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Research Article

Disposal methods for selected invasive plant species used as ornamental garden plants

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Abstract

Invasive alien plant species are frequently grown as ornamental plants in gardens. Until recently, in Slovenia, there were neither specific collection centres for a safe disposal of invasive plant species, nor any legislation that defined procedures for their removal and disposal. We investigated in two experiments how to dispose of pieces of selected invasive plant species, with the aim to prevent their survival and further dispersion. In the first experiment, we chose eight species that are known for spreading by either growing from pieces of cut stem (*Cornus sericea*, *Parthenocissus quinquefolia*, *Buddleja davidii*) or through subterranean rhizomes and tubers (*Solidago canadensis*, *Solidago gigantea*, *Rudbeckia laciniata*, *Helianthus tuberosus*, *Symphytrichum novae-angliae*). The plant fragments were exposed to three different storage treatments: drying, composting on an open compost heap, and storage in black bin liners, all of which can be used in the home garden. After 5 months of storage, the materials were planted in box planters, and their development was monitored. Drying and composting was highly efficient for disposal, as the conditions destroyed the majority of the plant material. However, storage in a bin liner was inefficient because it did not kill any of the plant species tested, and did not delay their growth of new roots. In the second experiment we investigated selected woody invasive plants (*Cornus sericea*, *Parthenocissus quinquefolia*, *Buddleja davidii*, *Acer negundo*, *Forsythia* × *intermedia*) to determine whether their branch fragments can sprout new roots, and whether shredding of their branches represents an efficient dispersal pathway. These dried fragments did not grow roots under any circumstances, while freshly shredded fragments rooted in some cases. Therefore, the use of mulch that has not been treated properly might allow dispersal of woody invasive plants. We can conclude that not all recommended treatments for invasive plant disposal are equally successful to prohibit plant survival and further spread.

Key words: vegetative reproduction, regeneration, invasive plant species, rooting, mulch, garden waste

Introduction

Negative effects on biodiversity of invasive alien plant species have been well documented. Alien plants can distort the functions of ecosystems, such as forests, wetlands and agricultural habitats, as they can replace the native vegetation and change the structure of the plant communities (Hejda et al. 2009; Pyšek et al. 2012). Biological invasions are caused by human-mediated extra-range dispersal of species, which has been defined as "movement of propagules to regions beyond the boundaries of their range occupied over ecological time" (Wilson et al. 2009). One of the most important intentional extra-range dispersals of invasive species is the cultivation of exotic plant species for human or animal food, for a source of different plant materials, and for ornamental plants in gardens.

Many of the most noxious invasive plant species started their travel around the globe as ornamental plants in botanical or private gardens, and have since then "escaped" from cultivation, such as *Fallopia japonica* (Houtt.) Ronse Decr., *Impatiens glandulifera* Royle, *Solidago gigantea* Aiton, *Buddleja davidii* Franch. (Bailey and Conolly 2000; Čuda et al. 2017; Weber 1998; Tallent-Halsell and Watt 2009). The two most-common ways for plants to escape from gardens are through natural routes, such as dispersal of seeds, fruit or vegetative propagules by animals, wind or water, and through human activities, such as garden rubbish, compost heaps outside gardens, transport of soil containing seeds or vegetative propagules, and planting of ornamental plants outside gardens. Hodkinson and Thompson (1997) reported that the typical species that are disposed of by gardeners were mainly tall perennials with a tendency to vegetative reproduction.

To prevent, or at least reduce, the abundance of escapes of ornamental plant species from gardens, education and awareness-raising about invasive plant species is crucial for the general public and for different interest groups. In Slovenia, such activities have started only recently. Findings about several invasive plant species in Slovenia have been published in local scientific journals (Turk 1990; Strgar 1981). The first activities to raise the awareness of the general public started in 2008, with the project Thuja, which was then followed by Thuja 2 (Kus Veenvliet 2017). The goals of both of these projects were to educate different target groups (e.g., gardeners, beekeepers, maintainers of public areas, employees in nature parks, teachers) about the negative impacts of invasive alien species on biodiversity, and to publish educational materials about non-native species in the Slovene language (e.g., booklets, fact sheets, websites, travelling exhibitions for schools and other public institutions, teaching materials for schools). These two projects, and those that followed, recognised that the greatest interest among the target groups was for the identification of invasive plant species and the effective methods for their removal and disposal.

There are a number of scientific publications that deal with removal methods for different invasive plant species, many of which can be accessed through the websites of organisations that deal with such species (e.g., NOBANIS 2019; CABI 2019). However, to the best of our knowledge, there is almost nothing in the literature about the safe disposal of plant material. On the contrary, there are many websites with instructions on how to remove and dispose of materials from invasive plant species (e.g., Invasive Species Council of British Columbia 2019; Ecological Landscape Alliance 2011). However, again, these do not refer to any scientific literature. Here, the most recommended disposal methods are in the rubbish (e.g., heavy duty plastic bags for incineration or landfill), burning, composting, chipping and composting, air drying, construction of brush piles, and burying.

In order, to test the effectiveness of several disposal methods for plant materials, we conducted two experiments:

(i) In the first experiment we selected 8 ornamental invasive species that either disperse by growing from cut stem pieces (*Cornus sericea* L., *Buddleja davidii*, *Parthenocissus quinquefolia* (L.) Planch.) or through subterranean parts, such as rhizomes and tubers (*Solidago canadensis* L., *Solidago gigantea*, *Rudbeckia laciniata* L., *Helianthus tuberosus* L., *Symphyotrichum novae-angliae* (L.) G.L. Nesom). We used three recommended storage treatments that are available for owners of small gardens: drying, composting on an open compost heap, and storage in black bin liners. After 5 months of storage, we planted the material into pots in glasshouse and monitored their development.

(ii) In the second experiment, we evaluated whether branch fragments of woody plants chopped by shedders can regenerate, and if shredding the branches represents a good disposal path for such woody invasive plant species. In this experiment, we used 5 invasive woody species (*Cornus sericea*, *Buddleja davidii*, *Acer negundo* L., *Parthenocissus quinquefolia*, *Forsythia* × *intermedia* Zabel).

Materials and methods

Species and sampling

Two different types of plant materials were collected (Table 1). For the species that reproduce by fragmentation of underground organs, such as rhizomes, stolons or tubers, the underground parts were collected. These species were: *Symphyotrichum novae-angliae*, *Helianthus tuberosus*, *Rudbeckia laciniata*, *Solidago gigantea* and *Solidago canadensis.* For the woody species that reproduce by fragmentation of branches, we collected pieces of branches. These species were: *Parthenocissus quinquefolia*, *Cornus sericea*, *Buddleja davidii*, *Acer negundo* and *Forsythia* × *intermedia.* The plant material was collected in plastic bags and stored for a few days in a dry cool place until the start of the experiment.

The samples of all of the selected invasive plant species for testing of the different storage treatments were collected in October 2016, in Ljubljana, Slovenia. The material for the control treatment was collected from the same locations in the following spring, on 15 and 16 March 2017. Detailed sampling information is listed in Supplementary material Appendix 1.

The branches of five woody ornamental plant species (*Parthenocissus quinquefolia*, *Cornus sericea*, *Acer negundo*, *Buddleja davidii*, *Forsythia* × *intermedia*) were collected on 29 March 2017 from the same locations as in

Table 1. List of tested invasive species with literature data about their reproduction, dispersal, status most common habitats in Slovenia, and sampling.

Species	Reproduction and dispersal	Status and habitats in Slovenia	Sampled material
Acer negundo L.	Vegetative: cut branches, sprouting from exposed or damaged roots (Merceron et al. 2016); sexual: seeds mainly dispersed by wind	Invasive: wetlands, urban areas (Dakskobler et al. 2016)	Branches
Buddleja davidii Franch.	Vegetative: stem and root fragments; sexual: seeds dispersed by wind and water (Tallent-Halsell and Watt 2009)	Invasive: river banks, abandoned building sites, quarries (Mavrič and Strgulc Krajšek 2017)	Branches
Cornus sericea L.	Vegetative: sprouting from decumbent or cut branches (Kelly 1990); sexual: berries dispersed by birds (Charles-Dominique et al. 2010)	Invasive: wetlands, vicinity of urban areas (Bačič et al. 2015)	Branches
Forsythia × *intermedia* Zab.	Vegetative: cut branches (Sladek and Strgulc Krajšek 2019)	Naturalised: forests and forest edges, vicinity of urban areas (Sladek and Strgulc Krajšek 2019)	Branches
Helianthus tuberosus L.	Vegetative: tubers and stolons (Tesio et al. 2012)	Invasive: riverbanks (Schnitzler et al. 2007)	Tubers
Parthenocissus quinquefolia (L.) Planch.	Vegetative: root and stem fragments (Pilkington 2011); sexual: berries dispersed by birds	Invasive: along rivers and forest edges, near to urban areas (CKFF 2005–2019)	Branches
Rudbeckia laciniata L.	Vegetative: fragmentation of the rhizome (Frajman 2009)	Invasive: flood plains, along stream banks, and in moist forests (Frajman 2009)	Rhizomes
Solidago canadensis L. and *S. gigantea* Ait.	Vegetative: fragmentation of the rhizome; sexual: achenes dispersed by wind (Werner et al. 1980)	Invasive: abandoned fields, along rivers, roads, railways and forest edges ... (Dancza and Botta-Dukát 2008)	Rhizomes and stolones
Symphyotrichum novae-angliae (L.) G. L. Nesom	Vegetative: rhizome fragmentation; sexual: achenes dispersed by wind (Verloove 2014)	Invasive: along rivers, roads, railways and forest edges (Jogan et al. 2012)	Rhizomes and stolones

autumn 2016. On the same day, the branches were shredded using a garden shredder (ALF 2600; Gartenhäcksler, Atika). The branch fragments of each of these species were stored in separate plastic bags until the experiment. The sizes of the fragments ranged from < 1 cm up to ~ 3 cm.

Experiment 1: Testing regeneration after the different storage treatments

The branches of the woody plants were cut into ~ 15-cm-long fragments. Rhizomes and tubers of uniform sizes were chosen, washed under tap water, and dried. The material for each species was divided into equal parts to test the three storage treatments, as:

(1) *Drying*: The material of each species was spread on low trays that were covered with newspaper sheets and dried at room temperature in the dark.

(2) *Open compost heap*: The material of each species was put into labelled plastic mesh bags. All of the material was placed on an open-air compost heap located in the garden of Bežigrad Gymnasium in Ljubljana, under a roof to avoid exposure to precipitation.

(3) *Black plastic rubbish bags*: The material of each species was put into labelled black plastic rubbish bags, which were tied, put into an open plastic basket, and stored beside the open-air compost heap.

The material was left until the end of March 2017. During this period, the temperature in Ljubljana ranged from −13.3 °C (in January) to 23.8 °C in

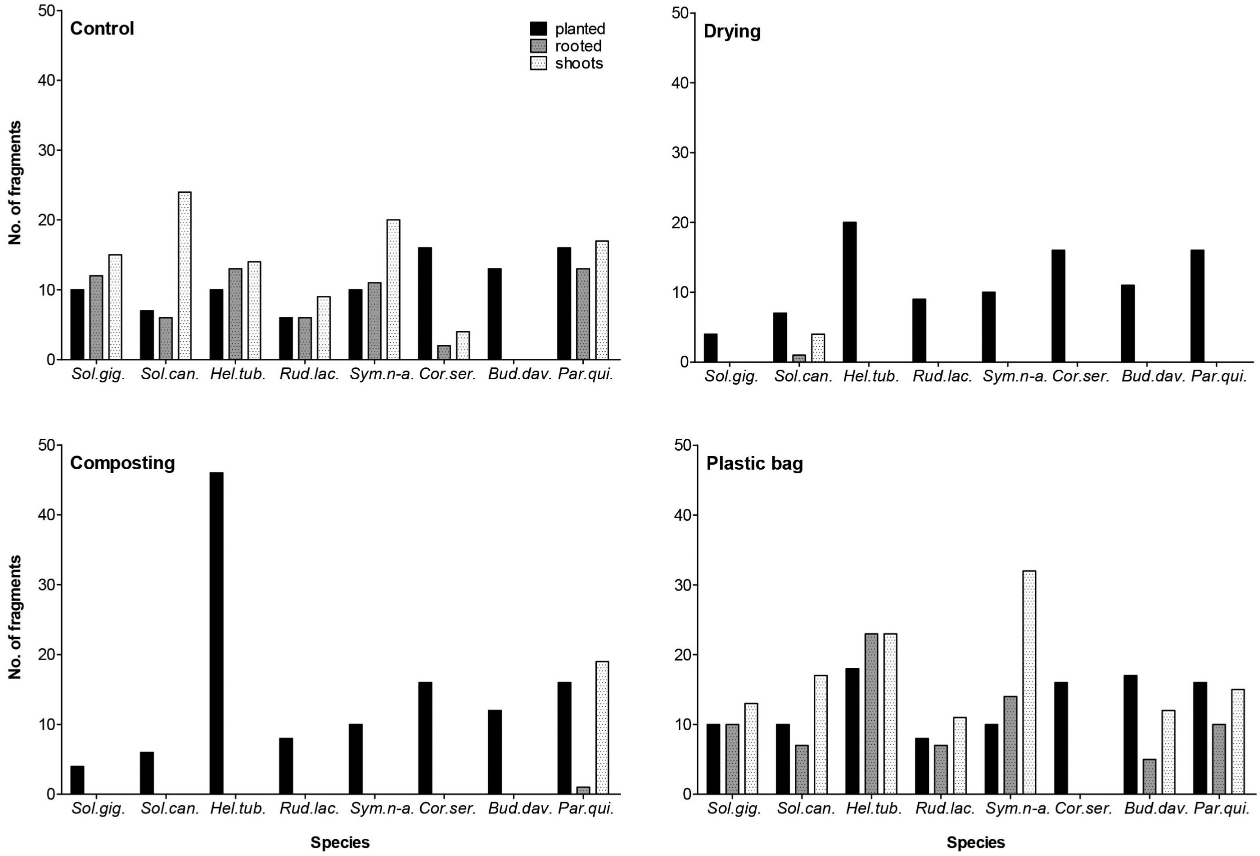

Figure 1. Number of regenerated plant fragments after different storage treatments. Absence of column means that fragments did not develop roots or shoots. *Sol.gig. = Solidago gigantea, Sol.can. = Solidago canadensis, Hel.tub. = Helianthus tuberosus, Rud.lac. = Rudbeckia laciniata, Sym.n-a. = Symphyotrichum novae-angliae, Cor.ser. = Cornus sericea, Bud.dav. = Buddleja davidii, Par.qui. = Parthenocissus quinquefolia.*

March 2017, the air humidity was < 50% for 34 days and > 80% for 52 days (Slovenian Environment Agency 2018).

After 5 months of the storage treatments (i.e., 22 March 2018), all of the plant materials were planted in marked box planters that contained a mixture of sterilised loam (Bio Plantella, Start; Unichem, Slovenia) and agra-vermiculite (*Pullrhenen*, The Netherlands) at the volume ratio of 2:1. The quantities of the planted materials are given in Figure 1. Each box planter contained the material of one species and from one treatment only. The box planters were left in a light and warm place in a greenhouse in Ljubljana for 2 months, with weekly watering with 0.5 L tap water.

(4) *Control*: Fresh plant material of each species was collected in March 2018, and then handled and planted in the same way as the treated samples (but without the 5-month treatments).

During this period, the above-ground shoots were counted and the box planters were photographed every 7 days. At the end of the experiment (i.e., 25 May 2017) the pieces of the plant materials with developed roots and/or green shoots were defined as "survived". All of the aboveground shoots were cut, and their lengths from ground level to shoot apex were measured.

Table 2. Fresh mass of the shredded branches used, number of regenerated fragments and number of shoots.

Species	Mass of shredded branches [g]	Number of rooted fragments (number of shoots)	
		Fresh fragments	Dry fragments
Cornus sericea	592	0 (5)	0 (0)
Buddleja davidii	360	0 (3)	0 (0)
Parthenocissus quinquefolia	676	8 (16)	0 (0)
Acer negundo	172	0 (8)	0 (0)
Forsythia × intermedia	228	2 (15)	0 (0)

Experiment 2: Regeneration after fragmentation of branches using a garden shredder

The shredded materials of the selected woody plant species (*Parthenocissus quinquefolia*, *Cornus sericea*, *Acer negundo*, *Buddleja davidii* and *Forsythia × intermedia*) were weighed (Table 2) and divided into two equal parts. One part was planted in box planters, by being laid on the top of a mixture of sterilised loam (Bio Plantella, Start; Unichem, Slovenia) mixed with agra-vermiculite (*Pullrhenen*, The Netherlands) at the volume ratio of 2:1. The box planters were left in a light and warm place in a greenhouse in Ljubljana for 2 months, with weekly watering with 0.5 L tap water. The second part of these materials was spread on a low tray and covered with newspaper and left in a dry and dark place at room temperature for 14 days to dry. Two weeks later, the materials were planted and treated the same way as the fresh materials.

The monitoring of the plant development and the end of the experiment were the same as described for Experiment 1.

Statistical analysis

The data processing and statistical analyses were carried out with MS Excel (2016) and GraphPad Prism 5.01 (2007). The descriptive statistical parameters were calculated, and the differences between the treatments were tested using one-way ANOVA and Tukey's multiple comparison test.

Results

Experiment 1: Plant regeneration after the different storage treatments

All of the five species tested for vegetative reproduction by fragmentation of the underground rhizomes and stolons (*Symphyotrichum novae-angliae, Rudbeckia laciniata, Solidago gigantea* and *Solidago canadensis)* or tubers (*Helianthus tuberosus)* survived in the plastic bag treatment (Figure 1). The number of rooted underground fragments was almost the same as in the control group. For *Solidago gigantea* (control), *Helianthus tuberosus* (control and plastic bag) and *Symphyotrichum novae-angliae* (control and plastic bag), more rooted fragments were dug out of the substrate at the end of the experiment than were planted. This was seen because the planted fragments partly decomposed and fragmented to even smaller fragments

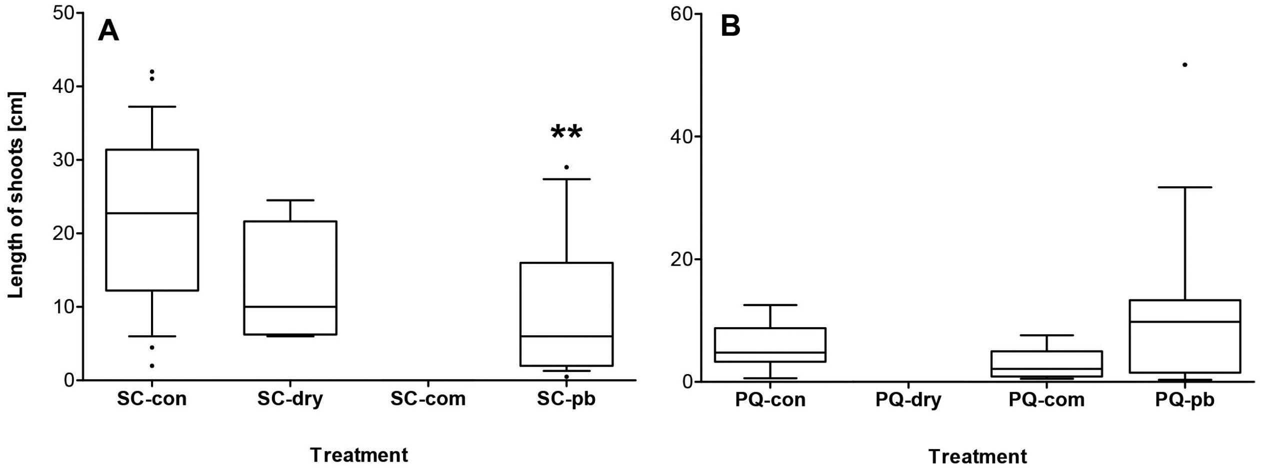

Figure 2. Shoot length of *Solidago canadensis* (A) and *Parthenocissus quinquefolia* (B), measured from the ground level to the shoot apex at the end of the experiment. Medians, 1st and 3rd quartile (box), and 10th to 90th percentile intervals (whiskers) are shown. SC = *Solidago canadensis*, PQ = *Parthenocissus quinquefolia,* con = control, pb = plastic bag, dry = drying, com = composting; black dot (●) = outlier, asterisk = statistically significant difference between treatment and control (**, $P < 0.01$ using Tukey's multiple comparison test).

during the growing phase of the experiment. Only one fragment of *Solidago canadensis* survived the drying treatment, while none of the five species survived the composting treatment (Figure 1).

Among the woody species that show vegetative reproduction through the rooting of branch fragments, the *Cornus sericea* fragments did not survive any of the treatments, where even in the control group only 2 of 16 planted fragments rooted and developed green shoots. The *Buddleja davidii* fragments rooted only when they were stored in the plastic bags. *Parthenocissus quinquefolia* was the most successful here, as only the dried fragments did not develop roots, while the number of rooted fragments in the plastic bag treatment was almost the same as in the control group. In the composting group for *Parthenocissus quinquefolia*, only one of 16 fragments developed roots, but 9 planted fragments developed altogether 19 shoots with leaves, with some even showing flower buds.

For two species, *Solidago canadensis* and *Parthenocissus quinquefolia,* where the plants survived the three treatments, the lengths of the developed shoots were compared at the end of the experiment (Figure 2). The only statistically significant difference here was between the control group and the plastic bag treatment of *Solidago canadensis*, where the median shoot length following the plastic bag treatment was 74% shorter than the control. For the other treatments, there were no significant differences compared to the relevant control groups.

Experiment 2: Plant regeneration after fragmentation of branches using a garden shredder

The data for the testing for regeneration of fresh and dry fragments of shredded branches used as mulch showed some large difference between the two methods used (Table 2). When the shredded branches were dried before planting, there was no regeneration of the fragments in terms of either root development or green shoots. In contrast, for the fresh fragments, all of tested species developed green shoots. However, these were limited for *Acer negundo*, *Buddleja davidii* and *Cornus sericea*, as all of these fragments failed to develop adventitious roots. For *Forsythia* × *intermedia* and *Parthenocissus quinquefolia*, some fragments showed rooting, and so more of the green shoots survived until the end of the experiment. This regeneration was only seen for fragments that were > 1 cm long, as the smaller fragments did not regenerate.

Discussion

Ornamental horticulture is one of the major routes of introduction of invasive alien species into new environments (Niemiera and Von Holle 2009; McLean et al. 2017). The main spreading pathways from gardens and parks are through avian, wind and water distribution of seeds, plus human-mediated dispersal, such as composting of plant material (Rusterholz et al. 2012), transport of soil containing plant propagules, and use of dirty grass mowers (Joly et al. 2011; Strgulc Krajšek et al. 2016), among the many possibilities.

Further knowledge of the potential reproduction of such invasive alien species is needed to be able to define their spreading possibilities and the appropriate disposal methods. In the present study, we focused on herbaceous perennials that show vegetative reproduction by fragmentation of rhizomes or tubers, and on woody plants that can reproduce by rooting of branch fragments. These two groups of plants, along with annual plants, are included in some recommendations for disposal of materials from invasive plant species (e.g., Bennett 2010; Connecticut Department of Energy and Environmental Protection and University of Connecticut 2014). For both plant groups, the suggested disposal methods for gardeners and home use are drying, burning (incinerating), landfill, sealed plastic bags for several weeks, brush piles and burying. Composting is not recommended, with the exception of completely dry material (Bennett 2010; Connecticut Department of Energy and Environmental Protection and University of Connecticut 2014).

The uprooted herbaceous plants could be disposed as whole or aboveground parts could be separated from roots before the disposal, as in the case when gardeners first cut the shoots and afterwards dig the rhizomes and roots from the soil. In our experiment, the herbaceous plants were collected at the end of the growing season, when aboveground parts were already in the senescence. For that reason, only the belowground parts were used. Branches of woody plants were cut to smaller pieces or shredded as it is common practice by gardeners. The regeneration capability of fragmented plant material was already studied on some invasive plant species (Song et al. 2013; Bímová et al. 2003; Dong et al. 2011). It was shown that some highly invasive clonal plants (e.g. *Fallopia* spp.) have a high capacity of regeneration from small fragments (Bímová et al. 2003), but it does not explain the differences in invasiveness among stoloniferous clonal species (Song et al. 2013). The regeneration from root fragments is also one of the strategies of short-lived weeds for disturbance survival in their specific environment (Klimešova et al. 2008). The vital parts of plants that enable the vegetative regeneration are meristems, often positioned within different types of buds (Klimešova and Klimeš 2007). However, the presence of rhizomal internodes is also crucial, as internodes have an important storage function. The remobilisation and reuse of the reserves in stolon internodes may be an adaptive strategy for stoloniferous plants, as *Alternanthera philoxeroides* (Mart.) Griseb., to cope with fragmentation of clones (Dong et al. 2011). The regeneration from rhizomes is usually higher than from stems, as it was shown for *Fallopia japonica* (Bímová et al. 2003), and in some cases it is season dependent (Liew 2013; Monty et al. 2015).

The data from our study only partially support the various recommendations given across a number of websites, with very little information available in the literature. Drying and composting on an open compost heap were the most effective disposal methods for the invasive plant species tested here. However, none of these methods was completely successful, as at least one of each of the plants survived in each of them. One particularly unexpected result of note was regeneration of the dried rhizome fragments of *Solidago canadensis*, which rooted and developed six shoots after 5 months of drying. It was expected that the drying would destroy all of this plant material (Bennett 2010; Connecticut Department of Energy and Environmental Protection and University of Connecticut 2014; Ecological Landscape Alliance 2011). The second particularly unexpected result was the weak regeneration of the composted plant materials, where only one branch of *Parthenocissus quinquefolia* rooted. Composting is generally strictly listed as not a recommended method of disposal of these invasive alien species. It would appear that composting in a larger compost heap with more covering plant material than used in the present study, or use of a compost box with a lid, can increase the survival rate of such composted plant fragments, probably because they would not dehydrate, as occurred in the present study. Rusterholz et al. (2012) provided evidence that numerous non-native horticultural plant species can escape from dumping sites (as sorts of compost heaps) to colonise forests. The amount of garden waste examined in their study ranged from 2.2 m^3 to 35.8 m^3 (mean, 17.8 m^3), which was larger than in the present, where compost heap was < 0.25 m^3. In Slovenia, the waste management services collect biodegradable waste and process it through industrial composting procedures, during which all of the viable plant fragments (including seeds) are destroyed due to the long duration of the process and the high temperatures (Waste Management Services 2019; Resnik, JP VOKA SNAGA, Ljubljana *personal communication*).

Table 3. Effectiveness of the disposal methods for the selected invasive plant species.

Species	Plant organ	Disposal method				
		Drying	Composting on open heap	Storage in plastic bag	Fragmentation (shredded)	Fragmentation (shredded) + drying
Solidago gigantea	Rhizome	+	+	–	nt	+
Solidago canadensis	Rhizome	○	+	–	nt	+
Helianthus tuberosus	Tuber	+	+	–	nt	+
Rudbeckia laciniata	Rhizome	+	+	–	nt	+
Symphyotrichum novae-angliae	Rhizome	+	+	–	nt	+
Cornus sericea	Branch	+	+	+	○	+
Buddleja davidii	Branch	+	+	–	○	+
Parthenocissus quinquefolia	Branch	+	○	–	–	+
Acer negundo	Branch	nt	nt	nt	○	+
Forsythia × *intermedia*	Branch	nt	nt	nt	–	+

+ = method effective and recommended; ○ = method mostly effective; – = method not effective; nt = not tested.

If such a service is available, disposal of invasive plants in containers for biodegradable waste is allowed.

Storage of the removed invasive alien plants in black bin liners is listed among some of the most efficient methods for plant disposal. However, this method appears to only be effective in combination with the exposure of the plastic bags to the sun for several weeks (Invasive Species Council of British Columbia 2019; Ecological Landscape Alliance 2011). Here we have shown that disposal of these plant materials in plastic bags without the "sun treatment" is ineffective. The storage of the plant materials in black bin liners not only preserved their ability to grow roots and shoots, but in some cases also promoted their growth (e.g., *Helianthus tuberosus*, *Symphyotrichum novae-angliae*). The number of rooted fragments after the plastic bag treatment in the present study was almost the same as in the control group. Moreover, at least some of the plant fragments of all of the species tested, except for the branches of *Cornus sericea*, survived and sprouted after 5 months in the black plastic bags.

One of the recommendations for disposal of woody invasive plants is fragmentation (shredding) of the branches (Borland et al. 2009; Bennett 2010). In recent years, an increasing number of garden owners in Slovenia have been using garden shredders to shred tree and shrub branches into smaller fragments to produce mulch. In the present study, only the fresh fragments of woody invasive species developed roots and shoots, while the dry fragments did not. From this we can infer that the use of mulch that has not been previously dried might foster regeneration and dispersal of woody invasive plants. The results of our experiment were similar to those of Monty et al. (2015) who tested the regeneration of *Buddleja davidii, Fallopia japonica, Solidago gigantea, Rhus typhina* L. and *Spiraea* × *billardii* K. Koch and detected the regeneration of fresh shredded shoots or belowground parts.

A summary of the efficiencies of all of the disposal methods tested here for these selected invasive plant species is presented in Table 3. We emphasize that these recommendations are based on the data from the present study, and particular attention should be paid for extrapolation to other species. Incineration and landfill are safe options for the disposal of these invasive alien plants, to prevent their dispersal, but this cannot be recommended from the sustainable development point of view. There are some other alternatives, such as the use of the collected plant materials of invasive alien plants as a source of raw material. In the Municipality of Ljubljana, Slovenia, the project Applause encourages citizens to collect plant materials of selected invasive plant species (i.e., *Fallopia* spp., *Solidago* spp., *Cornus sericea*, *Robinia pseudoacacia* L., *Rhus typhina*, *Ailanthus altissima* (Mill.) Swingle) and to dispose of these in its collection centres. The material gathered is then used for the production of paper, dyes and wood products. Another important goal of the Applause project is education and awareness raising of the citizens, who are encouraged to recognize invasive plant species in nature, and thus to correctly remove and dispose of them, or to use them at home as a source of materials (Berden 2018; Bačič 2018).

As many different invasive or potentially invasive plant species are still grown in gardens mainly as ornamental plants, there remains the urgent need and interest to increase the awareness of garden owners of the problems associated with the disposal of such plant materials. This is of particular importance in terms of illegal (garden) waste dumping, as this is one of the important mechanisms for the plants to escape from cultivation into nature (Rusterholz et al. 2012; Kus Veenvliet et al. 2012).

While avian and wind seed dispersal of ornamental plants from gardens are difficult to control (Cruz et al. 2013), dispersal caused by humans can be limited by education and awareness raising. To achieve good results here, accurate and correct information is crucial. Therefore, it is very important for further scientific studies to be carried out on different invasive and potentially invasive plant species, with a view to the preparation of science-based recommendations for the disposal of these plant materials, particularly as scientific publications in this field are still scarce.

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Supplementary material

The following supplementary material is available for this article:

Appendix 1. Detailed sampling information.

This material is available as part of online article from:
http://www.reabic.net/journals/mbi/2020/Supplements/MBI_2020_Strgulc-Krajsek_etal_Appendix_1.pdf