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Rhizome regeneration of *Fallopia japonica* (Japanese knotweed) (Houtt.) Ronse Decr. I. Regeneration rate and size of regenerated plants

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Abstract

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Japanese knotweed, *Fallopia japonica* (Houtt.) Ronse Decr. comes from submeriodional and oceanic areas of Eastern Asia. The material for our research was sampled from a Japanese knotweed stand situated on a SW oriented slope by a main road, under a line of family houses in construction. The part of the stand adjacent to the road was regularly mown by the Technical Services of the Banská Štiavnica town. The stand was 5 x 3 m in size. The experiment was running over two growing seasons: 2002 and 2003. The study material consisted of 30 rhizome segments with three different lengths (2 cm, 5 cm, 8 cm). The plants had been regenerated in the following proportions: 90% exemplars of 8 cm segments, 63% of 5 cm segments and 60% of 2 cm resulted in new plants towards the end of experiment No 1. Experiment No. 2 gave rather different results: by 70% regenerated exemplars in case of 8 cm and 2 cm segments, 67% in case of 5 cm segments. The reasons of these differences are explained in the discussion. The growth dynamics and final size of the regenerated plants were dependent on the segment length.

Key words

Fallopia japonica (Houtt.) Ronse Decr., vegetative regeneration, rhizome segments, invasive species

Introduction

Fallopia japonica (Houtt.) Ronse Decr. comes from submeridional and oceanic areas of Eastern Asia (Jarolímek, and Zaliberová, 1997). The species has its origin in Korea, Northern China, Japan and Taiwan, with the habitats reaching up to 4,000 m asl. In 1825, the Japanese knotweed was introduced to Central and Northern Europe (Chrtek, 1990).

It often spreads uncultivated in floodplain vegetation, primarily in spots with disturbed soil cover. It also grows in hygrophilous shrubbery associations, on abandoned plots and waste dumps. Japanese knotweed prefers acid, stone-debris substrate, without liming. The species is connected with the communities of the orders *Convolvuletalia sepium* and *Lamio albi- Chenopodietalia bon- henrici* (Chrtek, 1990). *Fallopia japonica* occurs up to the mountain forest vegetation tier.

The spreading of Japanese knotweed in Slovakia is turning to a serious danger, because this species, similar to most invasive plants, is a synanthropic one, (occurring in places influenced by human activity), for example: railway and road embankments, catch-water dikes, road banks, near walls of buildings, in wood deposits in forests. (Eliáš, 1998).

It has been found that the spreading of Japanese knotweed is primarily provided by vegetative regeneration, the role of generative component is only secondary – the seeds germinate appropriately just in a greenhouse (Adler, 1993). Generative regeneration of knotweed seems to be very limited and probably exceptional, because autumnal frosts can destroy seeds (if any) before their maturity (Hrušková and Hofbauer, 2002). Therefore, in our conditions, *Fallopia japonica* mostly spreads by vegetative regeneration, primarily by reproduction from rhizome segments, from vegetation buds on nodes, or nodes themselves on necrotizing aboveground parts (Skořepová and Rieger, 2002).

The aim of our research was to give a proof of vegetative propagation of the invasive species *Fallopia japonica* from variously long and large rhizomes or their segments. We analysed regeneration, regeneration rate and size of stems produced by different long rhizome segments to verify the hypothesis whether longer rhizome segments result in higher regeneration ability, vitality of growth. We wanted to prove that *Fallopia japonica* (Houtt.) Ronse Decr. has a great invasive potential, it is able to propagate by vegetative way with a strong growth dynamics, and, consequently, represents a severe danger for natural habitats of autochtonous plant taxons.

Material and methods

The town of Banská Štiavnica is situated in centre of the Protected Landscape Area Štiavnické vrchy Mts. The topography is fairly broken and hilly – just at the centre of the mountain range. The altitudinal band of the town is noticeable: 550–938 m asl, with the highest point at the Paradajz Mountain at 938.9 m asl and the Tanád Moutain having 938.8 m asl. The examined population of *Fallopia japonica*, from which we sampled material (rhizomes) was situated at 580 m asl.

The type of climate is submountain and mountain, encompassing from warm to moderately cold, with annual sum of temperatures exceeding 10 °C from 1,600 to 2,900 °C. Mean annual precipitation is 600–900 mm, mean annual temperature is 8 °C.

The stand of *Fallopia japonica* was located on a south-western oriented slope near a main road, under a line of families houses in construction. The part of the stand adjacent to the road was periodically mowed by the Technical Services of Banská Štiavnica town. The habitat size was approximately 5 x 3 m.

On November 9, 2002, we sampled the study material – knotweed rhizomes from a depth of approximately 10–15 cm. The experiment was launched on November 11, 2002, and it was finished on January 12, 2003. We repeated the same experiment again in the next year, to obtain data for comparison. The samples were taken on December 7, 2003, and the experiment lasted for 9 weeks: since December 14, 2003 to February 8, 2004. We labelled the repetitions as experiment No. 1 and experiment No. 2. There were prepared the following rhizome segments:

- o 1-st variant – 30 segments, 2 cm long
- o 2-nd variant – 30 segments, 5 cm long
- o 3-rd variant – 30segments, 8 cm long.

To obtain reasonable control, the segments were placed in special, sufficiently long, containers. The growing substrate was soil from the private garden in A. Bernolaka Street No. 1, Banská Štiavnica. The soil chemical structure was analysed at the Department of Agrochemistry and Plant Nutrition of the Slovak Agriculture University in Nitra, in 2000 (Table 1).

The segments were put into the plant containers, on slightly compacted soil and covered with another layer of loose soil (3 cm thick). The overall thickness of soil in the containers was approximately 13 cm. The ambient temperature was 19–20 °C (cool room). At the beginning of the experiment, the measurements were made weekly, towards the end fortnightly. The experiment was launched on 9. 11. 2002 and lasted to 12. 01. 2003 (last measurement). Each time we observed:

- o the number of regenerated vital individuals per week – regeneration rate
- o the size of regenerated individuals (cm) – growth dynamic.

The statistic values were calculated using the Statgraphic software, Version 5 (Average, Min., Max., Modus, Median, Standard deviation, Variation coefficient). The tables and graphs were prepared using MS Excel 2000.

Regeneration rate is the number of regenerated individuals per number of the potted rhizome segments for any time. Growth dynamic is the average size of regenerated individuals for any time.

Results

The amounts of 90% exemplars from 8 cm rhizome segments, 53% exemplars from 5 cm rhizome segments, and 47% exemplars from 2 cm rhizome segments were regenerated towards the end of experiment 1 (Fig. 1).

Table 1. Chemical structure of soil used in regeneration experiment

Aggregated nitrogen (mg kg^{-1} of soil)	Phosphorus (P) (mg kg^{-1} of soil)	Potassium (K) (mg kg^{-1} of soil)	Calcium (Ca) (mg kg^{-1} of soil)	Magnesium (Mg) (mg kg^{-1} of soil)	pH
23	170	750	2,650	48	6.1

Experiment 2 has carried different results: 70% exemplars regenerated in the first and the third variant (8 cm rhizome segments and 2 cm rhizome segments), but only 67% plants from 5 cm rhizome segments (Fig. 1).

The final sizes of the regenerated plants were similar in both experiments, the biggest plants were grown from 8 cm rhizome segments, and the smallest plants were obtained from 2 cm rhizome segments, respectively (Fig. 2); but in all variants high variation coefficients were found (Tables 1, 2).

Regeneration rates of rhizome segments were similar in both experiments; the first stems appeared on 8 cm long rhizome segments already during one or 2 weeks after the plantation, 5 cm long rhizomes produced first stems after two or three weeks, and 2 cm long segments after 4 weeks after the plantation (Figs 3 and 4). Regeneration rate in experiment one decreased with decreasing length of segments, but in experiment two it did not.

The growth dynamic of the survived individuals in experiments one and two was similar as in case of regeneration rate. The longest rhizome segments were created by the biggest plants in all time of both experiments, except two weeks in the second half of experiment one (Figs 3 and 4).

Statistical evaluation of regenerated individuals of *Fallopia japonica* is summarized in Tables 1–2.

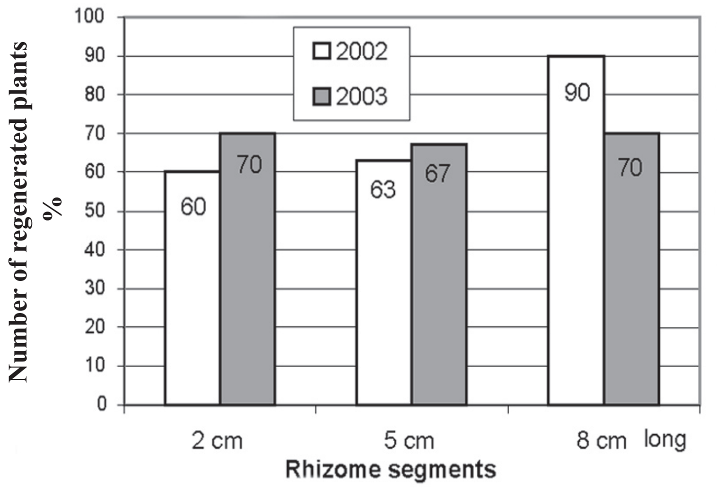

Fig. 1. Final number of regenerated plants from rhizome segments of *Fallopia japonica* (2002 – experiment No. 1, 2003 – experiment No. 2

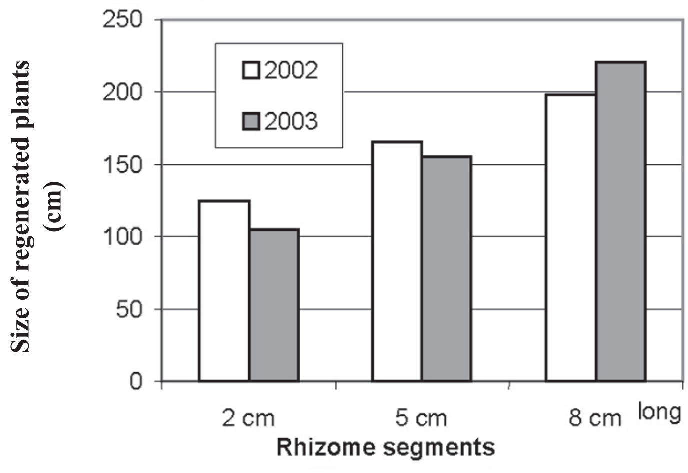

Fig. 2. Final average size of regenerated *Fallopia japonica* plants

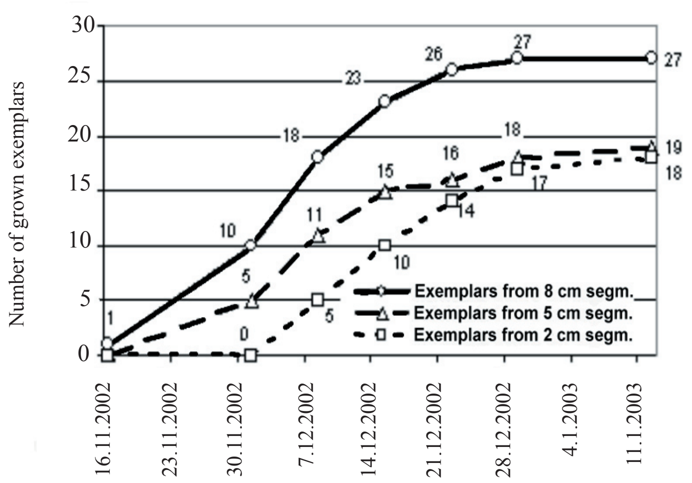

Fig. 3. Regeneration rate of rhizome segments of Fallopia japonica (experiment No.1)

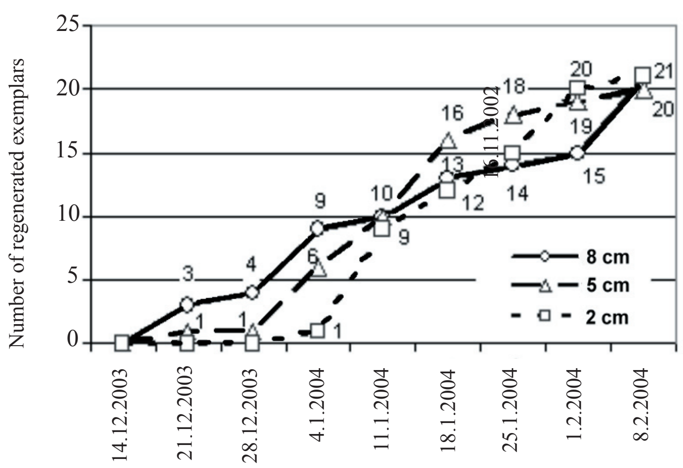

Fig. 4. Regeneration rate of rhizome segments of Fallopia japonica (experiment No.2)

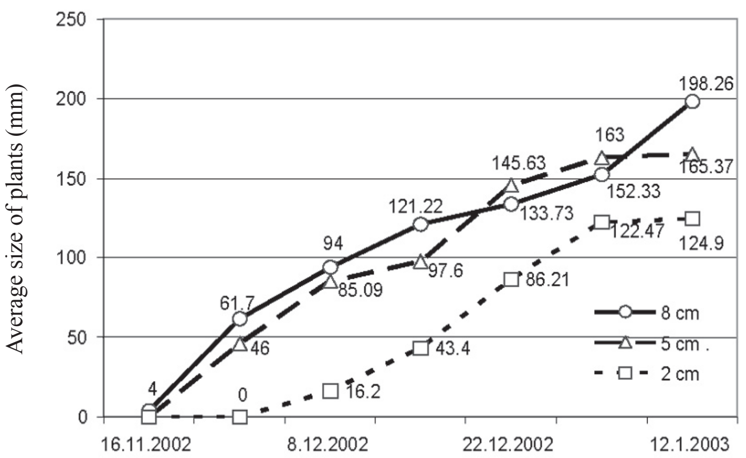

Fig. 5. Growth dynamic of regenerated Fallopia japonica plants in experiment No. 1 (average data for each variant and date were used)

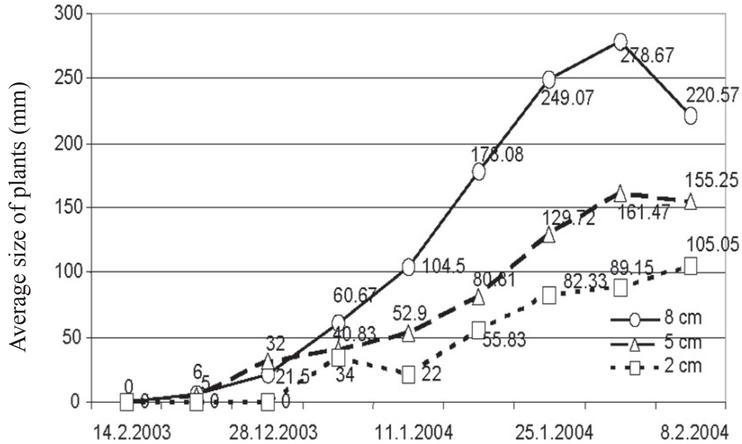

Fig. 6. Growth dynamic of regenerated Fallopia japonica plants in experiment No. 2

Table 2. Statistical evaluation of regenerated individuals

Date of measurement	Number of regenerated plants		
	2 cm	5 cm	8 cm
16. 12. 2002	0	0	1
01. 12. 2002	0	5	10
08. 12. 2002	5	11	18
15. 12. 2002	10	15	23
22. 12. 2002	14	16	26
29. 12. 2002	17	18	27
12. 01. 2002	18	19	27
Average	9.14	12.00	18.86
Min	0	0	1
Max	18	19	27
Modus	0	*	27
Median	10	15	23
Standard deviation	7.06	6.59	9.25
Variation coefficient	77.21	54.92	49.05

Table 3. Statistical evaluation of regenerated individuals

Date of measurement	Number of regenerated plants		
	2 cm	5 cm	8 cm
14. 02. 2003	0	0	0
21. 12. 2003	0	1	3
28. 12. 2003	0	1	4
04. 01. 2004	1	6	9
11. 01. 2004	9	10	10

Table 3. Continued

Date of measurement	Number of regenerated plants		
	2 cm	5 cm	8 cm
18. 01. 2004	12	16	13
25. 01. 2004	15	18	14
01. 02. 2004	20	19	15
08. 02. 2004	21	20	21
Average	8.67	10.11	9.89
Min	0	0	0
Max	21	20	21
Modus	0	1	*
Median	9	10	10
Standard deviation	8.27	7.88	6.30
Variation coefficient	95.46	77.94	63.68

Discussion

Japanese knotweed spreads through hemerochory. It produces many vegetative outgrowths. Broken parts of plants are transported by water in rivers to suitable places for rooting. The species produces adventitious roots. It spreads also by hydrochrony, traffic and anemochory (Kuderavá, 1997).

Invasive species differ with their biological characteristics. It can have various living forms and strategies. They are often perennial species with vegetative regeneration and with high regeneration ability. They also have very effective reproductive mechanisms.

Generally we can say that they are species with perfect reproductive abilities in their natural environment, and they have high invasive potential (Eliáš, 2001).

From these results it follows that the species of the genus *Fallopia* are able to reproduce vegetatively from differently long rhizome segments. They are able to grow adequately fast, and they can be vital also in dense vegetation. The results also show that longer rhizome segments can better germinate from rhizomes and better grow high. The plants are stronger, they have more leafs and they have larger leaf area. It depends on the rhizome segment size. The segments have bigger reserves of nutrients in the tissues and there is better nutrients uptake from the soil. The genus *Fallopia* is able to reproduce from small, 2 cm rhizome segments, too. They can be adequately vital but their germination and growth is somewhat slower than from 5 and 8 cm segments. Plants of *Fallopia japonica* can reliably regenerate from less than 5 g of root material, the rhizomes beneath a 1 m^2 stand of knotweed produced 238 new shoots (Brock and Wade, 1992).

Adler (1993) also reports in his work that from about vegetative reproduction by spreading rhizome fragments to different distances from the parent plant and germinating from segments 1–1.5 cm segments with at least with one node.

We observed a very vital rhizome regeneration of *Fallopia japonica*, 70–90% plants were regenerated from 8 cm long rhizome segments. Bímová et al. (2003) show in their work that regeneration from stems was less efficient than that from rhizomes in all taxa (Reynoutria [Fallopia]) except *R. sachaliensis*. *R. x bohemica* exhibits higher regeneration potential (61%) than all the other taxa and it can be considered as the most successful taxon of the Czech representatives of the genus *Reynoutria* in terms of regeneration and establishment of new shoots. High regeneration capacity was also exhibited by *Reynoutria japonica* var. compacta (52%). Other taxa showed generally lower regeneration rates (*R. japonica* var. *japonica* 39% and *R. sachaliensis* 21%), but under some conditions the percentage of regenerated segments was high, too.

The different regeneration of rhizomes in our experiment can be related to the different quality of the analysed genotypes. Pyšek, Brock, Bímová et al. (2003) show that the regeneration rate and final shoot mass were affected by the genotype in *R. x. bohemica* but not in *R. sachaliensis*. In *R. x. bohemica*, easily regenerating genotypes grew faster. In total, pooled across taxa and genotypes, 100 of 150 rhizomes regenerated (66.6%). Six germinated buds (3.0%) later died; of these, five were *Reynoutria sachaliensis* and one was *R. x bohemica*. Some of rhizomes germinated but had not produced measurable amounts of shoot biomass before the experiment was finished.

Conclusions

Longer rhizome segments regenerated better, small differences between the number of regenerated plants in three variants in experiment No. 2 can be associated with state of rhizome or with the genotype. Growth dynamics and final size of plants was approximately the same in both experiments and depended on the initial length of the rhizome segments.

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Regenerácia podzemkov *Fallopia japonica*. I. Intenzita regenerácie a veľkosť rastlín

Súhrn

Fallopia japonica (Houtt.) Ronse Decr. pochádza zo submeridionálnych a oceánskych oblastí východnej Ázie (Jarolímek and Zaliberová, 1997).

Porast pohánkovca japonského, z ktorého sme odoberali vzorky mal juhozápadnú expozíciu pri hlavnej ceste, pod výstavbou rodinných domov. Časť porastu, bližšie pri ceste bola pravidelne kosená technickými službami mesta Banská Štiavnica, kvôli úprave cestnej komunikácie. Porast bol veľký 5 x 3 m. Dňa 9. 11. 2002 sme odobrali vzorky t. j. podzemky pohánkovca japonského, približne z hĺbky 10–15 cm. Z odobratých podzemkov sme narezali: prvý variant – 30 odrezkov o dĺžke 2 cm, druhý variant – 30 odrezkov o dĺžke 5 cm, tretí variant – 30 odrezkov o dĺžke 8 cm. Každý variant sme dali zvlášť do dlhých kvetináčov. Ako substrát sme použili pôdu zo súkromnej záhrady na ul. A. Bernoláka č. 1 v Banskej Štiavnici. Nasledujúci rok sme pokus opakovali. Pokus trval 9 týždňov a merania sme robili v týždňových intervaloch.

Pri každom opakovaní sme merali: počet vzídených jedincov v každom týždni (ks) a výšku vzídených jedincov (cm). Z každého merania boli vypočítané štatistické ukazovatele.

Na konci prvého pokusu bolo vzídených: 90 % jedincov pri variante s 8 cm odrezkami z podzemných častí, 63 % jedincov pri variante s 5 cm odrezkami z podzemných častí, 60 % jedincov pri variante s 2 cm odrezkami z podzemných častí. Odlišné boli výsledky druhého experimentu – bolo vzídených 70 % jedincov pri variante s 8 cm odrezkami z podzemných častí, 67 % jedincov pri variante s 5 cm odrezkami z podzemných častí, 70 % jedincov pri variante s 2 cm odrezkami z podzemných častí. Pomerne vyrovnané hodnoty regenerovaných podzemkov môžu súvisieť s kondíciou a tiež s genotypom rastlín. Ďalej sme zistili, že dynamika rastu rastlín z regenerujúcich segmentov podzemkov a ich veľkosť na konci experimentov závisí na počiatočnej dĺžke segmentov – najrýchlejšie sa vyvíjali a najväčšiu veľkosť dosiahli rastliny z najdlhších segmentov podzemkov (8 cm).

Z týchto výsledkov vyplýva, že invázne druhy rodu *Fallopia* sú schopné vegetatívneho rozmnožovania z rôzne dlhých segmentov podzemkov. Taktiež sú schopné rásť dostatočne rýchlo a sú vitálne aj v zahustenom poraste, len neskôr začína ich výšková diferencia a s tým spojené aj konkurenčné vzťahy. Výsledky poukazujú aj na to, že čím sú dlhšie segmenty z podzemkov, tým je lepšie vzchádzanie a rýchlejší výškový rast. Je to pravdepodobne spôsobené tým, že väčšie segmenty majú väčšiu zásobu živín vo svojich pletivách a taktiež ich prijímajú intenzívnejšie z pôdy. Ale aj napriek tomu invázne druhy rodu *Fallopia* sú schopné sa vegetatívne rozmnožovať aj z malých 2 cm segmentov a dokážu byť dostatočne vitálne.