow its supply of nutrients. Unlike other products that only burn weeds, 3D destroys the roots of weeds along with them. **Sodium + Iodosulfuron methyl sodium + Amidosulfuron Iodosulfuron-methyl-sodium:** usually used at a dose of 1–2 g/ha. This mixture is effective against broadleaf weeds, including Sosnowski's hogweed, especially in the early phases of growth (up to 30 cm in height).

To increase efficiency, surfactants (surfactants) or adjuvants should be added, which improve the penetration of the herbicide into the leaves. Applications in large areas or in protected areas require an environmental assessment and approval with the relevant authorities. Local application within the project will take into account an individual treatment plan, taking into account the type of soil, the phase of growth of hogweed and weather conditions.

Glyphosate + Flazasulfuron – this mixture provides both rapid inhibition of growth and long-term blocking of the re-germination of many weeds, including hogweed. A mixture of a systemic non-selective herbicide that penetrates through the leaves and moves to the root system. Flazasulfuron is a selective herbicide from the group of sulfonylureas, which inhibits the growth of broadleaf weeds, has a long-term soil effect.

• Processing time: late May - early June, when hogweed is actively growing, but not yet blooming.

• Temperature conditions: +15+25°C, no rain for 6 hours after treatment.

• Spraying: evenly covering the leaves, avoiding runoff

• Avoid processing windy weather - the risk of drifting to cultivated plants.

Treatment of areas near rivers is allowed only mechanically (so as not to pollute the water).

Due to the fact that Sosnovsky's hogweed causes burns upon contact with humans, all work on its destruction should be carried out in special protective clothing.

Microwave method

Microwave radiation is a promising physical method for destroying hogweed. Studies show that exposure to microwaves for 15 minutes ensures 100% plant death without harming soil ecotoxicity. This method is safe for the environment and avoids the use of chemicals. However, its effectiveness requires further detailed study and confirmation of safety for humans. A promising option is the use of microwave treatment using remotely controlled robotics, which allows you to treat hard-to-reach areas without the risk of human contact with the plant.

Biological control method

Grazing sheep and cattle is an effective biological method of controlling hogweed in areas with a high level of infestation where machinery cannot reach. Sheep and cattle are immune to the toxic sap of the plant and are able to consume it without harm to health, while reducing the density of the weed population. This method is especially effective on slopes, pastures and areas along watercourses, where traditional mechanical or chemical treatment is limited.

PART 2. LABORATORY AND FIELD METHODS PLANNED IN THE ZeroHeracleum PROJECT

Research methodology in WP2

The methodology for the tasks carried out within WP 2 includes five stages:

Stage 1 involves defining the precise boundaries of the analysis area in the communes of Poland and Ukraine and acquiring satellite remote sensing data for these territories. Multispectral images with a spatial resolution of less than 3 meters are planned for use. Additionally, preliminary field information will be collected in both countries through WebGIS regarding known hogweed locations, including GPS coordinates, photographic evidence, approximate population size, and landscape description. These data will serve as a reference base for subsequent classification.

Stage 2 involves developing two WebGIS applications for collecting field data on the distribution of Sosnowski's hogweed in Poland and Ukraine. The applications will be created in two versions with different levels of detail and adapted for specialists (researchers), non-specialists and volunteers, including local community employees familiar with local hogweed sites. The applications will operate using GNSS positioning of mobile devices and will allow users to collect coordinates, photos, estimates of infestation area, population density, and landscape type in communes in both Poland and Ukraine.

Based on the spatial data collected through WebGIS in Poland and Ukraine, a training dataset will be created for GeoAI and ML algorithms.

Stage 3. Within this stage, additional field verification will be carried out at: 50 additional locations in Poland and 50 additional locations in Ukraine. The purpose is

to confirm the presence of hogweed, verify the accuracy of the initial model, and improve satellite image classification. All updated data will be synchronized with WebGIS to further enhance model accuracy.

Stage 4 covers the main remote sensing analyses. The OBIA method will be applied to multispectral satellite images for territories in Poland and Ukraine to automatically detect hogweed populations.Model accuracy will be assessed, and the results will be prepared as a GIS database and published as an interactive online map (WebGIS beta version) accessible for both countries. Field data from Ukraine and Poland will be used to improve classification accuracy and refine the identified population boundaries.

Stage 5 involves aerial imaging of hogweed-infested areas using multispectral sensors mounted on UAVs. Imaging will be carried out: in Poland on selected plots using a multispectral drone, in Ukraine covering at least 1,000 ha across designated communes. Based on the collected data, vegetation indices will be calculated to refine population boundaries, assess their condition, and monitor the effectiveness of control measures. Aerial surveys are planned multiple times during the vegetation season in both countries, enabling monitoring of plant regeneration, control effectiveness, and changes in the natural environment.

Stage 6 includes updating the WebGIS application to its final version and integrating all data obtained in Poland and Ukraine: satellite imagery, field points, aerial survey results, and verification.

The outcome will be the final WP2 report, which will include:

- a comprehensive map of hogweed distribution in the communes of both countries,
- results of remote sensing and UAV surveys,
- an integrated database for use in subsequent work packages.

Research methodology in WP3

Stage 1: Conducting field research over two growing seasons to collect data for a database containing a list of characteristics of the Sosnowski hogweed population in 30 municipalities in Poland and nine in Ukraine. The database will contain the following information:

- GPS coordinates and photographic documentation of the populations;

- name of the locality and site code;

- habitat type;

- population size (number of individuals or/and area of population per hectare);

- viability of population individuals (% share of individual developmental plant stages);

- biometrics of six scattered population individuals (leaf dimensions, plant height, number of umbels or absence thereof, density of hogweed);

- manner of clustering of hogweed individuals (sociability);

- list of accompanying species (phytosociological survey using the Braun-Blanquet method).

Any visible traces of control measures against the species under study will also be assessed. All field data will be entered into the application and onto standardised research forms.

Stage 2: While assessing the characteristics of the population in the field, biological samples (such as leaf fragments, whole leaf blades and seeds) will be collected for genetic and biochemical laboratory testing.

Stage 3: Soil condition (pH, organic matter content and nutrient content) will be assessed using a soil scanner.

Stage 4: The database of information obtained will form the basis for developing recommendations for combating hogweed in individual municipalities. The collected biological material will be used for biochemical and genetic laboratory analyses.

Research methodology in WP4

The aim of the research conducted within the WP4 package is to develop recommendations for combating hogweed based on biochemical genetic analyses of the populations being controlled.

Research on the genetic structure of the Sosnowski hogweed population

The first stage involves collecting samples in 30 municipalities in Poland and 9 in Ukraine and delivering them to the University of Life Sciences in Lublin and Maria Curie-Skłodowska University in Lublin as leaf fragments dried at room temperature, no later than by the end of August 2026. Within each location, fragments from at least five individuals from random but distant sites within that location should be collected separately in paper bags. GPS coordinates for each sample should be written on the respective bag. The youngest leaves should be collected from the plants to avoid excessive accumulation of secondary metabolites that hinder the isolation of pure nucleic acids.

In the second stage, the obtained samples will be disintegrated to destroy the tissue structure and cell walls. After obtaining cell lysates, nucleic acids will be isolated using silica membranes. The quantitative and qualitative parameters of the isolated preparations will be determined by spectrophotometric, electrophoretic, and fluorimetric methods.

In the third stage, DNA preparations with the best quantitative and qualitative parameters will be selected. To verify the suitability of nucleic acids for genomic analysis, test reactions will be performed using the real-time PCR method. Samples that do not contain reaction inhibitors and show high amplification efficiency (within the range of 90-110%) will be used for reduced representation genome sequencing using the DArTseq method. After being adjusted to the same concentration, the DNA samples will be sent to the sole supplier of the patented technology for analysis. As a result, sequence data covering tens of thousands of restriction fragments in each sample will be obtained. These data will be converted into binary matrices for bioinformatic analysis.

In the fourth stage, bioinformatic analyses of the genetic data will be carried out to determine the genetic similarity of the studied objects and to characterize the population structure. The following parameters will be determined: (I) three types of genetic populations - G1a-G1c: homogeneous, medium diversity, and high diversity, respectively; (II) four levels of similarity - G2a-G2d: low (up to 50%), medium (50-75%), high (75-90%), and very high (>90%), respectively; and biochemical parameters: (III) number of identified compounds - B1a-B1c: low, medium, high, respectively; (IV) concentration of compounds - B2a-B2c: low, medium, high, respectively. Genetic data will be compiled and compared with other traits identified for the studied populations, such as biochemical, morphological, and phenological characteristics.

In the fifth stage, based on the obtained results, recommendations for control methods tailored to individual genetic groups will be developed.

Qualitative and quantitative studies of secondary metabolites in the Sosnowski hogweed population (Faculty of Biology and Biotechnology, Maria Curie-Skłodowska University, Lublin).

The study will examine the quality and quantity of secondary metabolites, paying particular attention to furanocoumarins, which irritate the human body and cause photodermatosis. This assessment will inform the selection of an optimal method for combating hogweed and protecting human and animal health in a given population. Level of bioactive compounds – biochemical parameters: (III) number of recognized compounds, B1a-B1c – low, medium, high, respectively; (IV) concentration of compounds, B2a-B2c – low, medium, high, respectively.

Stage 1: Preparation of extracts for secondary metabolite analysis from plant samples collected in the field. Multiple extraction to obtain a concentrated solution. Preparation of dilutions for detailed analyses.

Stage 2: Biochemical analysis using high-performance liquid chromatography (HPLC), mass spectrometry (MS) and UV/VIS spectroscopy to qualitatively and quantitatively assess the active substances contained in the samples (e.g. furanocoumarins, flavonoids and anthocyanins).

Stage 3: identification of the substances detected using standards and databases (MS libraries).

Stage 4: imaging of the identified substances in leaf tissues using an HTX MALDI M3+TM Sprayer.

Stage 5: supplementing the database with data obtained from genetic and biochemical tests. Incorporating the results into recommendations for municipalities.

Research methodology in WP5

The first stage of the task will be to select sites for the control of Sosnowski's hogweed. This species will be controlled in the municipalities of Końskowola and Werbkowice. Two methods will be tested there: a mechanical-chemical method and a cryogenic method. 9 test plots of 1 hectare each will be selected in Ukrainian communes, including Korostiv, Zhupany, Spas, Dovhe, Tukhlya, Lybohora, Pidhorodtsi, Smerechka, and Yasenytcia.

The mechanical-chemical method of controlling hogweed involves the mechanical removal of the above-ground parts of the plant using a specialised mower, combined with the use of herbicides (flazasulfuron and glyphosate). In this method, the above-ground parts of the plant will be removed using specialised hand or mechanical equipment. Next, the herbicide mixture will be applied to the root collar or inside the stem using a herbicide sprayer with specialised nozzles. To achieve the desired effect, herbicide spraying will be applied throughout the area to young regrowing plants. After the herbicide treatments, plant health will be monitored using a non-contact chlorophyll meter. At the end of the growing season, a visual assessment of the effectiveness of the method will be carried out and soil samples will be taken to determine the residues of active herbicide substances. The same mechanical-chemical method will be applied on all Ukrainian test plots, following population characteristics identified in WP3 and genetic/biochemical recommendations from WP4.

The cryogenic method will involve the use of extremely low temperatures (-196oC) to eliminate both young and adult plants. This method will use a specialised device for the precise application of liquid nitrogen. Before the gas is applied, the above-ground parts of mature plants will be mechanically removed (mowed). In the case of seedlings and young plants that have reached a maximum height of 30 cm, the gas will be applied

to the surface of the entire plant. In the case of mature plants, the liquefied gas will be administered (injected) directly into the stem and/or roots of the plants using an applicator. The treatments will be repeated twice during the growing season. After the second series of treatments, plant residues will be destroyed using a rotary tiller. After cryotherapy treatments and at the end of the growing season, a visual assessment of the effectiveness of the method will be carried out. Note: Cryogenic method will only be applied in Poland due to logistical constraints, while Ukrainian plots will use mechanical-chemical, mulching, and grazing methods.

In addition, biological tests will be carried out under controlled laboratory conditions. The effectiveness of selected herbicide mixtures, used alone or with an adjuvant, on seedlings and young plants of Sosnowski's hogweed will be assessed. The herbicides will be precisely applied in a laboratory spray chamber. The experiments will be conducted in a climate chamber with adjustable temperature, lighting and air humidity. Ukrainian Partners will participate in laboratory trials at partner facilities in Poland for training and methodology standardization.

The latest tested methods for controlling Sosnowsky's hogweed include grazing livestock on pastures in the Werbkowice commune. The project included testing various variants: animal species (cattle, sheep), livestock density (LSU/ha), different development stages of Sosnowsky's hogweed, and different months of the growing season (August-September 2025 and April-September 2026). In Ukraine, grazing experiments will also be conducted on selected plots with livestock, complemented by manual mowing and overseeding with grasses and legumes, adapted to local conditions. Ukrainian Partners will monitor livestock density, plant regrowth, and habitat restoration success over the same periods.

Research methodology in WP6

Stage 1: Selection of areas for the control of HS and provision of communal enterprises with necessary equipment. In the 9 target communes of Ukraine, tractors, ploughs, mowers, dump trucks, and personal protective equipment will be purchased and transferred to the ownership of communal enterprises, enabling them to conduct systematic hogweed eradication. For hard-to-reach and hazardous areas with steep slopes, a remotely controlled robot equipped with a rotary tiller and a transport platform will be acquired and deployed across all nine communes. Agreements will be concluded with the enterprises to ensure the implementation of the measures and define further actions of the communes in eliminating hogweed.

Stage 2: Mechanical destruction of HS over an area of 1000 hectares during two years in the nine target communes of Ukraine. The work will be carried out by personnel of the communal enterprises using the purchased tractors, ploughs, mowers, dump trucks, protective equipment, and the remotely controlled robot. Simultaneously, progress monitoring, control over the implementation of the measures, and collection of data on vegetation condition and effectiveness of mechanical removal will be conducted.

Stage 3: Renaturalisation of 10 hectares of land after hogweed removal in the Strilky commune (Lopushanka-Khomyna village). The area will be prepared for grass restoration through mowing, rototilling, herbicide application, fertilization and liming if necessary, followed by harrowing, sowing of recommended grass mixtures, and rolling of the seeded area. Once the grass cover is established, the land will be used for livestock grazing by local community members, with monitoring of pasture condition and evaluation of the effectiveness of the renaturalisation.

Stage 4: Monitoring of pastures and assessment of the effectiveness of the measures. Grass cover condition, effectiveness of applied herbicides and fertilizers, compliance with agronomic procedures, as well as indicators of milk production and livestock numbers will be tracked to determine the feasibility of establishing public pastures in other communes, restoring biodiversity, and maintaining sustainable control of hogweed after the project's completion.