Control of *Heracleum sosnowskyi* in Lithuania

Bekämpfung von Heracleum sosnowskyi *in Litauen*

Darija Jodaugienė*, **Aušra Marcinkevičienė, Aušra Sinkevičienė**

Aleksandras Stulginskis University, Studentu str. 11, LT-53361 Akademija, Kaunas distr., Lithuania

*Corresponding author, darija.jodaugiene@asu.lt

DOI 10.5073/jka.2018.458.039

Abstract

Sosnovsky's hogweed (*Heracleum sosnowskyi*) is a dangerous perennial, invasive alien plant in Lithuania. Control of this plant is complicated due to well-developed biological properties. To achieve efficient control of the species, it is crucial to choose highly efficient herbicides and their combinations.

Field experiments, designed to compare the efficacy of different herbicides and their mixtures used to control *Heracleum sosnowskyi*, were conducted in 2016 and 2017 in Lithuania, Varnupiai (54° 29' 19.54", 23° 30' 45.9"), Marijampolė distr. The efficacy of the herbicides and their mixtures applied for Sosnovsky's hogweed control was different. The use of both lower and higher rates of glyphosate did not have the expected result, as 4-6 weeks after application new plants started to emerge. A mixture of glyphosate with triasulfuron showed better effect. The efficacy of dicamba and its mixtures with fluroxypyr and triasulfuron, fluroxypyr, triasulfuron and their mixture, fluroxypyr + clopyralid + MCPA mixture depended on the experimental years' meteorological conditions. In 2017, the effect of the above mentioned herbicides and their mixtures on Sosnovsky's hogweed stood out 4-6 weeks after application. Both the smaller and higher rates of tribenuron-methyl + metsulfuron-methyl mixture gave effective control of Sosnovsky's hogweed. The effect of fluroxypyr + metsulfuron-methyl mixture was more rapid, and 6 weeks after application only single plants remained in the plots.

Keywords: Control, efficacy, *Heracleum sosnowskyi*, herbicides

Zusammenfassung

Heracleum sosnowskyi, der Sosnowsky-Bärenklau, ist eine mehrjährige aggressiv invasive Pflanzenart, die in Litauen vorkommt. Die Komplikationen der Ausbreitungsbekämpfung von diesen Problempflanzen sind durch ihre gut entwickelten biologischen Eigenschaften verursacht. Bei den Bekämpfungsmaßnahmen ist es empfehlenswert, wirksame Herbizide und Mischungen zu erproben.

Unsere Untersuchungen wurden 2016-2017 in Varnupiai (54° 29' 19.54", 23° 30' 45.9") im Rayon Marijampole durchgeführt haben gezeigt, dass die Wirksamkeit verschiedener Herbizide und Mischungen zur Bekämpfung des Bärenklaus verschieden war. Durch den Einsatz von verschiedenen Glyphosat-Aufwandmengen wurde die erwartete Wirkung nicht erreicht, im Laufe von 4 bis 6 Wochen trieben die Pflanzen wieder aus. Eine Mischung aus Glyphosat und Triasulfuron wirkte besser. Die Wirksamkeit von Dicamba und seiner Mischungen mit Fluroxypyr und Triasulfuron, Fluroxypyr, Triasulfuron und ihre Mischungen, Fluroxypyr+Clopyralid+MCPA-Mischung hing von den meteorologischen Bedingungen des Jahres ab. Die Untersuchungen haben gezeigt, dass sowohl niedrigere als auch höhere Mengen einer Tribenuron-Methyl+Metsulfuron-Methyl-Mischung gegen die Ausbreitung des Bärenklaus nachhaltig wirkten. Die Wirkung von Fluroxypyr+MetsulfuronMethyl auf die Pflanzen war effizienter, und im Laufe von 6 Wochen sind nur einzelne Pflanzen übrig geblieben.

Stichwörter: Bekämpfung, Effizienz, *Heracleum sosnowskyi*, Herbizide, Pflanzendichte

Introduction

Sosnovsky's hogweed (*Heracleum sosnowskyi*) is a dangerous, highly invasive alien plant species of the family *Apiaceae*. At around the 1950's, the species was introduced to Europe from the Caucasus and was recommended to be grown for silage production. Before long it started to spread spontaneously in a wide range of habitats, including roadsides, areas alongside footpaths and riverbanks, scrublands, abandoned land, and rarely mowed grasslands. The species it now invading woods and arable fields (STRAVINSKIENĖ, 2016). As an alien species it is most widely distributed in the countries of Central and Eastern Europe – Poland, Belarus, Lithuania, Latvia, Estonia, Russia, Ukraine, maybe it also occurs in Germany (GUDŽINSKAS et al., 2014). It is estimated that in Lithuania the total area covered by this species is more than 10 thousand hectares (RAŠOMAVIČIUS, 2008).

One plant of *Heracleum sosnowskyi* is capable of producing up to 100 thousand seeds, which remain viable for several years (from 5–6 to up to 15 years) (NIELSEN et al., 2007; GUDŽINSKAS at al., 2014). Researchers have documented that under Lithuanian climate conditions, one plant of this species can produce from 15.4 to 16.1 thousand seeds, and the seed viability reaches 78% (BALEŽENTIENĖ and BARTKEVIČIUS, 2013; BALEŽENTIENĖ et al., 2013). The largest number of Sosnovsky's hogweed seeds (95%) is concentrated within the top 5cm of the soil layer (NIELSEN et al., 2005; DENNESS et al., 2013).

Since 2001, *Heracleum sosnowskyi* has been included in the list of harmful species of wild plants and fungi that have to be controlled in Lithuania (GAZETTE, 2001, No. 4-106). Therefore, an effective strategy for the control of this species has to be worked out.

The key objective of *Heracleum sosnowskyi* control is to minimize the abundance and density of the species and to prevent its further multiplication and spread. Various control methods are known and are presently being applied, including burning, hot water treatment, multiple cutting, herbicide application (KRAUS, 2013). The plants are recommended to be cut 3–4 times per season. Sosnovsky's hogweed can be exterminated by cutting roots from at least 10 cm depth early in spring when the first leaves start to emerge; however, this practice can be repeated in the middle of summer (NIELSEN et al., 2005; GUDŽINSKAS et al., 2014). Another practice used to control Sosnovsky's hogweed is deep ploughing up to 25 cm, from which the seeds are not able to emerge. To prevent the invasion and spread of the species in arable fields, it is vital to apply crop rotation (GUDŽINSKAS et al., 2014).

To achieve efficient control of the species, it is crucial to choose highly efficient herbicides and their combinations. Herbicidal control of Sosnovsky's hogweed has to be commenced early in spring until the plants are still short (up to 20–30 cm in height), or the plants have to be cut, and after regrowth when they have reached the above indicated height, they have to be sprayed with herbicides. It has been documented that after the plants have reached a height of about 50, herbicides may be ineffective. The most commonly recommended herbicides for the control of Sosnovsky's hogweed are glyphosate and triclopyr as they provide high efficacy and cost effectiveness. These herbicides are intended for use on individual plants and on the overgrowth of plants. Through leaves, the herbicides travel to roots and inhibit the growth of sprouts (OLUKANS et al., 2005; DOMARADZKI and BADOWSKI, 2010; KRAUS, 2013). It should be noted that, as a non-selective herbicide, glyphosate kills all vegetation, while the active ingredient of triclopyr has not been registered in Lithuania. For this reason, it is necessary to look for other, selective-type herbicides that would target specifically Sosnovsky's hogweed but not the entire vegetation. The current study was aimed to compare the efficacy of herbicides and their mixtures used for the control of *Heracleum sosnowskyi*.

Materials and Methods

Experimental design

Field experiments, designed to compare the efficacy of different herbicides and their mixtures used to control *Heracleum sosnowskyi,* Sosnovsky's hogweed, were conducted in 2016 and 2017 in Lithuania, Varnupiai (54° 29' 19.54", 23° 30' 45.9"), Marijampolė distr.

In 2016, the experiment included the following 15 treatments:
1. glyphosate 1440 g ha^{-1},
2. glyphosate 2160 g ha^{-1},
3. glyphosate 2880 g ha^{-1},
4. glyphosate 3600 g ha^{-1},
5. glyphosate 720 g ha^{-1} + dicamba 480 g ha^{-1},
6. glyphosate 720 g ha^{-1}+ fluroxypyr 60 g ha^{-1} + clopyralid 30 g ha^{-1}+ MCPA 300 g ha^{-1},
7. glyphosate 720 g ha^{-1} + fluroxypyr 180 g ha^{-1},
8. glyphosate 720 g ha^{-1} + triasulfuron 4 g ha^{-1},

9. dicamba 960 g ha^{-1},
10. dicamba 480 g ha^{-1} + fluroxypyr 180 g ha^{-1},
11. dicamba 480 g ha^{-1} + triasulfuron 4 g ha^{-1},
12. fluroxypyr 360 g ha^{-1},
13. triasulfuron 8 g ha^{-1},
14. fluroxypyr 120 g ha^{-1} + clopyralid 60 g ha^{-1} + MCPA 600 g ha^{-1},
15. triasulfuron 4 g ha-1 + fluroxypyr 180 g ha^{-1}.

In 2017, the number of treatments was increased to 18 by adding to the ones tested in 2016 another 3 treatments:

16. tribenuron-methyl 2 g ha^{-1}+ metsulfuron-methyl 4 g ha^{-1},
17. tribenuron-methyl 3 g ha^{-1} + metsulfuron-methyl 6 g ha^{-1},
18. fluroxypyr 360 g ha^{-1} + metsulfuron-methyl 4 g ha^{-1}.

The experimental plot size was 18 m^2; the experimental treatments were replicated 4 times. Plant density, height and chlorophyll index, which indicates the intensity of photosynthesis and at the same time plant viability, were estimated and measured before herbicide application and every two weeks after application, 5 times per vegetation season in 2016 and 6 times in 2017. The paper presents the variation of plant densities.

Statistical analysis

The data were estimated according to t criterion, using the statistical programme STAT from the software package STATISTICA 10. At the time of experiment establishment, the experimental plots significantly differed in plant density, therefore we did not compare herbicides and their mixtures but plant densities before herbicide application and 2, 4, 6, 8 and 10 weeks after application.

Results

The number of plants in the plots before herbicide application differed and ranged from 76.7 to 91.7 m^{-2} in 2016 and from 56.7 to 80.0 m^{-2} in 2017 (Tab. 1). Having sprayed the plots with different rates (1440-3600 g ha^{-1}) of glyphosate, the number of plants within 2 weeks after application decreased by 3.7-63.7% in 2016 and by 12.2-48.8% in 2017; however, significant differences were established only having applied glyphosate at a rate of 2160 g ha^{-1} in 2016 and at a rate of 3600 g ha^{-1} in 2017.

Tab. 1 Influence of different glyphosate doses on *Heracleum sosnowskyi* density.

***Tab. 1** Einfluss verschiedener Glyphosat-Aufwandmengen auf die Pflanzendichte von Heracleum sosnowskyi.*

Herbicides	Year	Weed density (number m^{-2})					
		before spraying	after 2 weeks	after 4 weeks	after 6 weeks	after 8 weeks	after 10 weeks
Glyphosate 1440 g ha^{-1}	2016	76.7a	63.3a	146.7a	168.3a	133.3a	-
	2017	68.3ab	60.0ab	78.3ab	85.0ab	90.0a	51.7b
Glyphosate 2160 g ha^{-1}	2016	91.7cd	88.3d	210.0ab	258.3a	183.3bc	-
	2017	80.0a	46.7b	46.7b	83.3a	115.0a	68.3ab
Glyphosate 2880 g ha^{-1}	2016	88.3a	53.3a	121.7a	146.7a	101.7a	-
	2017	56.7ab	46.7ab	36.7b	61.7ab	81.7a	50.0ab
Glyphosate 3600 g ha^{-1}	2016	91.7ab	33.3c	86.7bc	110.0ab	130.0a	-
	2017	65.0a	33.3ab	20.0b	61.7a	53.3ab	51.7ab

In 2016, when the plant density was assessed 4 weeks after application, it was noticed that in the plots, particularly those applied with lower glyphosate rates, new plants started to grow.

A similar trend was established in 2017, only new plants started to emerge slightly later, i.e. 4-6 weeks after application. In 2017, plant density 10 weeks after application was found to be lower than 8 weeks after application. This can be explained by the fact that the plants of Sosnovsky's hogweed started to compete and smother one another.

Glyphosate mixtures with other herbicides had different effects on the Sosnovsky's hogweed plant density (Tab. 2). The best efficacy was exhibited by a glyphosate mixture with triasulfuron. The number of plants consistently decreased. A significant reduction (3.5-4.7 times) in the number of plants was recorded 8 weeks after application compared with the number before application. Other mixtures demonstrated weaker efficacy.

Tab. 2 Influence of different glyphosate mixtures on *Heracleum sosnowskyi* density.

Tab. 2 *Einfluss verschiedener Glyphosat-Mischungen auf die Pflanzendichte von Heracleum sosnowskyi.*

Herbicides and their mixtures	Year	Weed density (number m^{-2}) before spraying	after 2 weeks	after 4 weeks	after 6 weeks	after 8 weeks	after 10 weeks
Glyphosate 720 + dicamba 480 g ha^{-1}	2016	83.3a	73.3a	98.3a	121.7a	161.7a	-
	2017	58.3a	40.0a	61.7a	66.7a	81.7a	70.0a
Glyphosate 720 + fluroxypyr 60 + clopyralid 30 + MCPA 300 g ha^{-1}	2016	95.0ab	86.7b	176.7a	178.3a	193.3a	-
	2017	63.3ab	53.3ab	28.3b	68.3a	86.7a	46.7ab
Glyphosate 720 + fluroxypyr 180 g ha^{-1}	2016	85.0b	61.7b	95.0ab	103.3ab	131.7a	-
	2017	95.0a	56.7ab	31.7b	36.7b	31.7b	36.7b
Glyphosate 720 + triasulfuron 4 g ha^{-1}	2016	70.0a	51.7a	41.7ab	31.7ab	20.0b	-
	2017	70.0a	33.3ab	21.7b	16.7b	15.0b	15.0b

The effect of dicamba differed between the experimental years (Tab. 3). In 2016, the number of plants did not change within 4 weeks after application, and later new plants started to emerge.

Tab. 3 Influence of different dicamba mixtures on *Heracleum sosnowskyi* density.

Tab. 3 *Einfluss verschiedener Dicamba-Mischungen auf die Pflanzendichte von Heracleum sosnowskyi.*

Herbicides and their mixtures	Year	Weed density (number m^{-2}) before spraying	after 2 weeks	after 4 weeks	after 6 weeks	after 8 weeks	after 10 weeks
Dicamba 960 g ha^{-1}	2016	56.7b	56.7b	56.7b	75.0b	116.7a	
	2017	51.7a	48.3a	28.3a	30.0a	48.3a	38.3a
Dicamba 480 + fluroxypyr 180 g ha^{-1}	2016	90.0b	90.0b	95.0b	145.0b	201.7a	
	2017	63.3a	56.7a	21.7ab	15.0b	13.3b	16.7b
Dicamba 480 + triasulfuron 4 g ha^{-1}	2016	65.0a	48.3a	41.7a	36.7a	50.0a	
	2017	56.7a	55.0a	21.7b	25.0b	20.0b	23.3b

For this reason, a higher number of plants was recorded: after 6 weeks 1.3 times, after 8 weeks 2.1 times, compared with the number before application. In 2017, 4 weeks after application were 1.8 times fewer plants. Later, even though new plants emerged, their number was lower than before herbicide application. The efficacy of the dicamba + fluroxypyr and dicamba + triasulfuron mixtures also differed between the experimental years – it was higher in 2017. Within 8 weeks after application, the number of Sosnovsky's hogweed plants decreased significantly by 4.8 times in the plots applied with dicamba 480 + fluroxypyr 180 g ha^{-1} mixture and in the plots applied with dicamba 480 + triasulfuron 4 g ha^{-1} mixture it decreased by 2.8 times.

When the plants had been sprayed with fluroxypyr, its effect became most distinct 4-6 weeks after application (Tab. 4). In 2016, the effect of triasulfuron was insignificant; however, in 2017, 4 weeks after application the number of plants was significantly (2.8 times) lower than before application. This difference remained until the end of experiments. 10 weeks after application, the number of Sosnovsky's hogweed plants was as low as 1.7 m^{-2}, i.e. 27.5 times lower than before the herbicide application.

In 2016, mixtures of fluroxypyr + triasulfuron and fluroxypyr + clopyralid + MCPA did not exert significant effect on Sosnovsky's hogweed, while in 2017 they significantly reduced the number of plants within 4 weeks after application.

Based on the Latvian researchers' experience of controlling the spread of ***Heracleum sosnowskyi***, in 2017 we tested the efficacy of tribenuron-methyl 3 + metsulfuron-methyl 6 g ha^{-1} mixture. In Lithuania, these active ingredients are registered at 1.5 lower rates than in Latvia. Our findings suggest that both rates of these herbicide mixtures gave good control of Sosnovsky's hogweed (Tab. 5). Application of the tribenuron-methyl 2 + metsulfuron-methyl 4 g ha^{-1} mixture significantly reduced the number of plants within the first 2 weeks after application. 10 weeks after application, there were 33.1 times fewer plants than before the application. Similar control was given by the higher rate of these active ingredients (tribenuron-methyl 3 + metsulfuron-methyl 6 g ha^{-1}); however, significant differences stood out only after 6 weeks.

Tab. 4 Influence of different herbicide and their mixtures on *Heracleum sosnowskyi* density.

Tab. 4 *Einfluss verschiedener Herbizide und ihrer Mischungen auf die Pflanzendichte von Heracleum sosnowskyi.*

Herbicides and their mixtures	Year	Weed density (number m^{-2}) before spraying	after 2 weeks	after 4 weeks	after 6 weeks	after 8 weeks	after 10 weeks
Fluroxypyr 360 g ha^{-1}	2016	73.3a	75.0a	60.0a	56.7a	100.0a	-
	2017	73.3a	78.3a	30.0b	13.3c	16.7c	13.3c
Triasulfuron 8 g ha^{-1}	2016	96.7a	75.0a	93.3a	60.0a	81.7a	-
	2017	46.7a	55.0a	16.7b	5.0c	2.9c	1.7c
Triasulfuron 4 + fluroxypyr 180 g ha^{-1}	2016	81.7a	76.7a	66.7a	118.3a	113.3a	-
	2017	88.3a	86.7a	26.7b	11.7b	15.0b	15.0b
Fluroxypyr 120 + clopyralid 60 + MCPA 600 g ha^{-1}	2016	143.3ab	143.3ab	128.3b	160.0a	141.7ab	-
	2017	93.3a	81.7a	56.7b	11.7c	11.7c	10.0c

Tab. 5 Influence of different herbicide mixtures on *Heracleum sosnowskyi* density.

Tab. 5 *Einfluss verschiedener Herbizid-Mischungen auf die Pflanzendichte von Heracleum sosnowskyi.*

Herbicides mixtures	Weed density (number m^{-2}) before spraying	after 2 weeks	after 4 weeks	after 6 weeks	after 8 weeks	after 10 weeks
Tribenuron-methyl 2 + metsulfuron-methyl 4 g ha^{-1}	88.3a	58.3b	51.7b	8.3c	5.0c	2.7c
Tribenuron-methyl 3 + metsulfuron-methyl 6 g ha^{-1}	61.7a	51.7ab	38.3ab	16.7bc	3.2c	1.9c
Fluroxypyr 360 + metsulfuron-methyl 4 g ha^{-1}	48.3a	46.7a	10.0b	0.3c	0.3c	0.2c

Even better results were obtained in the treatments applied with the fluroxypyr + metsulfuron-methyl mixture. A significantly lower number (4.8 times) of plants was recorded 4 weeks after application. 6 weeks after application, the plots contained only single plants, whose density totalled 0.25 m^{-2}.

Discussion

Our experimental findings suggest that the efficacy of the herbicides and their mixtures applied for ***Heracleum sosnowskyi*** control was different. The use of both lower and higher rates of glyphosate did not yield the expected result, as 4-6 weeks after application new plants started to emerge. A mixture of glyphosate with triasulfuron showed better effect. The efficacy of dicamba and its mixtures with fluroxypyr and triasulfuron, fluroxypyr, triasulfuron and their mixture, fluroxypyr + clopyralid + MCPA mixture depended on the experimental years' meteorological conditions. In 2017, the effect of the above mentioned herbicides and their mixtures on Sosnovsky's hogweed stood out 4-6 weeks after application. Polish researchers have reported that the best result was achieved (90–95% control) by using mixtures of triclopyr and other herbicides: triclopyr + fluroxypyr + clopyralid, propoxycarbazone sodium + iodosulfuron methylsodium + amidosulfuron and triclopyr + fluroxypyr + clopyralid + propoxycarbazone sodium + iodosulfuron methylsodium + amidosulfuron (DOMARADZKI and BADOWSKI, 2010). Belarus researchers (YAKIMOVICH and IVASHKEVICH, 2013) have indicated that the highest efficacy in controlling Sosnovsky's hogweed was achieved by using sulfometuron-methyl acid, imazapyr and their mixtures with glyphosate. The USA researchers recommend controlling Sosnovsky's hogweed with a mixture of triclopyr and chlorothalonil or 2,3,6–trichlorobenzoic acid and MCPA in April–June (BHOWMIK and CHANDRAN, 2015). Latvian researchers suggest controlling it by applying glyphosate, triclopyr and imazapyr in March–May (OLUKANS et al., 2005). Many authors point out that integrated approach provides the most effective control of Sosnovsky's hogweed. Our study evidenced that both the smaller and higher rates of the tribenuron-methyl + metsulfuron-methyl mixture gave effective control of Sosnovsky's hogweed. The effect of the fluroxypyr + metsulfuron-methyl mixture was more rapid, and 6 weeks after application only single plants remained in the plots.

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Wir danken herzlich für die wissenschaftliche Begutachtung der Tagungsbeiträge durch:
We like to thank all reviewers for their effort:
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Schwarz, Jürgen, Julius Kühn-Institut, Kleinmachnow, Deutschland
Söchting, Hans-Peter, Julius Kühn-Institut, Braunschweig, Deutschland
Sölter, Ulrike, Julius Kühn-Institut, Braunschweig, Deutschland
Ulber, Lena, Julius Kühn-Institut, Braunschweig, Deutschland
Verschwele, Arnd, Julius Kühn-Institut, Braunschweig, Deutschland
Wellhausen, Christina, Julius Kühn-Institut, Braunschweig, Deutschland
Zwerger, Peter, Julius Kühn-Institut, Braunschweig, Deutschland

Bibliografische Information der Deutschen Nationalbibliothek
Die Deutsche Nationalbibliothek verzeichnet diese Publikation
In der Deutschen Nationalbibliografie: detaillierte bibliografische
Daten sind im Internet über http://dnb.d-nb.de abrufbar.

ISSN 1868-9892
ISBN 978-3-95547-054-8
DOI 10.5073/jka.2018.458.000

Printed in Germany by Arno Brynda GmbH, Berlin.