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EFFICACY OF *Stagonospora cirsii* S-47 AGAINST PERENNIAL SOWTHISTLE IN POTATO CROPS

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Abstract

Potato (*Solanum tuberosum* L.) is a crop that needs biological control of perennial weeds (for example, perennial sowthistle *Sonchus arvensis* L.) due to the insufficient assortment of post-emergent chemical herbicides. The fungus *Stagonospora cirsii* J.J. Davis from the VIZR culture collection (All-Russian Institute of Plant Protection), being a producer of herbicidal metabolites, is able to infect *Sonchus arvensis* plants. In the present work, the possibility of using strain *Stagonospora cirsii* S-47 to control perennial sowthistle in small-scale field experiments was shown for the first time. The aim of the study was to evaluate the effectiveness of the use of *Stagonospora cirsii* S-47 in the form of chopped mycelium against perennial sowthistle on potato plantings in small-scale field trials. The trials were conducted during the growing seasons of 2020 and 2021 at the experimental field of the All-Russian Institute of Plant Protection (VIZR, Leningrad Province). Experiments were conducted on plantings of potatoes (*Solanum tuberosum* L.) of Nevsky variety belonging to the medium-early group. Soil of the experimental site is sod-podzolic, loamy, with a humus content in the arable layer of 3-4 %, pH 6.3. The soil was ploughed in the autumn, and in the spring, the site was disked, cultivated, and furrows were cut. The planting rate of tubers was 25 per ha. Fertilizers were not applied. To exclude the influence of non-target objects on the results of the experiments, the treatment of the experimental plots with the herbicide Gezagard (2.0 l/ha) (OOO Syngenta, Russia) was carried out before the emergence of potato plants. The starter inoculate of *Stagonospora cirsii* S-47 was obtained by culturing the fungus for 3 days in liquid sucrose-soybean meal nutrient medium. The biomass was grown in a glass fermenter with a working volume of 5 l (Applikon Biotechnology, the Netherlans). The fermentation medium (4.8 l) was inoculated with 200 ml of the starter culture. After 6 days, the raw biomass was separated from the culture liquid by centrifugation (4000 rpm, SL40, Thermo FS, USA) and weighed. A 0.01 % solution of Tween 80 was added to the raw mycelium to a concentration of 50 g/l, and the mycelium was chopped with a blender (MaxoMixx, Bosch, Germany) for 1 min. Potato plantings were treated using a Mesto RESISTENT 3610 manual knapsack sprayer (MESTO Spritzenfabrik Ernst Stockburger GmbH, Germany) in accordance with the experimental scheme. The herbicide Agritox (1.2 l/ha; Nufarm GmbH & Co. KG, Australia) containing 500 g/l MCPA (2-methyl-4-chlorophenoxyacetic acid) in the form of a mixture of dimethylamine, potassium and sodium salts was used as a standard. We used the treatments: 1 — *S. cirsii* S-47 (50 kg/ha; working fluid consumption was 1000 l/ha), 2 — *S. cirsii* S-47 (100 kg/ha; 2000 l/ha), 3 — *S. cirsii* S-47 + Agritox (50 kg/ha + 0.6 l/ha; 1000 l/ha), 4 — Agritox (0.6 l/ha; 300 l/ha), 5 — Agritox (1.2 l/ha; 300 l/ha), 6 — untreated control. During the treatments, the height of potato plants was 10-15 cm, and perennial sowthistle plants were in the stages from rosette to stalking, not exceeding 10 cm in height. The counts were performed on day 14 and day 28 after treatment by quantitative weight method. Biological efficacy (BE) was calculated vs. untreated control. Potato tubers were harvested manually from each plot to quantify the yield. In the absence of extreme weather conditions, the application of 50 kg/ha of *S. cirsii* mycelium significantly (by 53.9-59.2 %) reduced the weight of perennial sowthistle plants. However, the fungus did not completely eliminate the weed and was less effective than the herbicide Agritox at a dose of 0.6 l/ha. A twofold increase in the rate of application of *S. cirsii* led to an increase in its effect on the number of perennial sowthistle by 13 % on average. The use of *S. cirsii* in combination with Agritox (0.6 l/ha) improved treatment efficiency by an average of 15 % compared to the use of the herbicide alone. This made it possible to reduce the amount of the applied chemical by half without reducing the effectiveness of perennial sowthistle suppression. In 2020, the use of microbiological and chemical products contributed to an increase in crop yield by 4.7-10.1 %. The statistically significant ($p < 0.05$) increase in crop yield was with an individual application of 100 kg/ha of *S. cirsii* S-47 mycelium and 1.2 l/ha of herbicide Agritox. In 2021, the crop yield from the treated plots increased by 6.8-8.3 %, however there were no statistically significant differences between the treatments and the untreated control. To ensure maximum effect from the mycoherbicide, it should not be used in dry conditions (with a lack of moisture and high temperatures).

Keywords: mycoherbicide, *Stagonospora cirsii*, potato, *Sonchus arvensis*, MCPA, 2-methyl-4-chlorphenoxyacetic acid

Advances in pest biocontrol techniques to improve plant protection are of particular importance in recent decades. Despite the obvious successes in the protection of greenhouse crops by entomophages and the fairly widespread practical use of insecticidal and fungicidal microbial preparations, it should be recognized that there is some lag in the use of methods of biological weed control [1]. It is necessary to test new developments taking into account the needs of the market and the current range of herbicides. In our opinion, potato (*Solanum tuberosum* L.) is one of the most promising crops for the practical implementation of biological and biorational herbicides. It is widely cultivated and in demand among the population of the Russian Federation, and a significant amount of commercial chemicals for protecting this crop is available [2].

The modern herbicides for protecting potatoes from weeds are divided into groups depending on the harmful objects that they can combat. Narrowly specific anti-cereal herbicides based on clethodim, quizalofop-P-tefuryl, fluazifop-P-butyl and chisalofop-P-ethyl can effectively control annual and perennial cereal weeds in potato plantings [3, 4]. The largest group includes drugs to combat annual dicotyledonous and annual cereal weeds, based on metribuzin, prometrin, prosulfocarb, flurochloridone, clomazone and diquat [5-10]. The drugs based on rimsulfuron have the widest range of action. They can affect annual and perennial cereals and some dicotyledonous weed species [11, 12].

Analysis of modern means for protecting potato plants from weeds allows us to conclude that a vacant area for the introduction of biological products is the control of perennial weeds, such as *Sonchus arvensis* L. and *Cirsium arvense* (L.) Scop. [2].

Typically, glyphosate-based herbicides are used to control such species [13], but these drugs are only allowed in the post-harvest period (late summer or autumn) in fields intended for planting potatoes, or after planting, 2-5 days before the appearance of crop seedlings. That is, this is a preventive measure which does not fully correspond to modern ideas about the ecologically friendly plant protection. Restrictions on the glyphosate also must be accounted [14].

In this regard, it seems relevant to develop biologicals controlling perennial dicotyledonous weeds, in particular field sow thistle, in potato plantings.

To control weeds, their pathogens or various natural phytotoxins can be used [15, 16]. For example, the fungus *Stagonospora cirsii* J.J. Davis and its phytotoxins are promising for suppressing root sucker weeds such as thistles [17, 18]. However, field trials of their effectiveness have not yet been conducted.

In laboratory experiments, it was shown that crushed deep mycelium of *S. cirsii* C-163 infects the leaves of thistle more effectively than conidia [19]. A liquid nutrient medium was selected using soybean flour as a source of nitrogen and the duration of cultivation of this fungus was selected to significantly increase the pathogenicity of the mycelium [20, 21].

It has been established that *S. cirsii* C-163 and S-47 serve as producers of the phytotoxic ten-membered lactones stagonolide A and herbarumin I in technologically significant quantities. They are believed to be responsible for the herbicidal activity of *S. cirsii* [22, 23]. A likely mechanism of action for stagonolide A is inhibition of photosynthesis in sensitive plants [24], while herbarumin I is thought to inhibit cAMP phosphodiesterase [25].

This work demonstrates for the first time the possibility of using the *Stagonospora cirsii* S-47 to control field sow thistle in a small-plot experiment.

The purpose of this study was to evaluate the effectiveness of using *Stagonospora cirsii* S-47 in the form of crushed mycelium against field thistle plants in potato plantings.

Materials and methods. Small-plot tests were performed during the growing seasons of 2020 and 2021 (the experimental field of the All-Russian Research Institute of Plant Protection — ARRIPP, Leningrad Province; 59.74′N, 30.42′E) on potato (*Solanum tuberosum* L.) mid-early variety Nevsky with a marketable yield of 380-500 c/ha. The soil of the site was typical for the North-Western region (soddy-podzolic, loamy, the arable layer is 3-4% humus, pH 6.3). Tillage was plowing in the fall and disking and cultivated in the spring, and furrows were cut. The tuber planting rate was 25 c/ha. No fertilizer was applied.

To exclude the influence of non-target objects, before the potato plants emerged, test plots were treated with the herbicide Gesagard, SC (suspension concentrate, 2.0 l/ha) (Syngenta LLC, Russia) against annual dicotyledonous and cereal weeds.

The strain used was *S. cirsii* S-47 from the collection of the Laboratory of Phytotoxicology and Biotechnology ARRIPP. The strain was stored in tubes on potato-glucose agar slants at 4 °C. For deep culture, a liquid sucrose-soy nutrient medium (SS) was used (sucrose 60 g/l, soy flour 15 g/l, K_2HPO_4 1 g/l, $MgSO_4 \cdot 7H_2O$ 0.5 g/l, KCl 0.5 g/l, pH 6.0). The inoculum was a 3-day culture of the fungus in SS medium (500 ml conical flasks with 100 ml of medium, an orbital shaker at 180 rpm, 24 °C). To grow *S. cirsii* S-47 biomass, a 5-l glass fermenter (Applikon Biotechnology, Holland) with an ez-Control process control system and BioXpert software was used. Fermentation medium (4.8 l) was inoculated with 200 ml of the culture in SS medium. The fermentation parameters were as follows: 24 °C, air supply speed 5 l/min, stirring speed 200 rpm for 2 days and 400 rpm until the fermentation is completed. An antifoam agent (refined sunflower oil, 1% of the medium volume) was added to the medium before inoculation. After 6 days of culture, the raw biomass was separated from the culture liquid by centrifugation at 4000 rpm (a centrifuge SL40, Thermo FS, USA) and weighed. The yield of raw biomass was approximately 200 g/l. After 0.01% Tween 80 solution was added to a concentration of 50 g/l, the mycelium was crushed using a blender (MaxoMixx, Bosch, Germany) for 1 minute. Before the experiment, the crushed biomaterial was stored without loss of viability for 5 days at 5 °C.

The potato plantings were treated using a RESISTENT 3610 manual backpack sprayer (MESTO Spritzenfabrik Ernst Stock-burger GmbH, Germany) in accordance with the experimental design. To completely cover the plants with the preparation and provide sufficient moisture to infect field thistle, an increased rate of liquid was used, the 2000 l/ha (or 100 kg of raw mycelium/ha). When used together with a herbicide, the application rate of the drug was reduced to 1000 l/ha (50 kg of mycelium/ha).

The herbicide Agritox, WSC (water-soluble concentrate, 1.2 l/ha; Nufarm GmbH & Co KG, Australia) containing 500 g/l MCPA (2-methyl-4-chlorophenoxyacetic acid) as a mixture of dimethylamine, potassium and sodium salts. The choice of the standard was due to the fact that this active substance is used in the fight against harmful dicotyledonous plants (including perennial root sucker weeds including field sow thistle) in haylands and pastures, and it has already been used as a standard in experiments with mycoherbicides [26, 27]. An important feature of the herbicide Agritox, WSC is that in potato plantings, complete destruction of sow thistle from this herbicide is, as a rule, not occurred due to the lower application rate with regard to the permitted regulations. This made it possible not to create too harsh conditions for evaluating the biological product, since the use of pathogens against weeds in real field conditions is, as a rule, significantly inferior in effectiveness to the use of the chemical method. This deficiency can be compensated by co-application of biologicals and chemicals. Guided by this approach, we added the experiment scheme with the use of 50 kg/ha of *S. cirsii* in a tank mixture with 0.6 l/ha of the herbicide Agritox, WSC.

The experimental design included following treatments 1) *S. cirsii* S-47 (50 kg/ha, or 1000 l/ha), 2) *S. cirsii* S-47 (100 kg/ha; 2000 l/ha), 3) *S. cirsii* S-47 + Agritox, WSC (50 kg/ha + 0.6 l/ha; 1000 l/ha), 4) Agritox, WSC (0.6 l/ha; 300 l/ha), 5) Agritox, WSC (1.2 l/ha; 300 l/ha), and 6) control (without treatment).

Fourteen days after treatment, the plant pathogen was reisolated into a pure culture to make sure that the symptoms of the lesion were caused by *S. cirsii* and not a natural infection. The treated potato plants were 10-15 cm in height. Field sow thistle plants did not exceeding 10 cm in height and were in the stage from rosette to stemming. Counts were performed by quantitative-weight method 14 and 28 days after treatment, on four 0.25 m^2 sections for each test plot as per the Guidelines for registration testing of herbicides in agriculture [28] and Methodological recommendations for conducting registration tests of herbicides [29].

Biological efficiency (BE) was calculated by the formula

$$BE = (K - O)/K \times 100\%,$$

where K is the number (wet weight) of thistle plants in the control, nos/m^2 (g/m^2); O is the number (wet weight) of thistle plants in the treatment option, nos/m^2 (g/m^2).

The potato harvest was recorded manually from each test plot.

Statistical processing was carried out using Microsoft Excel. Based on the data obtained, the sample mean (M) and standard deviation of the mean (±SEM) were calculated. Yield data was processed by one-way analysis of variance (*F* test) with the calculation of LSD_{05}.

Results. Meteorological conditions in both years of the experiments were generally hotter and drier compared to the long-term average (Table 1). However, in 2020, air temperature during the growing season was only 7% higher than the long-term average, and air humidity was 8% lower. The parameters in 2021 differed more from the long-term average values, temperature was 21% higher, air humidity was 16% lower, and precipitation was 23% lower. All this had a direct impact on the results of the experiments: the effect of *S. cirsii* S-47 on field thistle plants in the first year was significantly stronger than in the second.

1. Meteorological parameters during assessment of the *Stagonospora cirsii* S-47 mycelium effectiveness against sow thistle (*Sonchus arvensis* L.) plants on potato (*Solanum tuberosum* L.) variety Nevsky (Leningrad Province)

Parameter	Month, decade											
	May			June J			July			August		
	I	II	III	I	II	III	I	II	III	I	II	III
Air temperature, °C:												
average long-term	8.5	11.1	12.3	14.3	15.7	16.6	17.3	17.8	17.9	17.2	16.0	14.4
2020	9.1	6.5	11.8	16.1	19.8	20.1	17.1	17.4	16.6	18.2	16.0	16.1
2021	5.7	17.6	11.4	18.0	19.8	24.2	23.4	24.2	19.6	17.3	18.0	13.9
Precipitation, mm:												
average long-term	10.3	12.2	14.7	13.8	17.0	24.5	22.1	21.2	22.7	24.2	20.4	24.8
2020	7.0	27.6	8.8	13.6	8.5	10.0	17.6	5.3	43.9	15.5	0.3	78.7

Continued Table 1

2021	45.0	40.9	38.1	0.0	5.8	19.6	7.9	10.1	25.9	87.4	51.6	27.2
Air humidity, %:												
average long-term	67	73	71	66	68	71	72	74	76	77	79	82
2020	58	68	52	68	62	56	70	67	75	73	67	77
2021	73	60	69	51	55	61	52	54	59	74	71	80

In both years, the predecessor for potato plantings was a fallow plot, which provides significant infestation with field thistle, in the absence of treatment, 24 plants/m^2 in 2020 and 32 plants/m^2 in 2021.

Four days after treatment with the drugs, the effect of *S. cirsii* S-47 began to be apparent. At the initial stage, round spots of yellow and brown color appeared on the leaves of weeds. Over time, the number of spots increased, and they merged, covering the edge of the leaf blade, which led to the death of leaves (Fig. 1, A). As a result of this effect of *S. cirsii* S-47, the decrease in the weight of sow thistle plants vs. control was more pronounced than the decrease in the number of weeds confirmed by the results of surveys carried out later, 14 and 28 days after the treatment.

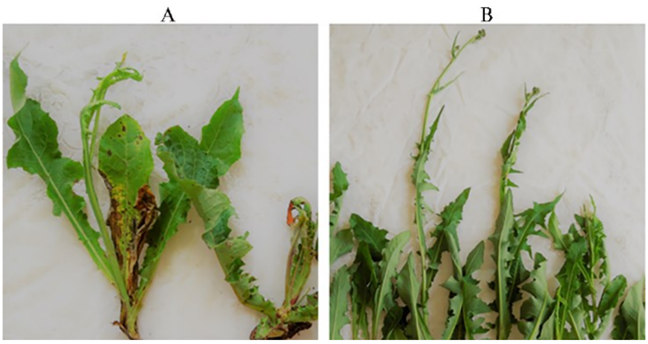

Fig. 1. Field sow thistle (*Sonchus arvensis* L.) plants in potato (*Solanum tuberosum* L.) Nevsky variety plantings 14 days after protective treatment: A — *Stagonospora cirsii* (50 kg/ha) + Agritox, WSC (0.6 l/ha); B — control (without treatment) (Leningrad Province, July 14, 2020; a small-plot test).

Visually distinguishable symptoms of the action of a chemical preparation based on MCPA on field thistle plants were detected later, on the days 7-10 after treatment. They consisted of damage to the growing points and twisting of the upper parts of the stems. Thistle plants damaged by MCPA were noticeably retarded in growth compared to control plants. Among the latter, by the first mass count, specimens were found that had reached the budding and flowering stages (see Fig. 1, B).

Phytoexamination of the selected leaves showed that *Stagonospora cirsii* was reisolated from the affected leaves, but not from the control leaves.

2. Bioeffectiveness (BE) **of crushed *Stagonospora cirsii* S-47 mycelium against field sow thistle (*Sonchus arvensis* L.) plants on potato (*Solanum tuberosum* L.) Nevsky variety** (M±SEM, N = 4; Leningrad Province, 2020-2021; small-plot tests)

Treatmetnt	Days after treatmetnt	Field thistle number				Field thistle plant weight			
		number per m^2		BE, %		g/m^2		E,%	
		2020	2021	2020	2021	2020	2021	2020	2021
1	14	14±3.0	24±1.9	39.1	20.0	173.2±64.0	265.0±104.3	59.2	43.5
	28	15±3.9[a]	25±1.2	37.5	21.9	244.2±58.6	453.2±142.1	53.9	44.0
2	14	12±1.9	19±2.9	47.8	36.7	158.4±34.0	105.4±21.0	62.6	77.5
	28	11±2.2	21±3.5	54.2	34.4	179.9±34.5	243.0±51.6	66.0	70.0
3	14	11±1.2	22±3.0	52.2	26.7	134.1±31.2	247.9±70.5	68.4	47.1
	28	11±3.9	18±4.0	54.2	43.8	128.7±29.1	242.4±88.5	75.7	70.1
4	14	12±2.7	23±2.2	47.8	23.3	199.7±58.7	229.7±64.1	52.9	51.0
	28	11±2.2	22±3.0	54.2	31.3	229.9±20.4	326.0±63.4	56.6	59.8
5	14	11±2.2	15±3.5	52.2	50.0	150.6±16.7	110.3±35.2	64.5	76.5
	28	10±3.0	16±3.8	58.3	50.0	192.4±53.4	203.3±75.8	63.7	74.9
6	14	23±4.8	30±3.0			424.0±20.4	469.0±61.4		
(control)	28	24±7.3	32±1.9			529.8±184.4	810.0±56.1		

N o t e. For a description of the experimental options, see the Materials and methods section. Plants were counted on 0.25 m^2 test plot sections. In all treatments, differences with the control (except for the value marked with the letter [a]) were statistically significant ($p < 0.05$), there were no significant differences between treatments

The results of the surveys we carried out in both years of research demonstrated a decrease ($p < 0.05$) in the number and weight of field thistle plants in all test treatments compared to the untreated control (Table 2). The only exception was the number of sow thistle plants 28 days after treatment with 50 kg/ha of *S. cirsii* S-47 in 2020.

In the growing season of 2020, the use of 50 kg/ha of *S. cirsii* S-47 provided a decrease in the weight of thistle plants by 53.9-59.2% and in the number by 37.5-39.1% (see Table 2). The effect of 50 kg/ha of *S. cirsii* S-47 on the biomass of weeds was comparable to that of 0.6 l/ha herbicide Agritox, WSC but was inferior to the standard in the number of field sow thistle plants. A twofold increase in the rate of application of the mycoherbicide led to an increase in its BE in terms of the number of the weed plants by an average of 13%, and in terms of biomass by 8%, being comparable to the effect of Agritox, WSC at 1.2 l/ha.

The use of 50 kg/ha of *S. cirsii* S-47 mycelium mixed with 0.6 l/ha of Agritox, WSC had a better effect vs. the pure mycoherbicide, on average by 15% (in terms of both number and weight of the weed). In this treatment, the reduction in the number of field sow thistle plants 28 days after treatment was 54.2%. i.e., as upon a separate use of 100 kg/ha *S. cirsii* S-47 and 0.6 l/ha Agritox, WSC, while the reduction in the biomass of the weed was 75.7%, being higher than that for pure Agritox, WSC at a dosage of 0.6 l/ha.

In the extremely hot and dry conditions of the 2021 growing season, the mycoherbicide had a weaker effect on field sow thistle plants (see Table 2). At a rate of 50 kg/ha, the pure mycoherbicide reduced the weed number by 20.0-21.9%, weight by less than 44%, which differed little from the BE of Agritox, WSC used at a rate of 0.6 l/ ha. Increasing the application rate of *S. cirsii* S-47 to 100 kg/ha significantly increased its effectiveness, in terms of the number of weeds up to 36.7-37.5%, in terms of their weight up to 70.0-77.5 %. Agritox, WSC has the same BE at an application rate of 1.2 l/ha.

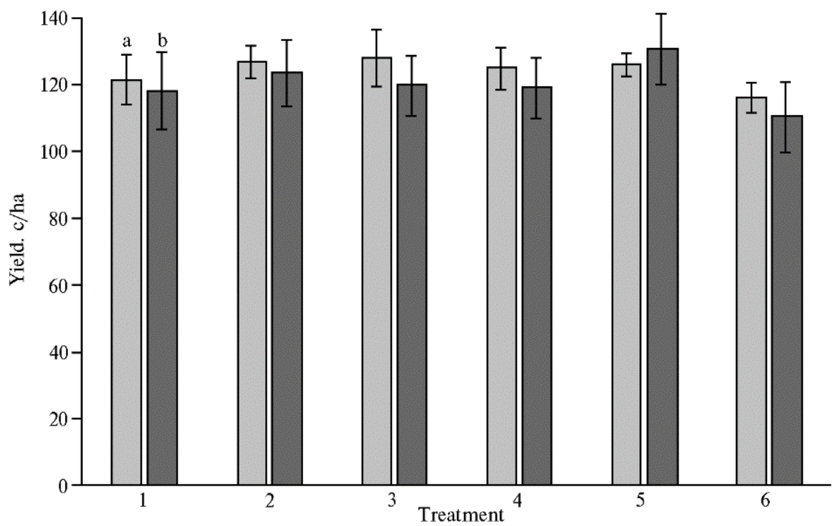

Fig. 2. Tuber yield of potato (*Solanum tuberosum* L.) variety Nevsky after protective treatments against field sow thistle (*Sonchus arvensis* L.) in 2020 (a) **and 2021** (b)**:** 1 — treatment with *Stagonospora cirsii* S-47 (50 kg/ha; consumption rate 1000 l/ha), 2 — *S. cirsii* S-47 (100 kg/ha; 2000 l/ha), 3 — *S. cirsii* S-47 + Agritox,WSC (50 kg/ha + 0.6 l/ha; 1000 l/ha), 4 — Agritox, WSC (0.6 l/ha; 300 l/ha), 5 — Agritox, WSC (1.2 l/ha; 300 l/ha), 6 — control (without treatment). LSD_{05} for 2020 was 16.0 c/ha, for 2021 26.4 c/ha (M±SEM, $N = 4$, plants were counted on 0.25 m^2 test plot sections; Leningrad Province, 2020-2021; small-plot tests).

A tank mixture of 50 kg/ha *S. cirsii* S-47 mycelium with 0.6 l/ha Agritox, WSC acted gradually. During the first survey, 2 weeks after treatment, the reduction in the number and weight of the weeds statistically corresponded to the BE for separate use of *S. cirsii* S-47 mycelium (50 kg/ha) and Agritox, WSC (0.6 l/ha). Four weeks after treatment, the effectiveness of the tank mixture increased to BE from the separate use of 100 kg/ha *S. cirsii* S-47 and 1.2 l/ha of Agritox, WSC.

Despite the suppression of field sow thistle plants and the treatments against other types of annual dicotyledonous and cereal weeds, potato plants were not able to fully realize their yield potential, primarily due to the significant overgrowing of the test plots with annual weeds by the end of the growing season. Nevertheless, in 2020, in a control free from treatments, the potato yield was 116.0 c/ha (Fig. 2). Microbiological and chemical preparations contributed to an increase in crop yield by 4.7-10.1%. Statistically significant ($p < 0.05$) was the increase in yield for 100 kg/ha of *S. cirsii* S-47 mycelium and 1.2 l/ha of Agritox, WSC used separately. In 2021, the potato yield in the control was 110.5 c/ha. Upon treatments increased by 6.8-8.3%, but there were no statistically significant differences between the treatments and the control.

The results we obtained suggest that *S. cirsii* S-47 is of particular interest for the development of a mycoherbicide against field sow thistle in potato plantings. Like other research [30-33], our data indicate the preference for using a biological control agent in combination with chemical treatment. In our experiments, the combined use of microbiological and chemical preparations halved the rate of Agritox, WSC, containing 500 g/l MCPA, without losing its effectiveness. This is especially important for acidic soils common in the north-west of the Russian Federation. It has been established that the degradation of MCPA in acidic soils is difficult [34], which aggravates the adverse effects of this active substance on the environment, and in the future can lead to inhibition of plant development, increased soil toxicity and pollution of surface and ground waters [35, 36].

An important result of our research was also the decrease in the effectiveness of *Stagonospora cirsii* that we identified under dry and hot weather conditions. Previously, similar trends were noted abroad for *Phoma herbarum* Westend, *Sclerotinia minor* Jagger, *Phytophthora palmivora* Butler and *Colletotrichum gloeosporioides* Penzig [37-39].

Thus, under non-extreme weather conditions, the application of 50 kg/ha of *Stagonospora cirsii* S-47 mycelium significantly (by 53.9-59.2%) reduces the biomass of field sow thistle in the Nevsky potato varie plantings. However, the fungus, as a rule, did not ensure complete death of the weed plants, which was inferior to the 0.6 l/ha herbicide Agritox, WSC. A twofold increase in the application rate of *S. cirsii* S-47 leads to approximately 13% increase in its effect on the number of field sow thistle plants. *S. cirsii* S-47 combined with 0.6 l/ha Agritox, WSC provide a higher efficiency in both the number and weight of field sow thistle plants, by an average of 15% compared to the herbicide without *S. cirsii* S-47. This reduces the amount of the applied drug by 2 times without a decrease in suppressing field sow thistle plants. The increase in yield of the Nevsky variety after these protective measures ranged from 4.7 to 10.1%. The effectiveness of *S. cirsii* S-47 highly depends on weather conditions, especially during treatment. To ensure maximum effect of the mycoherbicide, it should not be used in dry conditions (lack of moisture and high temperatures).

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