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ORIGINAL PAPER

Evaluation of the effectiveness of selected herbicides in controlling the young generation of black cherry *Prunus serotina* Ehrh.

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ABSTRACT

The methods of control of invasive alien species, such as the black cherry, includes the spraying of such species with herbicides. In forestry, preparations based on glyphosate salts as active substance are used to control black cherry. Due to concerns about the carcinogenicity of glyphosate, which is a threat to human health and the environment, this active substance faces the prospect of being withdrawn from use. The aim of the study was to assess the possibility of controlling young black cherry specimens by the spraying of selected herbicides representing various action groups according to the HRAC (Herbicide Resistance Action Committee) classification. In the experiment 14 herbicides (variants H1 – H14) were tested. The studies compared the effectiveness of 12 herbicides that did not contain glyphosate salts (H1-H9, H11 and H13-H14) and two that contained glyphosate salts (H10 and H12). Among the herbicides used in the experiment, there were a total of 18 active substances and they belonged to five HRAC classification groups. It was assumed that the herbicides used would be characterized by similar effectiveness to a preparation based on glyphosate salts. The research was carried out in the forest nursery of the Podanin Forestry District, where spraying was carried out on a plot with black cherry in two successive growing seasons. A five-point scale (0-4) was used to assess the effectiveness of the herbicides, where 0 indicated the plant did not respond to the treatment and 4 indicated the plant died. It was found that some of the herbicides used were similarly effective in combating young black cherry to the herbicide containing glyphosate. In the group of herbicides that resulted in 100% mortality in black cherry, there were four that did not contain glyphosate (variants H2, H5, H6, H14). Potential usefulness in the fight against black cherry was shown by active substances that were pyridine carboxylic acid derivatives (fluroxypyr – H5, triclopyr – H5), sulfonylurea derivatives (flazasulfuron H2, mesosulfuron-methyl H6, H14, thifensulfuron-methyl – H14), tribenuron-methyl – H6) and triazolopyridine derivatives (florasulam – H6). Glyphosate-containing herbicides used for the chemical control of black cherry in forestry can be replaced with non-glyphosate alternatives. The prospect of a future ban on the use of glyphosate-containing herbicides in the European Union should lead to the emergence of alternative plant protection products that are safe for humans and the environment, and effectively combat species with high invasive potential. Further studies should assess the impact of the above-mentioned herbicides on forest flora and fauna and soil biota, and in particular the procedure of approving them for use in forestry.

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KEY WORDS

chemical methods of weed control, forest practice, invasive species, plant protection, silviculture

Introduction

In pine and mixed stands with a predominance of Scots pine *Pinus sylvestris* L., the understory layer is often dominated by black cherry *Prunus serotina* Ehrh. (Starfinger, 1997; Bijak *et al.*, 2014). The encroachment of this species into alder forests and alder-ash riparian forests has also been observed (Dyderski and Jagodziński, 2015). A number of factors related to its invasive potential and specific life strategy are responsible for the success of black cherry in settling new positions (Closset-Kopp *et al.*, 2007; Halarewicz, 2011). An important factor promoting the expansion of black cherry into forest stands was the misconception that it could play the role of a phytomeliorative or valuable wood-producing species. The artificial introduction of black cherry to European forests from the end of the 18th century to the mid-20th century resulted in its rapid and uncontrolled expansion beyond the areas where it was planted (Starfinger, 1997; Starfinger *et al.*, 2003). In Polish forests, in accordance with the rules of forest breeding in force at that time, black cherry was still recommended for introduction into degraded habitats at the end of the 20th century (ZHL, 1988).

In entering European forests, black cherry contributed to their distortion or degradation, resulting in the impoverishment of forest ecosystem biodiversity (Starfinger, 1997; Danielewicz and Wiatrowska, 2012; Halarewicz, 2012). Due to its invasive potential -which enables rapid colonization of new sites at the expense of native plant species-black cherry is considered one of the most dangerous alien species found in Polish forests, although it is not on the list of invasive species (Rozporządzenie, 2022). This state of affairs has resulted in the ad hoc eradication of black cherry in forest ecosystems where remedial action is required (Namura-Ochalska, 2012; Krzysztofiak and Krzysztofiak, 2015; Namura-Ochalska and Borowa, 2015; Otręba *et al.*, 2017; Ligocki *et al.*, 2021; Korzeniewicz *et al.*, 2022). In forest practice, black cherry is combated in the youngest stages of stand development to hinder or prevent the initiation and development of natural and artificial regeneration. The solutions used to effectively eliminate black cherry from European forests very often combine labor-intensive mechanical treatments – with a chemical treatment (Drogoszewski, 1986; Muys and Maddelein, 1992; Starfinger *et al.*, 2003; Namura-Ochalska and Borowa, 2015; Korzeniewicz, 2020; Ligocki *et al.*, 2021; Wrońska-Pilarek *et al.*, 2023). The most effective herbicidal methods are controversial due to their potential toxicity for humans and the environment and the lack of registration allowing them to be used in forestry (Łukaszewicz and Krajewski, 2022). Among the herbicides used to combat black cherry and other competing vegetation in forest crops, the greatest controversy is caused by agents that contain glyphosate salts as an active ingredient. Information on glyphosate toxicity (Martini *et al.*, 2012), especially for humans, led the International Agency for Research on Cancer (IARC) in 2015 to reclassify glyphosate as a ‘probably carcinogenic’ active ingredient. This decision has led to pressure to reduce or completely ban the use of glyphosate. This process also applies to European Union (OJEU, 2017, 2022) countries, where there is temporary consent (until mid-December 2023) for the use of preparations containing this active substance (Kalofiri *et al.*, 2021). The real prospect of withdrawing glyphosate from use in the EU in future may necessitate its replacement with other herbicides for combating black cherry.

The aim of this study was to evaluate the possibility of using herbicides that do not contain glyphosate salts to control black cherry. It was assumed that: (i) 2-year-old and 3-year-old black cherry treated with the herbicides used in the experiment on two independent dates (O1 and O2) would react similarly to the preparations used; (ii) the results of the evaluation of the effectiveness of herbicides used to combat black cherry one month after spraying ($M1_{O1}$, $M1_{O2}$) would not differ from the results obtained in the next growing season, eight months after spraying ($M8_{O1}$, $M8_{O2}$), and would be similar in effectiveness to glyphosate-containing herbicides. Spraying with Roundup Flex 480, which contains glyphosate as an active ingredient, was used as a standard of effectiveness in the experiment.

Material and methods

The experiment was located in a forest nursery in the Podanin Forest District (WGS; N: 52.9876, E: 17.0706). In the spring of 2019, black cherry seeds from fruit-bearing specimens growing in stands adjacent to the nursery were sown into the ground for the purposes of the experiment. The research area was a nursery bed with black cherry saplings. The plot (5 m^2) with cherry saplings was divided into two parts, intended for two independent sprayings carried out in the subsequent years. These were further partitioned into 15 experimental subplots each (Table 1). The herbicide experiment was planned on the basis of the guidelines of the Ministry of Agriculture and Rural Development on conducting research on the effectiveness and phytotoxicity of plant protection products (MRiRW, 2018a) and the EPPO standard PP 1/135 (EPPO, 2012). Herbicide spraying was carried out on two independent dates (O1 and O2). The first spraying (O1) was carried out on 2-year-old cherry saplings on September 14, 2020, and the second spraying (O2) on 3-year-old cherry saplings on September 8, 2021. Each time, all black cherry saplings growing in the experimental plot (an average of 40 saplings per plot) were sprayed. In total, 1,128 black cherry saplings were used in the experiment. The average height of sprayed 2-year-old cherry saplings was 62.32 cm (STD=16.53 cm), while 3-year-old black cherry saplings were slightly taller (h=73.54 cm; SD=19.18 cm). Spraying of the working liquid (distilled water and herbicide) was carried out using a knapsack sprayer. The dose of the working liquid per one sapling is approx. 15 ml. STHIL equipment was used for spraying (manual knapsack sprayer, model SG 71), with medium-droplet spraying applied, and a working pressure of 3 bar. A set of 14 herbicides (H) was established on the basis of three criteria: firstly, the herbicide used in the experiment had to be approved for trade in Poland; secondly, it had to be a product intended to combat dicotyledonous plants or with total action; and thirdly, the applied herbicide was supposed to act systemically (Korzeniewicz *et al.*, 2020). The active substances used in herbicides (H) represented different groups according to the mechanisms of action of the HRAC (Herbicide Resistance Action Committee). In both spraying periods, the air temperature oscillated between 24-26°C and no precipitation was recorded within 5 days after spraying.

In the experiment 14 herbicides (variants H1-H14) were tested. The studies compared the effectiveness of 12 herbicides that did not contain glyphosate salts (H1-H9, H11 and H13-H14) and two that contained glyphosate salts (H10 and H12). Among the herbicides used in the experiment, there were a total of 18 active substances and they belonged to five HRAC groups. The description of the experimental variants together with information on the active substances used and their mechanism of action are included in Table 1. Two visual assessments of each herbicide's effect were made for each spraying date: The first (preliminary) assessment one month after the procedure (M1), and the final assessment (M8) in May, 8 months after the procedure. An original five-point ordinal scale for assessing the effectiveness of herbicides was used (Korzeniewicz, 2023) for M1 and M8. The subsequent numbers (ratings) 0-4 indicated the degree of reaction of black cherry to the herbicide spray applied ($R_{h0\text{-}4}$):

Table 1.

Variants by chemical composition and scheme of the experiment to evaluate the performance of selected herbicides in controlling 2- and 3-year-old black cherry

Herbicide variant	Plot Id.	Name of herbicide	Name/ share of active substance/ HRAC groups	Dosage range per ha^{-1}	Concentration of herbicide [%]
H1	1[O1)] 16[O2)]	AMINOPIELIK D MAXX 430 EC (MRiRW, 2021a)	2,4-D 2-EHE in the form of esters)/ 567 $g \cdot l^{-1}$ (equivalent to 376 $g \cdot l^{-1}$ (35.84%) of 2,4-D in acid form)/ 4 HRAC group; dicamba/ 54 $g \cdot l^{-1}$ (5.15%)/ 4 HRAC group	1.0-1.5 l	0.744
H2	2[O1)] 17[O2)]	CHIKARA 25 WG (MRiRW, 2022a)	Flazasulfuron/250 $g \cdot kg^{-1}$ (25%)/ 2 HRAC group;	100-150 g	0.099
H3	3[O1)] 18[O2)]	CHWASTOX TURBO 340 SL (MRiRW, 2019)	MCPA/ 300 $g \cdot l^{-1}$ (25.9%)/ 4 HRAC group; dicamba/ 40 $g \cdot l^{-1}$ (3.4%)/ 4 HRAC group	0.1-2.5 l	0.990
H4	4[O1)] 19[O2)]	ELUMIS 105 OD (MRiRW, 2022b)	mesotrione/ 75 $g \cdot l^{-1}$ (7.73%)/ 27 HRAC group; nicosulfuron/ 30 $g \cdot l^{-1}$ (3.09%)/ 2 HRAC group	1.0-1.5 l	0.774
H5	5[O1)] 20[O2)]	FERNANDO FORTE 300 EC (MRiRW, 2021b)	fluroxypyr/ 150 $g \cdot l^{-1}$ (14.68%)/ 4 HRAC group; triclopyr/ 150 $g \cdot l^{-1}$ (14.68%)/ 4 HRAC group	1.0-2.0 l	0.990
H6	6[O1)] 21[O2)]	FUNDAMENTUM 700 WG (MRiRW, 2022c)	tribenuron-methyl/ 400 $g \cdot kg^{-1}$ (40%)/ 2 HRAC group; mesosulfuron-methyl/ 135 $g \cdot kg^{-1}$ (13.5%)/ 2 HRAC group; florasulam/ 165 $g \cdot kg^{-1}$ (16.5%)/ 2 HRAC group	30 g	0.015
H7	7[O1)] 22[O2)]	LOGO 310 WG (MRiRW, 2017)	foramsulfuron/ 300 $g \cdot kg^{-1}$ (30.0%)/ 2 HRAC group; iodosulfuron-methyl-sodium/ 10 g kg^{-1} (1.0%)/2 HRAC group	100-150 g	0.075
H8	8[O2)] 23[O2)]	LUMER 50 WG (MRiRW, 2022d)	tribenuron-methyl/ 500 $g \cdot kg^{-1}$ (50%)/ 2 HRAC group	20-30 g	0.015
H9	9[O1)] 24[O2)]	MAISTER POWER 42,5 OD (MRiRW, 2022e)	foramsulfuron/ 31.5 $g \cdot l^{-1}$ (3.21%)/ 2 HRAC group; iodosulfuron-methyl-sodium/ 1 g l^{-1} (0.10%)/ 2 HRAC group; thiencarbazone-methyl/ 10 $g \cdot l^{-1}$ (1.02%)/ 2 HRAC group	1.0-1.5 l	0.744
H10	10[O1)] 25[O2)]	ORKAN 350 SL (MRiRW, 2022f)	MCPA/ 90 $g \cdot l^{-1}$ (7.87%)/ 4 HRAC group; glyphosate/ 260 $g \cdot l^{-1}$ (22.75%)/ 9 HRAC group	5-8 l	2.597

Table 1. continued

Herbicide variant	Plot Id.	Name of herbicide	Name/ share of active substance/ HRAC groups	Dosage range per ha^{-1}	Concentration of herbicide [%]
H11	11$^{O1)}$ 26$^{O2)}$	MUSTANG FORTE 195 SE (MRiRW, 2018b)	foramsulfuron/ 5 $g \cdot l^{-1}$ (0.47%)/ 2 HRAC group; aminopyralid/ 10 $g \cdot l^{-1}$ (0.94%)/ 4 HRAC group; 2,4-D/ 180 $g \cdot l^{-1}$ (17%)/ 4 HRAC group	0.5-1.0 l	0.498
H12	12$^{O1)}$ 27$^{O2)}$	Roundup Flex 480 (MRiRW, 2021c)	glyphosate/ 480 $g \cdot l^{-1}$ (35.75%)/ 9 HRAC group	1-4.5 l	2.200
H13	13$^{O1)}$ 28$^{O2)}$	STOMPAQUA 455 CS (MRiRW, 2018c)	pendimethalin/ 455 $g \cdot l^{-1}$ (39%)/ 3 HRAC group	2.5-3.5 l	1.720
H14	14$^{O1)}$ 29$^{O2)}$	TYTAN 75 SG (MRiRW, 2022g)	thifensulfuron-methyl/ 682 $g \cdot kg^{-1}$ (68.2%) / 2 HRAC group; mesosulfuron-methyl / 68 $g \cdot kg^{-1}$ (6.8%) / 2 HRAC group	70-90 g	0.045
C	15 30	Control	Not sprayed		

spraying dates: O1 – 14.09.2020; O2 – 08.09.2021

R_{h0} – 0 – no damage,
R_{h1} – 1 – slight symptoms, *e.g.*, wavy leaves, slight and slightly stronger discoloration and chlorosis of leaves, noticeable inhibition of leaf development in spring,
R_{h2} – 2 – clear symptoms, *e.g.*, yellow or light brown leaves, degenerated, twisted or macerated, chlorosis occurs, leaf development is clearly inhibited in spring,
R_{h3} – 3 – very strong symptoms, *e.g.*, strong defoliation or presence of a significant amount of brown, also dry leaves, inhibited buds in spring,
R_{h4} – 4 – dry shrub, with or without dried leaves present in a small amount, undeveloped or dry buds.

The weighted average was used to express the effectiveness of the herbicide (R_h), where:

$$R_h = \frac{n_0 R_{h0} + n_1 R_{h1} + n_2 R_{h2} + n_3 R_{h3} + n_4 R_{h4}}{(n_0 + n_1 + n_2 + n_3 + n_4)}$$

For statistical analyses, a non-parametric Kruskal-Wallis median test for multiple comparisons was used to compare the effectiveness of herbicides (R_h) against black cherry. Comparison of herbicide efficacy results (R_h) for two evaluation periods (M1 and M8) was performed for data meeting the assumptions of normal distribution using a Student's *t*-test for dependent samples. For data not meeting the assumptions of normal distribution, a Wilcoxon test at an assumed level of significance (α=0.05) was used. A Mann-Whitney U test was used to verify hypothesis (i), which assumed no differences in the response of 2-year-old and 3-year-old black cherry to herbicides used at two independent dates (O1 and O2).

Results

Comparison of the final results of the assessment of the herbicide effectiveness (R_h) for two independent spraying dates ($M8_{O1}$ and $M8_{O2}$), using the Mann-Whitney U test at an assumed significance level of α=0.05, indicated that 2-year-old and 3-year-old black cherry trees reacted similarly to the set of herbicides (H) used in the experiment (p=0.5614).

Comparison and analysis of R_h after one month ($M1_{O1}$) and after eight months ($M8_{O1}$) following the treatment performed within O1 is shown in Fig. 1, while values for O2 are shown in Fig. 2. It was shown that the average R_h in O1 one month after spraying was nearly 40%, and significantly lower (p=0.0012) compared to the assessment made after eight months ($M8_{O1}$). The reaction of 3-year-old black cherry saplings to the applied herbicides in O2 was slightly stronger, with an average R_h after a month ($M1_{O2}$) of close to 60%, and of over 77% after eight months ($M8_{O2}$) – significantly different to the results of the first assessment (p=0.0157).

Not all herbicides used in the experiment approached the effectiveness of the preparation used as a standard in the experiment (variant H12). The effectiveness analysis performed using the non-parametric Kruskal-Wallis median test for multiple comparisons (α=0.05) showed that the preparations used to control black cherry differed in effectiveness (regardless of the assessment date and the spraying carried out). Comparing the final results of the R_h of herbicides used to control 2-year-old black cherry saplings (O1), in the case of two preparations used (variants H4 and H13), no damage was noted on the saplings assessed in spring, and for variant H7 and

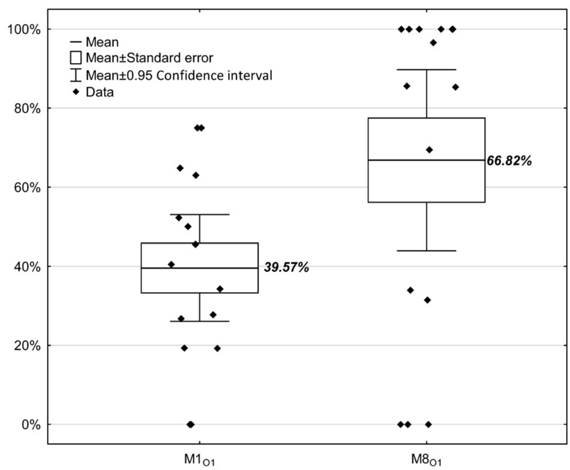

Fig. 1.

Effectiveness (R_h) of herbicides in controlling 2-year-old black cherry saplings at 1 month ($M1_{O1}$) and 8 months ($M8_{O1}$) after spray application

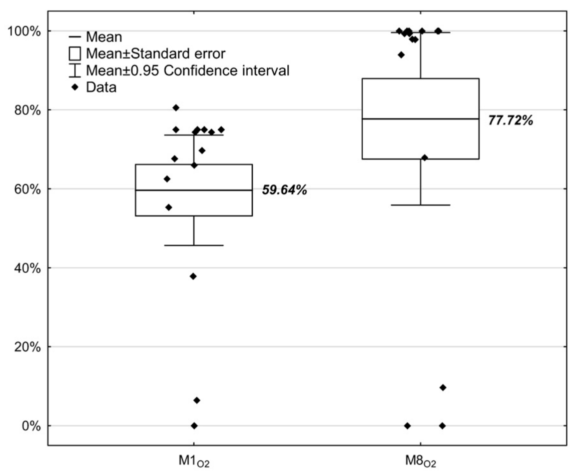

Fig. 2.

Effectiveness (R_h) of herbicides in controlling 3-year-old black cherry saplings at 1 month ($M1_{O2}$) and 8 months ($M8_{O2}$) after spray application variant H9 the results were below the average (R_h=71.6%) for the experiment (Fig. 3). The H4 and H13 variants also exhibited low R_h against the 3-year-old cherry saplings (O2). Compared to the other herbicides, the H8 variant was characterized by repeatable R_h below 70% in the control of both 2-year-old and 3-year-old black cherry saplings. The remaining tested herbicides approached the R_h of preparations containing glyphosate, often reaching a result of 100% (Fig. 4 and Table 1A). The best-acting herbicides (R_h=100%) without glyphosate that were characterized by reproducible results (in the control of 2-year-old and 3-year-old saplings of black cherry) comprised four preparations corresponding to variants given in table 1: H2, H5, H6, and H14 (Fig. 3 and 4).

Discussion

Our utilitarian experiment on the effectiveness of non-glyphosate herbicides against young specimens of black cherry was premised on the higher sensitivity of the younger development stages

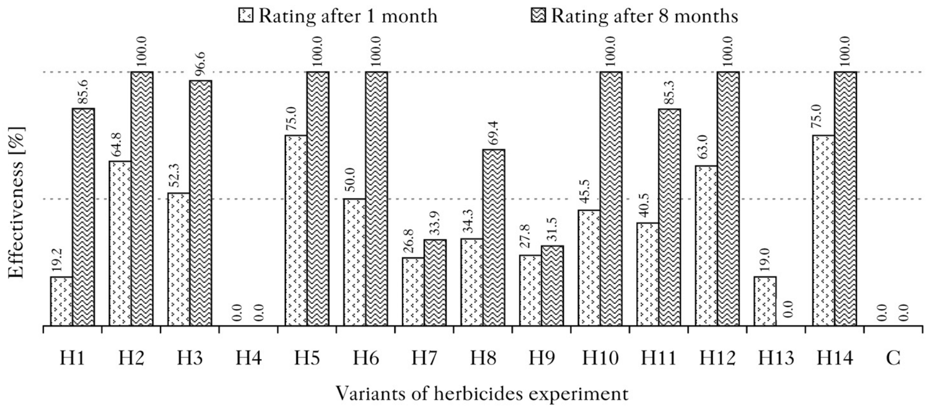

Fig. 3.

Effectiveness (R_h) of the selected herbicides in controlling 2-year-old black cherry saplings

H1 – Aminopielik, H2 – Chikara, H3 – Chwastox Turbo, H4 – Elumis, H5 – Fernando Forte, H6 – Fundamentum, H7 – Logo, H8 – Lumer, H9 – Maister Power, H10 – Orkan, H11 – Mustang Forte, H12 – Roundup Flex, H13 – Stompaqua, H14 – Tytan, C – Control

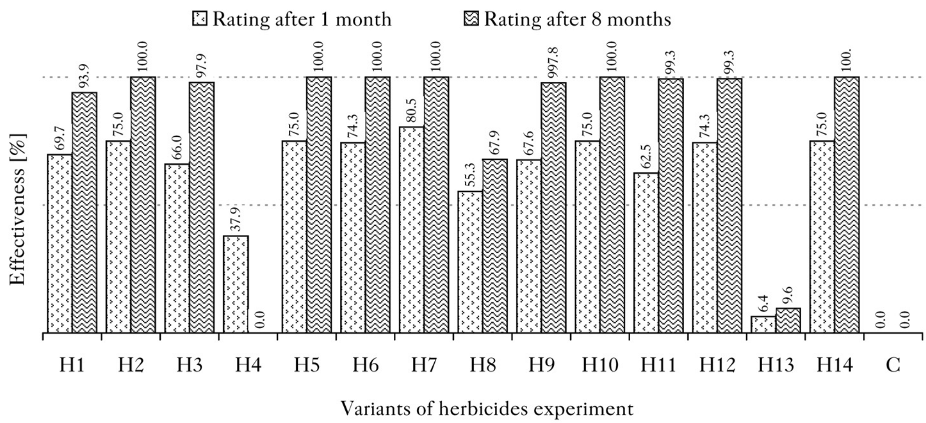

Fig. 4.

Effectiveness (R_h) of the selected herbicides in controlling 3-year-old black cherry saplings

H1 – Aminopielik, H2 – Chikara, H3 – Chwastox Turbo, H4 – Elumis, H5 – Fernando Forte, H6 – Fundamentum, H7 – Logo, H8 – Lumer, H9 – Maister Power, H10 – Orkan, H11 – Mustang Forte, H12 – Roundup Flex, H13 – Stompaqua, H14 – Tytan, C – Control of weeds to herbicides (Kieloch and Domaradzki, 2011). It was assumed that an important factor determining the decision to control black cherry is the ability to carry out the treatment before the plant reaches maturity *i.e.* the ability to reproduce generatively. Starfinger (1997) recognized that the ability to reproduce early and abundantly is an important reason for the invasive success of the species. Therefore, black cherry control should take place before the first flowering and fruiting, which occurs at the age of 4-7 years (Deckers *et al.*, 2005). It is acknowledged that spraying 2-year-old or 3-year-old cherry saplings is a way to limit the expansion of this species.

Spraying with Roundup Flex 480, which contains glyphosate as an active ingredient (classified within the 9th HRAC group), was used as a standard of effectiveness in the experiment. Glyphosate specifically inhibits the 5-enolpyruvyl-shikimate-3-phosphate (EPSP) synthase, thereby depleting the cell of EPSP serving as a precursor for biosynthesis of aromatic amino acids (Wróbel, 2007; Hertel *et al.*, 2021). Apart from Roundup Flex 480, the herbicides used in the experiment are not approved for use in Polish forestry (Łukaszewicz and Krajewski, 2022). Their active ingredients belong to four action groups according to the HRAC classification. HRAC Group 2 (Table 1), inhibitors of the functioning of branched-chain amino acid synthesis (ALS/AHAS), includes active substances that are derivatives of sulfonylurea, triazolopyrimidines, and triazolinones (Woźnica, 2012). HRAC Group 3 includes pendimethalin, the action of which causes cell-division disruption. Group 4 according to the HRAC (formerly O) classification, includes active substances that disrupt the hormonal balance of plants by imitating the action of indole-3-acetic acid (IAA), *i.e.*, natural auxin regulating plant growth and development (Woźnica, 2012). In this study, Group 4 was represented by compounds from the group of phenoxy carboxylic acids, derivatives of benzoic acid and pyridine carboxylic acids (Table 1). It is assumed that they cause changes at various points in the metabolic pathway, which causes disturbances in the hormonal balance of plants (Woźnica, 2012). Dicotyledonous plants react to active substances from the group of growth regulators by disturbing processes related to photosynthesis. These substances' actions also impair the development of chlorophyll, inhibit the growth and development of roots, and increases the rate of aging of plant organs and tissues (Baumann *et al.*, 2008). Herbicides from this group have already been tested for the control of black cherry shrubs and shoots (Drogoszewski, 1986). The active substance 2,4,5-T (Lignopurem forte, Tormona 80) was used by Drogoszewski (1986) in the form of spraying combined with mechanical treatments to inhibit the growth of black cherry shoots. In the experiment, the active substances classified as carotenoid inhibitors (group 27 (formerly F2) according to the HRAC classification) were represented by a compound from the triketone group: mesotrione (Table 1). Woźnica (2012) reported that a specific symptom of the action of an herbicide containing this active ingredient was purple discoloration of shoots and leaves, which was the result of disturbances in the biosynthesis of carotenoids. The reaction of black cherry to the set of active ingredients used in the current experiment did not indicate which group (in terms of HRAC-based mechanisms of action) the most useful agents would come from.

The results of the experiment showed that not only herbicides with glyphosate (variant H10 and H12) were 100% effective against black cherry (Fig. 3 and 4). The spring response of cherry to autumn spraying, in the form of a high proportion of dead saplings (rating R_{h4}), was an asset of the assessed herbicides. Notably, a low share of live black cherry saplings was observed for two highly rated variants (H1 and H11). However, in the case of the other two variants (H7 and H9), the action of which was based on active substances classified to the 2nd HRAC group (herbicides containing foramsulfuron, iodosulfuron methylsodium, and thiencarbazone-methyl), the results were not clear. Their obtained effectiveness against 2-year-old saplings (Fig. 3) forces a careful final assessment of their usefulness in controlling juveniles. No or weak response to spraying with two herbicides was confirmed (variant H4 and H13). In practice, effectiveness in controlling undesirable plants with herbicides depends on many factors, including the quality of water used as the herbicide carrier, and the thermal conditions and air humidity during spraying (Woźnica and Waniorek, 2008). A higher probability of precipitation in August or September may prevent proper treatment or reduce its effect. On the other hand, the effectiveness of herbicide penetration into plant tissues can be improved by using adjuvants (Adamczewski, 1978; Woźnica and Waniorek, 2008; Idziak *et al.*, 2023).

The presented results fit into the broader context of searching for methods of combating invasive species entering natural ecosystems, as the problem is not limited to black cherry (Drogoszewski, 1986; Muys and Maddelein, 1992; Starfinger *et al.*, 2003; Domaradzki and Badowski, 2012; Badowski, 2014; Krzysztofiak and Krzysztofiak, 2015; Namura-Ochalska and Borowa, 2015). While the use of herbicides and their mixtures (also in concentrated doses) against invasive species dangerous to humans and animals, such as Sosnowski's hogweed *Heracleum sosnowskyi* Manden., is accepted (Badowski, 2014), the control of black cherry may be controversial due to the pesticide policy applied in forests.

Combating invasive species also involves the problem of their resistance to the mechanical methods used and the costs of control (Górska, 2021; Ligocki *et al.*, 2021; Otręba *et al.*, 2021; Pietras-Couffignal and Witkowski, 2021), which in turn leads to considerations of the possibility of combining these methods with a chemical treatment. In the case of black cherry, limiting treatment to a combination of mechanical and chemical control is not sufficient, as it usually leads to a temporary improvement of the situation (Otręba *et al.*, 2021). Only integrated methods consisting of replacing an invasive species with a native one bring a lasting effect (Korzeniewicz *et al.*, 2022). In practice, the decision to combat the black cherry, and its implementation, should be based on consistent adherence to the ideological principles: 1) responsibility, 2) forest hygiene, 3) consistent action, 4) determination, 5) patience, and 6) a flexible approach in choosing techniques to combat the black cherry. Compliance with these principles increases the chances of reducing the occurrence of black cherry in the environment (Korzeniewicz *et al.*, 2022). Areas freed from black cherry allow for the next stage in reducing the occurrence of this invasive species, which is the introduction of native species of trees and shrubs (Baranowska *et al.*, 2020; Korzeniewicz *et al.*, 2022).

Conclusions

Under the conditions of the anthropogenic ecosystem of the forest nursery, at least 4 out of 12 tested herbicides not containing glyphosate showed high effectiveness in controlling 2 and 3-year-old saplings of black cherry and merit further testing.

Potential usefulness in the fight against black cherry was shown by active substances that were pyridine carboxylic acid derivatives (fluroxypyr and triclopyr – 4 HRAC group), sulfonylurea derivatives (flazasulfuron, mesosulfuron-methyl, thifensulfuron-methyl and tribenuron-methyl – 2 HRAC group) and triazolopyridine derivatives (florasulam – 4 HRAC group).

The application of the tested preparations in forestry practice requires extending their registration for use in combating the invasive black cherry in forest crops on clear-cuts and under the canopy of the stand. Further studies should assess the impact of the above-mentioned herbicides on forest flora and fauna and soil biota, and in particular the procedure for approving them for use in forestry.

The final assessment of the effectiveness of herbicides after treatment should be carried out at the beginning of the growing season. If 100% effectiveness is not achieved, the treatment can be repeated by additional spot spraying of resistant plants.

In order to increase potential and improve herbicide application techniques, further experiments should be conducted to assess the phytotoxic effect of herbicides not included in the list of plant protection products recommended for use in forestry.

Conflicts of interest

The author declare that potential conflicts of interest are not present.

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Annotation

The research with herbicides was carried out on the basis of the Decision of the Minister of Agriculture and Rural Development No. R-145/2020b and Decision No. 51/2020.

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Appendix

Table 1A.

Frequency [%] of effectiveness (Rh) of herbicides in controlling black cherry saplings

	Date of procedure	Frequency [%] rating (Rh)				
		0	1	2	3	4
		Variant H1				
O1	Rating after 1 month	46.15	30.77	23.08	0.00	0.00
	Rating after 8 months	0.00	3.85	7.69	30.77	57.69
O2	Rating after 1 month	0.00	0.00	27.27	66.67	6.06
	Rating after 8 months	0.00	0.00	6.06	12.12	81.82
		Variant H2				
O1	Rating after 1 month	0.00	7.41	25.93	66.67	0.00
	Rating after 8 months	0.00	0.00	0.00	0.00	100.00
O2	Rating after 1 month	0.00	0.00	0.00	100.00	0.00
	Rating after 8 months	0.00	0.00	0.00	0.00	100.00
		Variant H3				
O1	Rating after 1 month	0.00	31.82	27.27	40.91	0.00
	Rating after 8 months	0.00	0.00	4.55	4.55	90.91
O2	Rating after 1 month	0.00	0.00	36.11	63.89	0.00
	Rating after 8 months	0.00	0.00	0.00	8.33	91.67
		Variant H4				
O1	Rating after 1 month	100.00	0.00	0.00	0.00	0.00
	Rating after 8 months	100.00	0.00	0.00	0.00	0.00
O2	Rating after 1 month	6.06	48.48	33.33	12.12	0.00
	Rating after 8 months	100.00	0.00	0.00	0.00	0.00
		Variant H5				
O1	Rating after 1 month	0.00	0.00	0.00	100.00	0.00
	Rating after 8 months	0.00	0.00	0.00	0.00	100.00
O2	Rating after 1 month	0.00	0.00	0.00	100.00	0.00
	Rating after 8 months	0.00	0.00	0.00	0.00	100.00
		Variant H6				
O1	Rating after 1 month	0.00	0.00	100.00	0.00	0.00
	Rating after 8 months	0.00	0.00	0.00	0.00	100.00

Table 1A. continued

Date of procedure		Frequency [%] rating (Rh) 0	1	2	3	4
O2	Rating after 1 month	0.00	0.00	2.70	97.30	0.00
	Rating after 8 months	0.00	0.00	0.00	0.00	100.00
			Variant H7			
O1	Rating after 1 month	25.00	53.57	10.71	10.71	0.00
	Rating after 8 months	57.14	3.57	0.00	25.00	14.29
O2	Rating after 1 month	0.00	0.00	17.07	43.90	39.02
	Rating after 8 months	0.00	0.00	0.00	0.00	100.00
			Variant H8			
O1	Rating after 1 month	0.00	66.67	29.63	3.70	0.00
	Rating after 8 months	0.00	0.00	55.56	11.11	33.33
O2	Rating after 1 month	0.00	0.00	81.82	15.15	3.03
	Rating after 8 months	2.86	14.29	25.71	22.86	34.29
			Variant H9			
O1	Rating after 1 month	0.00	88.89	11.11	0.00	0.00
	Rating after 8 months	33.33	25.93	29.63	3.70	7.41
O2	Rating after 1 month	0.00	14.71	32.35	20.59	32.35
	Rating after 8 months	0.00	0.00	0.00	8.82	91.18
			Variant H10			
O1	Rating after 1 month	0.00	17.86	82.14	0.00	0.00
	Rating after 8 months	0.00	0.00	0.00	0.00	100.00
O2	Rating after 1 month	0.00	0.00	0.00	100.00	0.00
	Rating after 8 months	0.00	0.00	0.00	0.00	100.00
			Variant H11			
O1	Rating after 1 month	0.00	41.38	55.17	3.45	0.00
	Rating after 8 months	0.00	3.45	3.45	41.38	51.72
O2	Rating after 1 month	0.00	5.56	38.89	55.56	0.00
	Rating after 8 months	0.00	0.00	0.00	2.78	97.22
			Variant H12			
O1	Rating after 1 month	0.00	0.00	48.00	52.00	0.00
	Rating after 8 months	0.00	0.00	0.00	0.00	100.00
O2	Rating after 1 month	0.00	5.26	2.63	81.58	10.53
	Rating after 8 months	0.00	0.00	0.00	2.63	97.37
			Variant H13			
O1	Rating after 1 month	22.73	77.27	0.00	0.00	0.00
	Rating after 8 months	100.00	0.00	0.00	0.00	0.00
O2	Rating after 1 month	74.36	25.64	0.00	0.00	0.00
	Rating after 8 months	66.67	28.21	5.13	0.00	0.00
			Variant H14			
O1	Rating after 1 month	0.00	0.00	0.00	100.00	0.00
	Rating after 8 months	0.00	0.00	0.00	0.00	100.00
O2	Rating after 1 month	0.00	0.00	22.86	54.29	22.86
	Rating after 8 months	0.00	0.00	0.00	0.00	100.00
			Variant C			
O1	Rating after 1 month	100.00	0.00	0.00	0.00	0.00
	Rating after 8 months	100.00	0.00	0.00	0.00	0.00
O2	Rating after 1 month	100.00	0.00	0.00	0.00	0.00
	Rating after 8 months	100.00	0.00	0.00	0.00	0.00

STRESZCZENIE

Ocena skuteczności wybranych herbicydów w zwalczaniu młodego pokolenia czeremchy amerykańskiej *Prunus serotina* Ehrh.

Istotnym czynnikiem promującym ekspansję czeremchy amerykańskiej do drzewostanów było przeświadczenie, że może ona pełnić rolę gatunku fitomelioracyjnego lub produkującego cenne drewno. Trwające od końca XVIII do połowy XX wieku sztuczne wprowadzanie czeremchy do europejskich lasów spowodowało jej szybką i niekontrolowaną ekspansję poza obszary, gdzie była sadzona (Starfinger 1997; Starfinger i in. 2003). W polskich lasach, zgodnie z ówcześnie obowiązującymi zasadami hodowli lasu, jeszcze pod koniec XX wieku czeremcha była zalecana do wprowadzania na ubogie siedliska (Kocjan 1981; ZHL 1988). Obecnie dominuje pogląd, że czeremcha amerykańska, wkraczając do europejskich lasów, przyczyniła się do ich zniekształcenia lub degradacji, czego skutkiem jest zubożenie bioróżnorodności ekosystemów leśnych (Starfinger 1997; Danielewicz i Wiatrowska 2012; Halarewicz 2012). Jej inwazyjny charakter i swoiste strategie życiowe (Closset-Kopp i in. 2007; Halarewicz 2011), które umożliwiają szybką kolonizację nowych stanowisk kosztem rodzimych gatunków roślin, powodują, że jest ona uznawana za jeden z najbardziej niebezpiecznych kenofitów występujących w polskich lasach.

Zwalczanie czeremchy amerykańskiej prowadzi się różnymi technikami, m.in. za pomocą oprysku herbicydami małych krzewów lub odrośli (Drogoszewski 1986; Muys i Maddelein 1992; Starfinger i in. 2003; Namura-Ochalska i Borowa 2015; Ligocki i in. 2021; Korzeniewicz i in. 2022). W leśnictwie do zwalczania czeremchy amerykańskiej używa się preparatów, które bazują na glifosacie jako substancji aktywnej. Podejrzenia, że glifosat jest rakotwórczy i może być potencjalnym zagrożeniem dla zdrowia ludzkiego i środowiska, generują ryzyko wycofania tej substancji aktywnej. Znalezienie alternatywnych preparatów przeznaczonych do zwalczania czeremchy amerykańskiej może stać się warunkiem koniecznym dla realizacji programów ograniczenia jej występowania.

W pracy przedstawiono ocenę możliwości zwalczania młodych osobników czeremchy amerykańskiej (2- i 3-letnich) za pomocą oprysku wybranymi herbicydami reprezentującymi 5 grup działania według klasyfikacji HRAC (tab. 1). Założono, że zastosowane herbicydy będą charakteryzowały się zbliżoną skutecznością do powszechnie stosowanego w zwalczaniu czeremchy amerykańskiej preparatu, który bazuje na substancji czynnej w postaci soli glifosatu. Badania przeprowadzono na terenie szkółki leśnej Nadleśnictwa Podanin, gdzie na kwaterze z czeremchą amerykańską prowadzono opryski w 2 kolejnych sezonach wegetacyjnych.

Badania wskazują, że 2- i 3-letnie czeremchy podobnie zareagowały na zastosowany w doświadczeniu zestaw herbicydów (ryc. 1 i 2). Ustalono, że niektóre z zastosowanych herbicydów charakteryzują się podobną skutecznością w zwalczaniu młodej czeremchy jak herbicyd zawierający w składzie glifosat (ryc. 3 i 4; tab. 1A). W grupie herbicydów, których zastosowanie prowadziło do 100% śmiertelności czeremchy amerykańskiej, były 4 niezawierające glifosatu. Potencjalną przydatność w zwalczaniu czeremchy wykazały substancje aktywne będące pochodnymi kwasów pirydynokarboksylowych (fluroksypyr i triklopyr – 4 grupa klasyfikacji HRAC), pochodne sulfonylomocznika (flazasulfuron, metsulfuron metylu, tifensulfuron metylowy i tribenuron metylowy – 2 grupa klasyfikacji HRAC) oraz pochodne triazolopirydyny (florasulam – 4 grupa klasyfikacji HRAC). Istnieje możliwość zastąpienia herbicydów stosowanych w leśnictwie do chemicznego zwalczania czeremchy amerykańskiej, zawierających w składzie sole glifosatu. Ryzyko zakazu stoso-

wania na terenie Unii Europejskiej herbicydów z substancją czynną w postaci glifosatu powinno doprowadzić do wyłonienia alternatywnych środków ochrony roślin bezpiecznych dla ludzi i środowiska, a także skutecznie zwalczających gatunki o wysokim potencjale inwazyjności.

W przypadku czeremchy amerykańskiej ograniczenie się do zabiegu zwalczania mechanicznego lub chemicznego (także łączącego te techniki) jest niewystarczające, ponieważ zazwyczaj prowadzi do tymczasowej poprawy sytuacji. Jedynie integrowane metody, których końcowym efektem jest zastąpienie gatunku inwazyjnego rodzimymi, przynoszą trwały efekt. W praktyce decyzja o zwalczaniu czeremchy amerykańskiej i jej realizacja powinny być oparte na konsekwentnym stosowaniu się do ideowych zasad: 1) odpowiedzialności, 2) higieny lasu, 3) konsekwentnego działania, 4) determinacji, 5) cierpliwości i 6) elastycznego podejścia w wyborze technik zwalczania czeremchy amerykańskiej. Ich przestrzeganie zwiększa szanse na ograniczenie występowania w środowisku czeremchy amerykańskiej (Korzeniewicz i in. 2022).