Development of a biological method to control the poisonous weed plant heracleum sosnowskyi manden

N N Semchuk¹ and O V Balun²

¹Yaroslav-the-Wise Novgorod State University, 41, ul. B. St. Petersburgskaya, Velikiy Novgorod, Russian Federation
²Novgorod Research Institute, Borki v., 173516, Russia

E-mail: Nikolai.Semchuk@novsu.ru

Abstract. The level of aggression of invasive species in some cases is so high that natural plant communities undergo significant changes in vertical and horizontal structure of phytocoenosis. Often, the species composition of the ecosystem can also greatly decrease. For active introduction into historically established plant communities, a new species must have a special norm of genotype response, which in one or more parameters exceeds that of native species. This gives it an advantage that allows it to expand its range and dominate. The phenomenon with the species Heracleum sosnowskyi Manden is also different in that the plant causes dangerous diseases in humans. It is no coincidence that this weed has been controlled by the government in recent years.

1. Introduction
Plants Heracleum sosnowskyi M. have unique properties and a high degree of environmental plasticity to the conditions of growth. This allowed the representatives of this species to successfully withstand the fierce competition with native species and to acquire the status of one of the most dangerous invasive. The uniqueness of the situation is also aggravated by the fact that almost all parts of the plant can cause serious diseases in humans [1–8].

Academician I.A. Guldenstedt during the expeditionary research of the flora of the Caucasus (1768-1775) discovered this plant and made its first herbarium, which is currently stored in the composite herbarium of the Komarov Botanical Institute of the Russian Academy of Sciences [9]. As a separate species in 1944, it was studied and made a detailed description by Soviet and Georgian systematic botanist, Doctor of Biological Sciences Ida Panovna Mandenova (Meskhetia). It was she who gave the name of the plant in honor of the flora of the Caucasus researcher Dmitry Ivanovich Sosnovsky – Heracleum sosnowskyi [10].

2. Materials and methods
Heracleum sosnowskyi used various methods to study biological features of plants to influence the land vegetative part. Mowing of shoots at soil level was used as a control option. In the pilot version, the plants were isolated from sunlight by mulching with freshly cut grass with 15–20 cm layer capacity. The apical part of one leaf 4–7 cm long was placed above the surface of the mulch. Accounting was carried out – the number of shoots, the number of leaves, time from plant treatment to the beginning of photosynthetic apparatus restoration, the number of new leaves.
3. Discussion and results

The speed of species distribution depends on many reasons. In particular, the height of plants plays a role in this process. The lower it is, the higher the density of seed dispersal is obtained per unit area. In contrast, taller plants form a larger spreading area with a lower seed density per unit area [1]. This results in plants with an advantage in height having greater potential to expand their range. It should be noted that Sosnovsky borschevik is a tall plant. Its generative shoots reach heights of 5 meters and more.

Studies have shown that Heracleum sosnowskyi seeds have the ability to inhibit the germination of seeds of other species that are in the area of biochemical influence. This is due to the fact that its fruit shells contain several chemically active substances (in particular, angelicin, bergapten, methoxalene and emperorine), which are able to inhibit growth processes. Thus, for example, in the range of concentrations of 1.0–1.7 mg/ml extracts from fruit casings and seeds inhibited root and hypocotyl growth in salad sprouts (up to 50%). Its strong influence on germination of seeds of many plants (Festuca pratensis Huds., Lolium multiflorum Lam, Phleum pratensis, Trifolium repens L.) was also noted. L., Trifolium pretense L., etc.) [2].

The only seed in the new habitat "gets rid" of almost all competitors that multiply with seeds and are in close proximity to its location. By "clearing" the area, the seedling gains an advantage in the first stages of growth [2, 7]. Thus, active resistance to neighboring plants in phytocoenosis (in the form of suppression of seed germination) in Heracleum sosnowskyi begins even before the start of vegetation of the latter, because germination of its seeds begins before snow melts [2].

In addition, Heracleum sosnowskyi specimens quickly form a large leaf surface. This causes the shading of nearby plants, greatly depressing them. As another undoubted advantage - high resistance to adverse vegetation conditions, diseases and pests. As a result, Heracleum sosnowskyi is easily embedded even in very resistant untouched phytocoenoses: on forest edges, in meadow communities. The plant also easily assimilates urban and rural landscapes with disturbed plant cover. As a result, due to its strong dominance, the community where Heracleum sosnowskyi is introduced is very poor in terms of species composition (fluctuations ranging from 10 to 43 species), averaging 26 species [7].

Since Heracleum sosnowskyi plants are monocarpical, their vegetation can last for many years (over 10). This is followed by the formation of flowering shoots, fruit-bearing and dying out. This phenomenon is also closely related to ecological conditions: on poor, dry soils, plants have to accumulate nutrients for a long time for subsequent abundant fruit-bearing. It should be noted that no vegetative reproduction has been observed in this species. Apparently, this is the reason for the formation of a huge number of seeds (individual specimens - more than 100 000). And even if we take into account that on average one fruit-bearing plant forms about 20,000 seeds, we can imagine how great its breeding potential is [3].

High ecological plasticity of Heracleum sosnowskyi plants allowed not only to rapidly expand its range, but also to have a significant impact on landscape change by reducing the natural diversity of ecosystems [4].

At the same time, the Belarusian scientists have found that the allelopathic effect can be expressed not only in inhibiting the processes of germination of seeds of competitors' plants. For example, the swelling of Heracleum sosnowskyi seeds has a stimulating effect on the growth of seedlings of some Brassicaceae plants, in particular, rape, mustard, radish and turnip [11]. This fact illustrates the complexity of the relationship between species in phytocoenosis.

All parts of Heracleum sosnowskyi plants contain substances that may have phytotoxic effects: root, shoot, stem, leaf, flower, seed. However, it should be noted that the degree of impact on germinating capacity of seeds of other species depends on a combination of several factors. For example, water extracts from a two-year-old plant have a stronger impact than water extracts from an annual plant. The concentration of the extract itself is also important. The highest concentration of such substances in the plant is noted in the flowering phase. Like the majority of invasive species, Heracleum sosnowskyi gets a great advantage due to the inhibition of seeds of competitive plant species [5].

Most of the Heracleum sosnowskyi range is located mainly in Poland and some former Soviet countries. This is due to the fact that in the Soviet Union republics the plant was widely cultivated as a
new silage crop (6). The plants were characterized by intensive growth in spring and after mowing, as well as high average daily growth. The vegetative mass was mown and then silage was mown. Due to this, the concentration of poisonous substances was sharply reduced, and silage could be used for feeding farm animals. Over time, however, it became clear that the milk of cows fed with borschevik silage had a bitter flavour. For this reason, the culture was removed from the structure of the area under crops, and the species Heracleum sosnowskyi began an independent uncontrolled life. Now it is a poisonous weed plant with a huge range of distribution [6].

Many methods of struggle with borschevik Sosnowskyi have been developed [5, 7, 12, 14]. The effectiveness of mechanical and chemical methods of suppressing an aggressive plant has been well studied. Mechanical methods of control of borschevik Sosnovsky include digging out and destruction of stems and roots, cutting or mowing plants, removal of inflorescences [7]. Mechanical methods are considered ecologically clean, but they are rather dangerous and require a lot of attention and effort [12].

Thermal method of struggle against borschevik Sosnovsky is used - treatment of plants with hot (90-100°C) water. In this case sprout death occurs, and weekly treatment prevents the appearance of new sprout [15].

The most radical way to destroy vegetative plants of Sosnovsky borschevik is to use herbicides. For example, mixtures of roundapa with arsenal and roundapa with ankor-85, as well as complex polyvalent preparations of grunge, chepar and anti-missile defense atron showed high efficiency. As active substances they use derivatives of glyphosate, sulfonyl-urea, imidazolinones in synergistically active ratios. Besides, when using chemically active agents it is possible to prevent its recovery from soil seed stock [13].

One of the most promising directions may be the use of biologically active substances to affect the metabolism of the plant. In particular - on the process of seed ripening. Thus, for example, as a result of a study of the impact of gibberellin (GA3) on the process of fruit formation, it was found that the treatment of flowers at an early stage of development with exogenous form GA3 in different concentrations did not have a significant impact on the size of seeds, but caused a pathology of their development. Mature embryos were formed in the control variants, while the development of embryos in the variants with exogenous GA3 treatment slowed down their development. In the variant with high concentration of GA3 (0.43 mm) the seed germination rate decreased to 16.5%, while in the control variant it was 98.0%. Thus, treatment of Heracleum sosnowskyi plants with gibberellin solution in flowering phase can provide suppression of germinating seed formation and, consequently, prevent its spreading [16].

Our research has investigated the reaction of Heracleum sosnowskyi plants to changes in photosynthesis conditions. The partial shading of the photosynthetic leaf surface was used as an effect on the plant. This was done by mulching plants so that the apical part of one leaf plate remained in the light (figure 1). Mechanical method of weed control - mowing was used as a control option.

In the experimental version, photosynthesis continued only at the apex of one leaf plate of the plant. The rest of the photosynthetic surface remained under a layer of mulch. The reinsertion buds were in an active state, but the first leaf appeared above the surface of the mulch layer only after 7 days. In the control version, the beginning of formation of a new leaf surface was noted already the next day after mowing. Leaf growth occurred simultaneously on all vegetative terrestrial as well as in soil parts of shoots. A week later, the number of new leaves of various sizes reached 12.

Thus, we observe a significant difference in the reaction of Heracleum sosnowskyi M. to external influences. In the experimental version, the impact of light flux on a unit of leaf surface remained the same. The leaf apex caught the solar insolation at an intensity that corresponded to the weather conditions. There were no changes in this variant regarding the interaction of the plant with the environment. However, the flow of plastic substances and energy for the whole plant dropped dramatically, since the apex of one leaf plate was only a few percent of the total photosynthetic surface.
The reaction of the plant to changes in external conditions was slowed down. Consistent repetition of mulching resulted in rapid depletion of spare nutrients and plant death.

![Figure 1. Apex of Heracleum sosnowskyi leaf above the surface of the mulching layer of freshly cut grass.](image1)

![Figure 2. Appearance of a new leaf of Heracleum sosnowskyi plant above the surface of the mulching layer 7 days after mulching.](image2)

As a result, within a day after the alienation of shoots and leaves the photosynthetic apparatus began to recover and nutrients continued to accumulate in the underground part of the plant. In addition, it should be taken into account that the use of any tool (trimmer, mechanical braid, etc.) does not allow for the complete removal of the entire surface part of the plant.

The remaining parts of shoots, petioles and leaves above the soil surface continue photosynthesis continuously both during and immediately after the process of alienation of land vegetative organs.

The following should also be considered. Modern mowing technology using different trimmer modifications is accompanied by the release of cell juice, which is sprayed over a long distance. It is known that getting juice from Heracleum sosnowskyi plants on human skin is extremely dangerous and can lead to tragic consequences.

Taking into account that the method of suppressing the vital activity of Heracleum sosnowskyi plants and their death by means of limited mulching does not lead to cell destruction, release and sprinkling of poisonous juice on a large area, we filed an application for the invention and received patent No. 2704428 “Method of contactless removal of Heracleum sosnowskyi borshevik plant from the controlled territory”.

4. Conclusion
1. Limited sequential mulching, leaving one leaf above the surface of the apex mulch, leads to rapid depletion of spare nutrients and plant death.

2. The use of the contactless removal method of Heracleum sosnowskyi from the controlled area is safe for human health and can be widely used in control of this weed.

References
[1] Florian C Boucher, Anne-Sophie Quatela, Allan G Ellis and Verboom G Anthony 2020 Diversification rate vs diversification density: Decoupled of plant height for diversification of Alooidae in time and space PLOS ONE Electronic document URL: https://doi.org/10.1371/journal.pone.0233597 (accessed: 21.05.2020)

[2] Mishyna M, Laman N, Prokhorov V and Yoshiharu Fujii 2015 Angelicin as the Principal Allelochemical in Heracleum sosnowskyi Fruit Natural Product Communications Vol. 10 5 Electronic document URL: https://doi.org/10.1177/1934578X1501000517 (accessed: 27.05.2020)
[3] Nielsen C, Ravn H P, Nentwig W and Wade M et al. 2005 The Giant Hogweed Best Practice Manual. Guidelines for the management and control of an invasive weed in Europe. Forest & Landscape Denmark, Hoersholm p 44 Electronic document URL: http://labgis.ibot.cas.cz/wp-content/uploads/pdf/Booy%20et%20al.%20-%202005%20-%20The%20giant%20hogweed%20best%20practice%20manual%20guidelines%20for%20the%20management%20of%20invasive%20weeds%20in%20Europe.pdf (accessed: 21.05.2020)

[4] Baležentiene L, Stankevičiene A and Snieškiene V 2013 Heracleum sosnowskyi (Apiaceae) seed productivity and establishment in different habitats of central Lithuania Ekologija 59 123–133

[5] Baležentiene L 2012 Inhibitory effects of invasive Heracleum sosnowskyi on rapeseed and ryegrass germination Allelopathy Journal 30 197–208

[6] Moravková L, Gudžinskas Z, Pyšek P, Pergl J and Perglová I 2007 Seed ecology of Heracleum mantegazzianum and H. sosnowskyi, two invasive species with different distributions in Europe. In Ecology and Management of Giant Hogweed (Heracleum mantegazzianum) CABI 157–169

[7] Gudžinskas Z and Žalneravičius E 2018 Seedling dynamics and population structure of invasive Heracleum sosnowskyi (Apiaceae) in Lithuania Annales Botanici Fennici 55 309–320

[8] Abdushaeva Ya M, Shtro O V and Vetkina A V 2019 Vegetable Resources Monitoring As The Region's Raw Material Base Effective Management Tool Sciences EpSBS Vol. LXXVII 407–413

[9] Heltman D V 2007 Borschevik Sosnowsky (Heracleum Sosnowsky Manden) in North-West Russia Presentation of the report at the conference “Biological Invasions – Finding Solutions to the Problem”, St. Petersburg, April 6, 2007 Electronic document: URL: https://www.zin.ru/conferences/rtable2007/Pdf/doklad_Geltman.pdf (accessed: 15.04.2020)

[10] Luneva N N 2014 Borschevik Sosnovsky in Russian Federation Plant protection and quarantine 3 12–18

[11] Mishyna M U, Prokhorov VN 2011 Study of allelopathic influence of swelling of seeds of Heracleum sosnowskyi on the growth of seedlings of different types of cultivated plants. News of National Academy of Sciences of Belarus (Special issue Youth in Science-2011) 3 129–132

[12] Jakubowicz O, Zaba C, Nowak G, Jarmuda S, Zaba R and Marcinkowski J T 2012 Heracleum sosnowskyi Manden. Case study Annals of Agricultural and Environmental Medicine 19 (2) 327–328

[13] Spiridonov Yu Ya, Protasova L D 2012 Effectiveness of herbicides in the fight against Borschevik Pinosovskyy Electronic document URL: https://cyberleninka.ru/article/n/effektivnost-gerbitsidov-v-borschevikom-sosnovskogo (accessed: 15.04.2020)

[14] Shklyarevskaya O and Yakimovich E 2019 Strategies of struggle against borschevik Electronic document URL: https://cyberleninka.ru/article/n/strategii-borby-s-borschevikom (accessed: 25.05.2020).

[15] Antipin G S and Maganov I A 2018 Thermal influence as a method of struggle with Sosnovsky Borschevik Electronic document URL: https://cyberleninka.ru/article/n/termicheskoe-vozdeystvie-kak-metod-borby-s-borschevikom-sosnovskogo (accessed: 21.05.2020)

[16] Koryzmienė D, Jurkonienė S, Žalmerius T, Gavelienė V, Jankovska-Bortkevič E, Bareikienė N and Būda V 2019 Heracleum sosnowskyi seed development under the effect of exogenous application of GA3 PeerJ 7:e6906 Electronic document URL: https://doi.org/10.7717/peerj.6906 (accessed: 11.06.2020)