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THE APPEARENCE OF BRANCHED BROOMRAPE (*Phelipanche ramosa* L. Pomel) ON GALLANT SOLDIER (*Galinsoga parviflora* Cav.) AND SOME VEGETABLE CROPS

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SUMMARY

In the pot experiments conducted in the greenhouse and in the open, in the years 2009–2010, 2013–2014, and 2019–2020 in Skierniewice in Poland was found that *Phelipanche ramosa* L. Pomel (branched broomrape) can parasite on the roots of *Galinsoga parviflora* Cav. (gallant soldier) and was also confirmed its ability to parasite some vegetable crops such as Chinese cabbage (*Brassica rapa* L. subsp. *pekinensis* (Lour.) Hanelt.) and the crops from *Apiaceae* family: carrot (*Daucus carota* L. subsp. *sativus* (Hoff.)), celeriac (*Apium graveolens* L. var. *rapaceum* (Mill)) and parsley (*Petroselinum sativum* (Mill) Fuss.). *G. parviflora* is a segetal weed that commonly infests crops in many countries, including Poland. It was found that Chinese cabbage is a better host for *P. ramosa* than *G. parviflora* but the possibility of parasitising *G. parviflora* by *P. ramosa* is new information and it may be a new way to spread this parasite into new areas.

Keywords: *Phelipanche ramosa*, parasitism, *Galinsoga parviflora*, vegetable crops

INTRODUCTION

Phelipanche ramosa L. Pomel (branched broomrape) is a parasite species belonging to *Orobanchaceae* Vent. family. To this family belong over 200 species of parasitic herbaceous plants and from this group, only seven are considered a threat to economically important crops, namely: *Phelipanche aegyptiaca* (Pers.) Pomel (= *Orobanche aegyptiaca* Pers.), *Phelipanche ramosa* L. Pomel (= *Orobanche ramosa* L.), *Orobanche minor* Sm., *Orobanche cernua* Loefl., *Orobanche crenata* Forssk., *Orobanche cumana* Wallr. and *Orobanche foetida* Poir. [Musselman 1980, Kroschel 2001, Rubiales et al. 2009, Parker 2009, Rubiales and Fernández-Aparicio 2012]. *Orobanche* and *Phelipanche* species (the broomrapes) are root parasitic plants, some of which cause heavy yield losses of important crop species [Cimmino et al. 2014].

P. ramosa has the broadest host range, including plants of the families *Solanaceae* (Juss.), *Cannabaceae* (Martinov), *Brassicaceae* (Burnett), and *Fabaceae* (Lindl) [Musselman 1980, Kroschel 2001, Qasem and Foy 2007]. Two broomrape species *O. crenata* and *P. ramosa* attacks the crops of the *Apiaceae* family such a: carrot (*Daucus carota* L. subsp. *sativus* (Hoff.)) celeriac (*Apium graveolens* L. var. *rapaceum* (Mill)), parsley (*Petroselinum sativum* (Mill) Fuss.), fennel (*Foeniculum vulgare* Mill) and of *Fabaceae* family: broad bean (*Vicia faba* L.), pea (*Pisum sativum* L.),

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lentil (*Lens culinaris* Medik.), chick pea (*Cicer arietinum* L.), alfalfa (*Medicago sativa* L.). In many cases *P. aegyptiaca* and *P. ramosa* attack the crops of *Solanaceae* family like tomato (*Lycopersicon esculentum* Mill.), tobacco (*Nicotiana tabacum* L.), potato (*Solanum tuberosum* L.), eggplant (*Solanum melongena* L.) and cause the yield loss of more than 75% [Mauromicale et al. 2008, Hershenhorn et al. 2009].

Some authors found that *P. ramosa* parasite attacks the roots of tobacco [Buschmann et al. 2005a, Karkanis et al. 2007], potato [Haidar et al. 2003, Haidar and Sidahmed 2006], tomato [Mauromicale et al. 2005, 2008, Diaz et al. 2006, Longo et al. 2010, Stępowska et al. 2012, Disciglio et al. 2015, Borkowski et al. 2018], cannabis (*Cannabis sativa* L.) [Buschnann 2004], black medick (*Medicago lupulina* L.) [Musselman and Bolin 2008], cabbage (*Brassica* L.) [Małuszyńska et al. 1998, Piwowarczyk 2012], oilseed rape (*Brassica napus* subsp. *napus*) [Buschmann et.al. 2005b, Moreau et.al. 2016, Yanev et.al. 2020] and other *Brassica*s [Joel et al. 2007]. *P. ramosa*, except potato and tomato is well developing on the roots of red pepper (*Capsicum annuum* L.), eggplant and parasite the roots of some weed species like black nightshade (*Solanum nigrum* L.), henbane (*Hyoscyamus niger* L.) and Jimson weed (*Datura stramonium* L.) [Vouzounis and Americanos 1998, Haidar and Sidahmed 2006]. In Marocco *P. ramosa* infested carrot [Zehhar et al. 2003], in Eastern France celeriac [Gibot-Leclerc et al. 2014] and oilseed rape (*Brassica napus* L. var. *napus*) [Buschmann 2004, Buschmann et al. 2005a, Gibot-Leclerc et al. 2012].

P. ramosa plants parasitising tomatoes produce many slender, erect stems from small bulbs. The yellowish stems grow 10 to 60 cm tall and are coated in glandular hairs. In Poland, the height of *P. ramosa* plants ranged from 5–40 cm [Szafer et al. 1986]. In the experiments carried out on tomatoes at the Research Institute of Vegetable Crops in Poland, in the nineties of the twentieth century, the height of *P. ramosa* shoots was less than 20 cm but in later experiments the height of shoots frequently was over 20 cm [Borkowski et al. 2018]. *P. ramosa* is parasitic on many other plants, draining nutrients from their roots, and it lacks the leaves and chlorophyll. On every big shoot are several flowers, each with yellowish sepals of calyx and with a tubular white and blue to purple corolla of flowers. The life cycle of broomrape plants consists of two stages; a hypogeal (underground) stage and an epigeal (aboveground) stage [Musselman 1980, Lolas 1994, Wegmann 2004]. Broomrapes (*Orobanche* and *Phelipanche* spp.) spend most of their life cycle underground, where undergo processes of germination, haustorial differentiation from the radicle, haustorial penetration of the host, formation of vascular connection with the host, acquisition of host nutrients, and storage of resources in a parasite organ called the tubercle or nodule [Fernández-Aparicio et al. 2011].

Broomrape seeds germinate only in the presence of germination stimulants (sesquiterpene lactones, strigolactones) released by the host plants [Bouwmeester et al. 2003, Cardoso et al. 2010]. After germination they develop a specific attachment organ, described as haustorium, that forms a functional bridge to their hosts. Via haustorium they are able to take up mineral nutrients and assimilates [Dörr and Kollmann 1974, 1975, Fernández-Aparicio et al. 2011]. Because of their limited root system, *Orobanche* and *Phelipanche* species are also dependent on water supply by their host plant. The first step in host-parasitic plant interaction is the stimulation of parasite seed germination by compounds released from host roots. According to the host, the duration of its life cycle can range from 12 weeks (tomato/tobacco) to 40 weeks (oilseed rape). It was found that in tobacco *P. ramosa* plants emerge above ground after an underground shoot development at approximately 45 to 55 days (in warm climates), flowers 4 to 5 days later, and the tiny seeds (0.3 mm in diameter, approx. 100.000 per plant) ripen after another 20 to 25 days [Lolas 1994, Wegmann 2004]. However, this can vary according to soil types and transplanting dates. This provides the parasite with great genetic adaptability to environmental changes, including host resistance, agronomical practices, and herbicide treatments [Joel et al. 2007]. In the experiment with tomatoes, conducted in Poland, it was proved that *P. ramosa* shoots emerges above ground after 62 days or later [Borkowski and Dyki 2008].

P. ramosa is an important problem in some cultivation areas. *Phelipanche* is a parasite genus that needs a warm climate for growth and development. Progressive variability of climate on the whole world may cause that *P. ramosa* will be an increasing problem in many countries. Now the climate in Poland is getting warmer and *P. ramosa* would be more dangerous for cultivated crops [Dyki et al. 2015, Piwowarczyk 2012]. In Poland *P. ramosa* belongs to the group of rare species, potentially endangered, and during the years 2004–2014 was under strict protection and from 2014 it is under partial protection [Dz.U. 2014, poz. 1409].

The management of *P. ramosa* infestation and control depends on its growth stage and method of control. In solarised soil, no broomrape shoots emerged, and neither haustoria nor underground tubercles of the parasite were found on tomato roots [Mauromicale et al. 2005]. The development of herbicides based on natural metabolites from microbial and plant origin, targeting early stages of parasitic plant development, might contribute to the reduction of broomrape seed bank in agricultural soils.

Galinsoga parviflora (Cav.) (gallant soldier) is an herbaceous plant that descended from South America and is very common in Poland [Ławrynowicz and Warcholińska 1992] and in other European countries. It is an annual dicotyledonous weed species in many countries and is one of the most troublesome weeds in vegetable crops in Poland [Dobrzański 1996]. It grows most often in cultivation fields, but can also be found on roadsides, streets and dumpsters, both in the shade and sunlight places [Parylak 1988]. *G. parviflora* has a short growing season, emerges from the spring to autumn, grows very quickly, blooms 4–6 weeks after emergence, and in one season can give even 2–3 generations. The seeds can germinate immediately after falling onto the soil surface. Except for *G. parviflora* the common species observed on the field is hairy galinsoga (Galinsoga quadriradiata Ruiz & Pav = *Galinsoga ciliata* (Raf.) S. F. Blake).

The studies on the development and control of *P. ramosa* were carried out over 10 years at the National Institute of Horticulture Research (formerly the Research Institute of Vegetable Crops) [Borkowski et al. 2007, 2018, Dyki et al. 2009, Stępowska et al. 2011, 2012]. The experiments mainly concerned the parasitising of *P. ramosa* on tomato plants. In the studies on *P. ramosa* development parasitising tomato plants, light and scanning electron microscopy was used [Stępowska and Dyki 2012].

The studies aimed to determine in Polish conditions the parasitising ability of *P. ramosa* on the roots of *G. parviflora*, Chinese cabbage and vegetable crops from *Apiaceae* family: carrot, celeriac, and parsley. These species are the host plants of *P. ramosa*.

MATERIAL AND METHODS

The first observations on *Phelipanche ramosa* parasitise on *Galinsoga parviflora* roots

The field experiment on the growth regulators assessment in tomatoes was performed in 2008 in Skierniewice in Poland. The experiment was established in the place, where earlier the tests with *P. ramosa* control on tomatoes were carried out. After finishing the experiment, the plants of tomatoes were removed and the plots were left for some weeks without any treatments. Many weeds were left on the plots, among which the *Galinsoga parviflora* was the dominant one. During the hand weeding of these plots, small shoots of *P. ramosa* were visible and disappeared some days after weeding. It aroused the suspicion, that the roots of another host could be in the soil and it could be *Galinsoga parviflora*. The observation made in 2008 was the basis for undertaking the studies in the next years on *P. ramosa* development on the roots of *G. parviflora*.

The observations on the appearance of *Phelipanche ramosa* on Chinese cabbage and *Galinsoga parviflora* roots

The observations on the appearance of *P. ramosa* on Chinese cabbage and *G. parviflora* were made in the years 2009–2010 in Skierniewice in Poland, during the studies on the prevention of tipburn on Chinese cabbage, using calcium nitrate and biostimulants. In the experiments the seeds of Chinese cabbage cv. Bilko F_1, resistant to the clubroot (*Plasmodiophora Brassicae*) and fusariosis (*Fusarium oxysporum*), were sown in the greenhouse to multipods on March 28th in 2009 and April 8th in 2010 and the young seedlings of Chinese cabbage, having 3–4 true leaves, were planted in the open into the small containers (20 × 20 cm) on April 27th in 2009 and on May 7th in 2010. In 2009 the pods were filled up with the substrate, in which earlier the tomatoes parasitised by *P. ramosa* were grown, while in 2010 were filled up with peat substrate mixed with *P. ramosa* seeds. The experiment was set up in 11 replications. The containers were kept in the open until the end of the experiment.

The observations on tipburn on Chinese cabbage were completed at the beginning of July, and the healthy plants of Chinese cabbage were harvested, and small, rotted, and injured plants remained in containers, and were kept 3 months longer to make further observations. In the middle of July less than 30% of Chinese cabbage plants, remaining in containers, were alive and some various weed species, mainly *G. parviflora*, occurred in all containers. The seedlings of *G. parviflora* accounted for over 60% of the weed population. The Chinese cabbage plants have been removed from the half of containers and the weeds, except *G. parviflora*, were removed from all containers. *G. parviflora* occurred in containers with and without Chinese cabbage. The plants of *G. parviflora* were trimmed by 50%, to stimulate their regrowing. During the experiments, the dates of *P. ramosa* sprouting, the height of *P. ramosa* plants, flowering and forming capsules by *P. ramosa* were observed. The observations of *P. ramosa* shoots were carried out till October.

The results were statistically analysed by analysis of variance using Statistica Program v. 13.0 (Statsoft Inc.). The Newman-Keuls test ($p = 0.05$) was used to compare the significance of the means.

The studies on the appearance of *Phelipanche ramosa* on *Galinsoga parviflora*

The experiments aimed to confirm the parasite of *G. parviflora* by *P. ramosa*. The greenhouse experiments were conducted in the years 2013–2014 at the Research Institute of Vegetable Crops in Skierniewice. The experiment was conducted in 5 replications, in 5-liter pots filled up with the substrate made of pseudo-podzolic soil (75%) mixed with peat (25%) and fertilizers. The seeds of *G. parviflora* were sown into all pods, Chinese cabbage to 1/3 amount of pots, and the seeds of *P. ramosa* were sown into the pots with *G. parviflora* alone and pots sown with Chinese cabbage and *G. parviflora* together. The control was the pots with *G. parviflora* alone. The seeds of *P. ramosa* were mixed with substrate before filling the pots. The source of seeds was an earlier experiment on the appearance of *P. ramosa* on tomatoes, carried out in a previous year. To each pot 10 seeds of Chinese cabbage, 12 seeds of *G. parviflora*, and about 200 seeds of *P. ramosa* were sown. The pots were filled up with the substrate and the seeds of *G. parviflora* and Chinese cabbage were sown about 2 cm deep into the soil. The seeds were sown on May 15th, 2013, and on June 24th, 2014. After emergence, Chinese cabbage was thinned to 6 plants per pot and *Galinsoga parviflora* to 8 plants per pot. During the experiment, Chinese cabbage plants were fertilized with the liquid fertilizer Novokont, containing the macro and microelements.

After 2 months of vegetation *G. parviflora* plants were rotten and most of the leaves had dried up, so the upper parts of the plants were cut and the above parts of plants having 10 cm height were left. The plants of *G. parviflora* were cut 93–95 days after sowing the seeds because at that time, appear any shoots of *P. ramosa*. The aim of cutting was to stimulate the regrowing of this weed and keep it a longer time to give the possibility for germination of *P. ramosa* seeds, shoots emergence and growth, and flowering. *G. parviflora* were not removed from the pots throughout the season. The observation of *P. ramosa* germination was performed systematically until the end of October.

Preliminary studies on the appearance of *P. ramosa* on carrot, parsley, and celeriac

In 2019–2020 the pot experiments on the appearance of *P. ramosa* on the roots of three vegetable crop species from the *Apiaceae* family: carrot (*Daucus carota* L.), cv. Nerac F1, celeriac (*Apium graveolens* L. var. *rapaceum* (Mill)), cv. Maxim and parsley (*Petroselinum sativum* (Mill) Fuss.) cv. Eagle was carried out. The pots were filled up with pseudo-podzolic soil (75%) mixed with peat (25%) and for each crop 5 pots with *P. ramosa* seeds and 5 pots without *P. ramosa* seeds were prepared. For every pot 8 transplants of celeriac were planted and in the case of carrot and parsley 12 seeds per 1 pot were sown. The experiments were performed in 5 replications and the seeds were sown on June 8th, 2019 and, May 15th, 2020. One month after sowing/transplanting (July 10th, 2019, and June 14th, 2020) in all pots the young seedlings were thinned to 6 plants per pot.

In both years all pots were fertilized 7 times with foliar fertilizer Novocont and mixed fertilizers Azofoska and Rosasol. The pests were controlled according to official recommendations: aphids (*Aphis gossypii*) by lambda-cyhalothrin, spirotetramat and deltamethrin and powdery mildew (*Erysiphe cichora-*

ceum) by boscalid + pyraclostrobin and fluopyram + tebukonazol mixtures.

The observations on *P. ramosa* shoot sprouting in 2020 were carried out until December 30th. The winters of 2019/2020 and 2020/2021 were not frosty, so in such conditions, it was possible to continue the experiments in a cold greenhouse and the open until June. The observations were made during all vegetation periods. At finishing the experiments on every shoot of *P. ramosa* the bags with seeds were counted.

The morphological analyses of plants and their roots

In the pot experiments carried out in 2013–2014, the macroscopic evaluation of *G. parviflora* and *P. ramosa* plants was done and then the samples of plant material were collected for microscopic analyses. *G. parviflora* and *P. ramosa* plants were removed from pots together with the substrate and the soil was washed out carefully to keep the clean roots alone. The tight connections between the roots of *G. parviflora* and *P. ramosa* were observed in the root mass. The morphological studies on *P. ramosa* and *G. parviflora* roots and their structural connections were carried out using a stereomicroscope (STM) Olympus SZX 16 with a Cell B program to prepare photographic documentation. The photos of the characteristic root connection between *G. parviflora* and *P. ramosa* were done and presented at the end of this paper.

RESULTS AND DISCUSSION

The first observations on *Phelipanche ramosa* parasitising *Galinsoga parviflora*

The first observation suggesting that *P. ramosa* can parasitise *G. parviflora* was obtained in 2008, in a field experiment assessing the growth regulators in tomatoes [Borkowski et al. 2007, Borkowski and Dyki 2008], where at the end of the experiment the various weed species were observed on the plots. The number of *G. parviflora* plants exceeded 50% of the total weeds number in the weed population. After finishing the experiment, tomato plants were removed, and the plots were left for some weeks without any treatments. During the hand weeding of the plots, small shoots of *P. ramosa* were visible, and they were lost some days after weeding. The removal of tomato plants with roots parasitised by *P. ramosa* did not cause the death of parasite plants, what raised the suspicion that the origins roots of another host could be in the soil. *G. parviflora* was considered a possible host species. The source of *P. ramosa* was the soil, in which in previous years the experiments with *P. ramosa* control on tomatoes were carried out.

The observations on the appearance of *Phelipanche ramosa* on Chinese cabbage and *Galinsoga parviflora*

In the experiment conducted in the greenhouse and in the open, the sprouting shoots of *P. ramosa* near Chinese cabbage plants and in the pots with *G. parviflora*, without cabbage, were noted. In 2009 the first shoots of *P. ramosa* were found in 3 containers with Chinese cabbage on August 2nd (97 DAP) and on August 17th (112 DAP) the shoots were visible in 11 containers. The sprouting of *P. ramosa* shoots in those containers was observed until the end of September. Some shoots flowered (Tab. 1) but rarely formed capsules with seeds because the shoots quickly dried up. The maximum height of shoots in all containers was 5 cm on August 2nd and 6 cm on August 17th. Borkowski and Dyki [2008] reported that in earlier stud-

Table 1. The terms of sprouting and development of *P. ramosa* in experiments (Skierniewice, 2009–2010)

Year	Planting of Chinese cabbage	Sprouting of *P. ramosa* (first shoot)		Containers with *P. ramosa*	Height of *P. ramosa* plants (cm)	*P. ramosa* flowering	Forming capsules by *P. ramosa*
		Date	DAP				
2009	27.04	2.08	97	3	5	yes	no
		17.08	112	11	6	yes	no
2010	7.05	17.08	102	1	13	yes	yes
		31.08	116	6	15	yes	yes

DAP – days after planting

Fig. 1. A shoot of *P. ramosa*, close to a flowering and seed-forming *G. parviflora* plant

ies with tomatoes, conducted in a greenhouse, the first shoots of *P. ramosa* appeared 62 days after planting. The faster emergence of *P. ramosa* was caused by better growth conditions in the greenhouse, mainly higher temperatures.

In 2010 the first shoot of *P. ramosa* was visible on August 17th (102 DAP of Chinese cabbage) in containers where the Chinese cabbage was completely rotten and died, and only the plants of *G. parviflora* remained. *P. ramosa* plants were visible close to *G. parviflora* plants. Then the shoot flowered and later formed capsules (Tab. 1). At 116 DAP, the shoots of *P. ramosa* were observed in 6 containers. In macro and microscopic analysis it was found that the roots of *G. parviflora* were connected with the parasite plant (Fig. 2, 3). It confirms that *G. parviflora* is a new host of *P. ramosa*. In the experiment *P. ramosa* shoots were not higher than 13 cm (Tab. 2). In earlier studies with tomatoes [Borkowski et al. 2018] *P. ramosa* plants were even 29 cm high. It suggests that the tomato is a better host for *P. ramosa* than Chinese cabbage and *G. parviflora*. The observations confirmed the earlier assumption that *P. ramosa* may parasitise on the roots of *G. parviflora*. The preference of *P. ramosa* to parasitise the various plants can change in the future, mainly due to climate change. Gibot-Leclerc et al. [2012] report that over 30 years ago *P. ramosa* was not a problem in oilseed rape in France but now poses a threat.

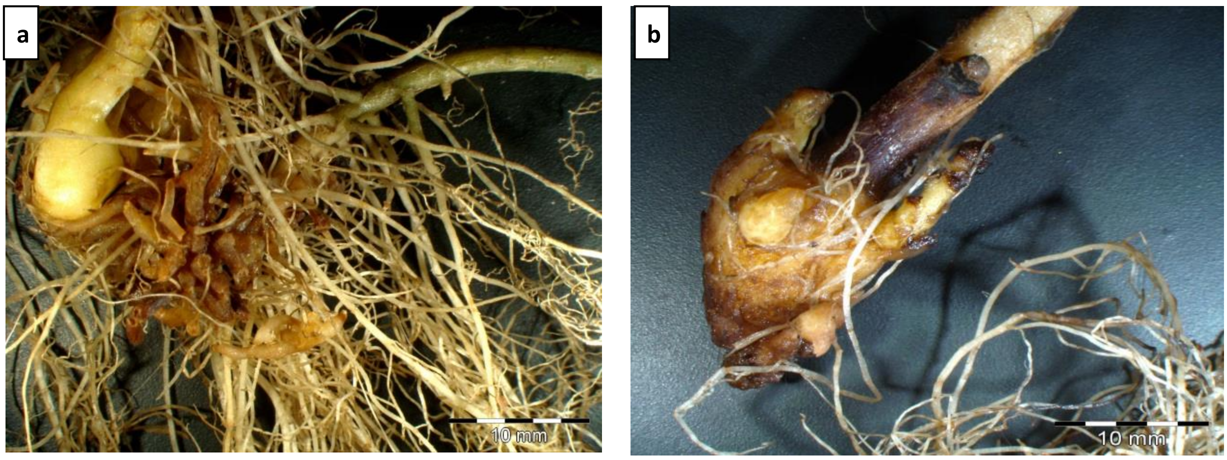

Fig. 2. The dark roots of *P. ramosa* overgrown the *G. parviflora* roots

Anyszka, Z., Golian, J., Borkowski, J., Dyki, B., Machlańska, A. (2025). The appearence of branched broomrape (*Phelipanche ramosa* L. Pomel) on gallant soldier (*Galinsoga parviflora* Cav.) and some vegetable crops. Acta Sci. Pol. Hortorum Cultus, 24(2), 65–77. https://doi.org/10.24326/asphc.2025.5481

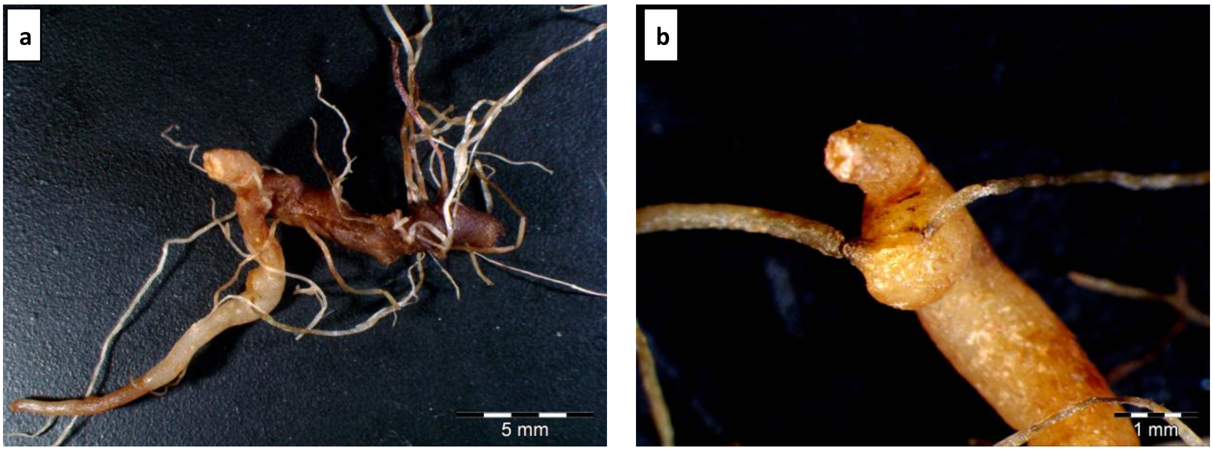

Fig. 3. The roots of *Galinsoga parviflora* connected with parasite *Phelipanche ramosa*

The studies on the appearance of *Phelipanche ramosa* on *Galinsoga parviflora*

In the greenhouse experiments conducted in 2013–2014, the seeds of *P. ramosa* were mixed with the substrate used for filling the pots with *G. parviflora* alone and *G. parviflora* with Chinese cabbage. The check was the pots with *G. parviflora* alone (Tab. 2). During vegetation, *P. ramosa* shoots were visible in the pots containing *G. parviflora* plants and also *G. parviflora* with Chinese cabbage. The first shoot of *P. ramosa* appeared 120–125 days after sowing the seeds.

The average height of *P. ramosa* shoots grown in the pots with *G. parviflora* and Chinese cabbage amounted to 4.2 cm (Tab. 2) and was higher than in the pots with *G. parviflora* alone (2.8 cm height). The highest shoot of *P. ramosa*, at 173–176 DAS was obtained in the pot with Chinese cabbage and *G. parviflora* and was 10 cm at the first observation, and 13 cm at the second observation (180–182 DAS). In the pots with *G. parviflora* alone, the highest shoot was lower in both terms of observations and resulted in 7 and 12 cm, respectively. It shows that in the pots with Chinese cabbage and *G. parviflora*, the growth of *P. ramosa* was faster than in the pots with *G. parviflora* alone, which suggests that Chinese cabbage is a better host for *P. ramosa* than *G. parviflora*.

The results obtained at 154–155 DAS showed that the number of *P. ramosa* shoots in the pots with

Table 2. The height of *Phelipanche ramosa* shoots in pot experiments (Skierniewice, 2013–2014)

Object	The average height of *P. ramosa* shoots per 1 pot (cm)					The average height (cm)	The height of the highest shoot (cm)	
	DAS							
	180–182					–	173–176	180–182
	I	II	III	IV	V	–	–	–
G. parviflora (check)	0	0	0	0	0	0	0	0
G. parviflora + *P. ramosa*	3.9	1.6	2.9	3.3	2.2	2.8 b	7.0 b	12.0 a
G. parviflora + Chinese cabbage + *P. ramosa*	4.5	1.8	6.2	3.0	5.5	4.2 a	10.0 a	13.0 a

DAS – days after sowing
I – V – replications

Table 3. Characteristics of *P. ramosa* plants occurring on *G. parviflora* and Chinese cabbage (Skierniewice, 2013–2014)

Object	The number of *P ramosa* shoots per pot			Shoots with flowers (%)	Shoots with capsules per pot
	DAS				
	154–155	173–176	180–182	180–182	188–190
G. parviflora – check	0	0	0	0	0
G. parviflora + *P. ramosa*	4.3 b	7.7 b	7.9 b	14.7 b	0.6 a
G. parviflora + Chinese cabbage + *P. ramosa*	8.6 a	20.2 a	20.4 a	25.5 a	0.7 a

DAS – days after sowing. The first shoot of *P. ramosa* appeared 120–125 DAS

G. parviflora and Chinese cabbage growing together (8.6 shoots per pot) was two times higher, in comparison to the pots with *G. parviflora* alone (4.3 shoots). On subsequent assessment terms, the differences were even greater. At 173–176 DAS the number of *P. ramosa* shoots increased to 20,2 and 7.7 shoots per pot, and at 180–182 up to 20.4 and 7.9 shoots, respectively.

The tallest shoots of *P. ramosa* were obtained in the pots containing *G. parviflora* with Chinese cabbage (Tab. 2) and 25.5% of shoots from these pots produced flowers, while from the pots with *G. parviflora* alone, only 14.7% (Tab. 3). The shoots with capsules were similar in both objects (0.7 and 0.6 shoots per pot).

It was noticed faster germination and better growth of *P. ramosa* in the pots with *G. parviflora* and Chinese cabbage, in comparison to *G. parviflora* alone (Tab. 3). The greater number of shoots per pot (Tab. 3) and the highest shoot of *P. ramosa* (Tab. 2) were obtained in the pots with *G. parviflora* and Chinese cabbage and the shoots of *P. ramosa* from these pots produced more flowers (Tab. 3).

The results confirm that Chinese cabbage is a better host plant for *P. ramosa* than *G. parviflora*. It should be noted that the number of *P. ramosa* shoots produced and their height depended on the host plant species, while the production of flowers and the formation of capsules depended mainly on the stage of the development cycle.

Preliminary studies on the appearance of *P. ramosa* on carrot, parsley, and celeriac

In the experiments conducted in Poland, it was found that *P. ramosa* can parasitise on carrot, celeriac, and parsley roots. *P. ramosa* is a root-holoparasitic angiosperm plant, which is a pest in agricultural fields, infesting a wide range of crop species [Parker and Riches 1993]. This species is known as a parasite plant almost the whole world [Zehhar et al. 2003, Buschmann 2004, Diaz et al. 2006, Joel et al. 2007, Borkowski and Dyki 2008, Piwowarczyk 2012, Dyki et al. 2015] and it has the serious menace for cultivated crops, especially in countries with warm climate.

In the greenhouse experiment carried out in 2019/2020, the shoots of *P. ramosa* for the first time were observed 128 DAS (October 14th, 2019) in one pot with carrot, 142 DAS (October 28th, 2019) in two pots with celeriac, and 205 DAS (December 30th, 2019) in one pot with parsley (Tab. 4). At the end of the year (205 DAS), the shoots were observed in 2 pots with carrots, 4 pots with celeriac and 1 pot with parsley. After winter time, at 299 DAS (April 3rd, 2020) the shoots of *P. ramosa* were visible in 2 pots with carrot, 4 with celeriac and 5 pots with parsley. The results show a different ability of *P. ramosa* to connect with the roots of vegetable crops from the *Apiaceae* family, and do not always occur the infestation.

The average number of *P. ramosa* shoots per 1 pot on April 3rd, 2020 (299 DAS) was the highest in the pots with celeriac (19.2) lower in parsley (6.8) and the lowest in carrot (5.2), while at the end of 2019, the number was 8.7, 2.2 and 1.2 shoots per 1 pot, respectively. It indicates that *P. ramosa* systematically forms connections with vegetable crop roots (Tab. 4). The results show that the emergence period and the growth dynamics of *P. ramosa* vary, depending on the host plant. The earliest emergence of *P. ramosa* was observed in the pots with carrots and the latest in the pots with parsley. The growth dynamic of *P. ramosa* was the highest in the pots with celeriac.

The height of *P. ramosa* shoots in carrot, parsley, and celeriac at 236 DAS (on January 30th, 2020) ranged between 10 and 13 cm, and at 299 DAS (on April 3rd) between 11 and 16 cm (Tab. 5). On January 30th, 2020 (236 DAS) the highest plants of *P. ramosa* were obtained in pots with celeriac (13 cm), while on April 3rd (299 DAS) with parsley (16 cm). It shows that *P. ramosa* grows well in celeriac and parsley and slightly slower in carrots. *P. ramosa* produced capsules with seeds in all objects. The most capsules were produced in the pots with parsley (116.8) and the least in pots with carrots (34.2 capsules). The capacity of capsule production is important for the spread of this parasite.

In the growing season of 2020/2021, the first shoot of *P. ramosa* was visible at 110 DAS (September 2nd, 2020) in one pot with carrot, 117 DAS (September 9th, 2020) in three pots with parsley, and 165 DAS (October 27th, 2020) in one pot with celeriac. On October 27th the shoots of *P. ramosa* were visible in 4 pots with carrots, 3 pots with parsley, and 1 pot with celeriac,

Table 4. The appearance of *P. ramosa* in vegetable crops from *Apiaceae* family (Skierniewice, 2019/2020)

Crop	Number of pots with *P. ramosa* shoots				Number of *P. ramosa* shoots per 1 pot	
	DAS					
	128	142	205	299	205	299
Carrot	1	1	2	2	2.2 b	5.2 b
Celeriac	0	2	4	4	8.7 a	19.2 a
Parsley	0	0	1	5	1.2 b	6.8 b

DAS – days after sowing. Dates of evaluation: 128 DAS – 14.10.2019; 142 DAS – 28.10.2019; 205 DAS – 30.12.2019; 299 DAS – 3.04.2020

Table 5. The appearance of *P. ramosa* in vegetable crops from *Apiaceae* family (Skierniewice, 2019/2020)

Crop	The average height of *P. ramosa* shoots (cm)				Number of capsules with seeds in 1 pot
	DAS				
	142	205	236	299	360
Carrot	7.2 a	9.1 ab	10 b	11 b	34.2 c
Celeriac	9.4 a	13.2 a	13 a	15 a	88.0 b
Parsley	0	4.8 b	10 b	16 a	116.8 a

DAS – days after sowing. Dates of evaluation: 142 DAS – 28.10.2019; 205 DAS – 30.12.2019; 236 DAS – 30.01.2020; 299 DAS – 3.04.2020; 360 DAS – 5.06.2020

Table 6. The appearance of *P. ramosa* in vegetables crops from *Apiaceae* family (Skierniewice, 2020/2021)

Crop	Number of pots with *P. ramosa* shoots					Number of *P. ramosa* shoots per 1 pot		
	DAS							
	110	117	165	195	346	195	229	357
Carrot	1	2	4	4	5	2.0 a	2.0 b	2.6 b
Celeriac	0	0	1	5	5	2.8 a	4.2 a	15.6 a
Parsley	0	3	3	3	4	2.2 a	2.2 ab	3.7 b

DAS – days after sowing. Dates of evaluation: 110 DAS – 2.09.2020; 117 DAS – 9.09.2020; 165 DAS – 27.10.2020; 195 DAS – 26.11.2020; 229 DAS – 30.12.2020; 346 DAS – 26.04.2021; 357 DAS – 7.05.2021 while at 346 DAS (April 26th, 2021), the shoots were observed in 5 pots with carrots and celeriac and 4 pots with parsley (Tab. 6). The number of shoots per 1 pot on November 26th, 2020 (195 DAS) ranged from 2.0 to 2.8 and on December 30th, 2020 (229 DAS) from 2.0 to 4.2. In the next year, on May 7th (357 DAS) the highest number of shoots was noted in celeriac (15.6), while much lower in carrot and parsley (2.6 and 3.7 shoots).

The smallest shoots of *P. ramosa*, in all terms of observations, were obtained in the pots with carrots, and the highest in the pots with parsley. On December 30th (229 DAS) the average height of *P. ramosa* shoots in carrots was 9 cm, in celeriac 11 cm, and in parsley 14 cm (Tab. 7). In the next year, on April 26th, 2021 (346 DAS) the average height of *P. ramosa* shoots was 8 cm in the pots with carrots, 10 cm in the pots with celeriac, and 11 cm in the pots with parsley. After winter the height of *P. ramosa* shoots was lower than before winter because the highest shoots died at low temperatures and remained only younger, lower plants.

The capsules with seeds were observed on *P. ramosa* shoots in all objects. The seeds of the crops grown in the test, and *P. ramosa* were sown in the year of 2020 and capsules of *P. ramosa* were counted in 2021. The highest number of capsules with seeds was obtained in the pots with celeriac and the lowest in the pots with carrots. In the pots with celeriac 291.6 capsules were obtained, in the pots with parsley 14.2 and in the pots with carrot 12.6 (Tab. 7).

The results of experiments show that *P. ramosa* can parasite carrot, celeriac, and parsley, and the plants of celeriac seem to be a better host for this parasite than carrot and parsley. *P. ramosa* may be harmful to all these crops. The results of the studies confirm previous reports of some authors on the occurrence of *P. ramosa* in these species. However, those reports mainly concern the occurrence of *P. ramosa* in South European countries. Joel et al. [2007] maintain that *P. ramosa* can damage parsley, celery, parsnip, lettuce, melon (*Cucumis melo* L.), watermelon (*Citrullus lanatus* Thunb.) and cucumber (*Cucumis sativus*), similarly to *P. aegyptiaca*. Gibot-Leclerc et al. [2014] have reported that celeriac on clay soil in the Champagne-Ardennes region in Eastern France was infested by *P. ramosa* where this parasite had been observed 4 years before. The negative symptoms like slower growth of celeriac, chlorosis along the leaves, and decreasing the yield were observed on host plants. The infestation of celeriac was confirmed by verifying the attachment of *P. ramosa* to celeriac roots. Gibot-Leclerc et al. [2012] have reported that in France *P. ramosa* can decrease the yield of oilseed rape up to 90%. Nowadays, it is a problem but 30 years ago *P. ramosa* was not parasite oilseed rape at all.

The morphological analyses of plants and their roots

The plants of *G. parviflora* and *P. ramosa* collected from the experiments were analysed morphologically, their roots removed from the pots were washed out carefully, to remain the clean roots alone, and subjected to microscopic analysis. Microscopic analysis showed a tight connection between the roots of *G. parviflora* and *P. ramosa*, observed in the root mass. It confirms that *P. ramosa* may parasitise on the roots of *G. parviflora*. The tight connections are a specific organ called haustorium, which is used to take up mineral nutrients and assimilates them [Dörr and Kollmann 1974, 1975, Fernández-Aparicio et al. 2011]. The photos

Table 7. The appearance of *P. ramosa* in vegetables crops from *Apiaceae* family (Skierniewice, 2020/2021)

Crop	The average height of *P. ramosa* shoots (cm)			Number of capsules with seeds in 1 pot
	DAS			
	195	229	346	383
Carrot	9 b	9 b	8 a	12.6 b
Celeriac	11 ab	11 ab	10 a	291.6 a
Parsley	13 a	14 a	11 a	14.2 b

DAS – days after sowing. Dates of evaluation: 195 DAS – 26.11.2020; 229 DAS – 30.12.2020; 346 DAS – 26.04.2021; 383 DAS – 2.06.2021 of connections between *G. parviflora* and *P. ramosa* were placed in the next of this work. The descriptions of *P. ramosa* plants and flowers with colored photos were also presented by Borkowski et. al [2018], Dyki and Borkowski [2016], and Stępowska et al. [2012]. The conclusion on the appearance of *P. ramosa* on *G. parviflora* roots is entirely new information, not found earlier in literature.

CONCLUSION

Studies have shown that *Phelipancha ramosa* can parasitise the roots of *Galinsoga parviflora*, Chinese cabbage, and some vegetable crops from the *Apiaceae* family: carrot, parsley, and celeriac. The Chinese cabbage and *G. parvifllora* have a short growing season, which in Poland may be unfavourable for the full development of *P. ramosa* and seed production. It should be assumed that in the absence of the host, *P. ramosa* can spread from Chinese cabbage to *G. parviflora* plants, so not plowing the soil after Chinese cabbage harvest may cause the transmission of *P. ramosa* on *G. parviflora* roots, its further growth and production the seeds.

Galinsoga parviflora commonly appears in Poland and many other countries, so the knowledge of the possibility of parasitising the roots of *G. parviflora* by *P. ramosa* is important, because this parasite may contribute to the spread of *P. ramosa* to new areas. *P. ramosa* is a thermophilic plant parasite and requires a higher daily temperature to germinate, so occurs mostly in warm climate countries. Without the host, this parasite does not develop at all. Due to global climate changes, the area where *P. ramosa* occurs is constantly increasing, so in the future can also become a threat to cultivated crops in Poland. It should be emphasized that in case of *P. ramosa* occurrence on the field, *G. parviflora* must be effectively controlled.

The information on *P. ramosa* parasitising the roots of *G. parviflora* is completely new and is not available in the literature.

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