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ORIGINAL PAPER

Horticultural practices of invasive plants: insights into priorities, awareness, and management among garden owners

C. Palmér · A. Wallin · J. Persson · K. Blennow

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Abstract Ornamental horticultural plants in domestic gardens can constitute a substantial dispersal pool of potentially invasive species. Understanding garden owners' preferences when selecting plants, their awareness of dispersal pathways and how they manage their gardens is critical for effective invasive species control. This study used a survey to investigate Swedish garden owners' (n = 743) plant selection priorities, awareness of invasive species dispersal pathways, and management methods across three biosphere reserves in different bio-climatic regions in Sweden. Results show that garden owners prioritise aesthetics, practical characteristics, such as habitat suitability, hardiness, and biodiversity benefits, such as pollinator support, over geographical origin when selecting plants. Management methods perceived as effective, such as hand weeding and digging, were used more frequently than methods such as hot water and salt, which were considered less effective or whose efficiency was uncertain to the respondents. Gardening interest was significantly associated with both ecological knowledge and preference for biodiversity-supporting benefits. Our findings suggest the need for targeted communication strategies that account for regional geographical and gardening variations, plant-specific information, and actual management method effectiveness. These insights can lead to effective stakeholder engagement in invasive species management in domestic gardens.

Keywords Invasive alien species · Domestic gardens · Yards · Plant selection preferences · Dispersal awareness · Management practices

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C. Palmér (✉) · K. Blennow
Department of Landscape Architecture, Planning and Management, Swedish University of Agricultural Sciences, Alnarp, Sweden
e-mail: Cecilia.palmer@slu.se

A. Wallin
Division of Cognitive Science, Department of Philosophy, Lund University, Lund, Sweden

J. Persson
Department of Philosophy, Lund University, Lund, Sweden

K. Blennow
Department of Physical Geography and Ecosystem Science, Lund University, Lund, Sweden

Introduction

The flora of domestic gardens consists of a majority of horticultural plant species that are alien to their respective regional floras (Loram et al. 2008; Padullés Cubino et al. 2015; Ward and Amatangelo 2018). Ornamental horticultural plants in gardens often constitute a substantial dispersal pool of potentially invasive plants (Haeuser et al. 2018; Hulme et al.

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2018). Given the widespread presence of gardens, their flora exerts considerable propagule pressure on the surrounding landscape (Mayer et al. 2017; Dehnen-Schmutz and Conroy 2018). While this has been documented in a variety of geographical locations such as South Europe (Padullés Cubino et al. 2015), North America (Ward and Amatangelo 2018), Australia (Kendal et al. 2012), and Puerto Rico (Meléndez-Ackerman and Rojas-Sandoval 2021), the Nordic context remains understudied. However, gardens also provide opportunities for early detection, rapid response and management of invasive species (Dehnen-Schmutz & Conroy 2018; Shackleton and Shackleton 2016). A cost-effective strategy in invasive plant management involves preventing the introduction and dispersal of potentially invasive species (Rouget et al. 2016; García-Llorente et al. 2011). Public knowledge and values regarding invasive species depend partly on how they perceive alien species and their impact on biodiversity, economy and human health, and this can significantly influence management outcomes (Verbrugge et al. 2013).

The success of voluntary efforts for invasive species control depends on various factors, including the garden owners' knowledge and attitudes, as well as the introduction pathway of invasive species. Some alien species are cultivated and valued for their aesthetic appeal (Shackleton et al. 2019) or because they are easy to cultivate, displaying rapid growth and resistance to pests (van Kleunen et al. 2018). According to Shackleton and Shackleton (2016) engaging garden owners in the control of invasive species introduced as ornamentals with aesthetic appeal can be challenging. Garden owners' plant choices can further be shaped by social norms (Goddard et al. 2013), the availability of species in nurseries (Cavender-Bares et al. 2020), and practical considerations like suitability for food production (Gulinck et al. 2020; Šiftová 2021). The interaction between personal preferences and availability creates a self-reinforcing pattern in the selection of plants for gardens (Avolio et al. 2018). As a result of this, garden owners typically rely on a selection of ornamental commercially available species, often overlooking their potential ecological impacts, such as invasiveness (Dehnen-Schmutz et al. 2007) and contribution to biotic homogenisation (McKinney 2006). Research by Kendal et al. (2012) found that garden owners select plants based on specific traits that align with their preferences, such as flower size, foliage colour and drought tolerance. Garden owners may decide to plant or keep invasive species, even when they are aware of their ecological harm, because of positive attributes such as aesthetics or cultural significance (Shackleton and Shackleton 2016; Dehnen-Schmutz & Conroy 2018).

To understand these challenges in a Nordic context, it is important to consider Sweden's diverse climate. Stretching from temperate oceanic conditions in the south to subarctic environments in the north, the country encompasses a wide range of growing conditions that strongly shape its vegetation (Sjörs 1956). This climatic gradient is also evident in the length of the vegetation period, which lasts up to approximately 230 days in the south but shortens to approximately 110 days in the north (SMHI 2025a). More than 50% of the Swedish population lives in houses with a garden (Statistics Sweden 2023), with garden sizes in urban areas typically ranging between 540 and 1120 m^2 (Bengtsson and Haller 2025). Swedish garden design during the latter half of the twentieth century was influenced by functionalism, but has become increasingly more individualistic, reflecting the personal tastes and preferences of garden owners (Wilke 2014). A risk assessment of invasive alien species for Sweden[1] indicates that at least 255 plant species may become invasive within the next 50 years (SLU Artdatabanken 2025), highlighting the specific challenges faced in Nordic climates. Additionally, many ornamental species are currently being cultivated at latitudes higher than their natural distributions, where their naturalisation is presently limited by suboptimal climate conditions (Haeuser et al. 2018). With a warming climate, these cultivated species may overcome current climatic constraints and spread more extensively (Bellard et al. 2013; Dullinger et al. 2017; Gallardo et al. 2017). This is particularly relevant as naturalised alien species tend to move toward higher latitudes, primarily due to larger native species pools at lower latitudes (Zhang et al. 2023). To mitigate the dispersal of invasive species, voluntary management and control efforts among gardeners are imperative (Niemiec et al. 2016; Junge et al. 2019).

[1] This national assessment classifies any plant species introduced by humans that have naturalised in Sweden since 1800 as alien (SLU Artdatabanken 2025).

Moreover, a desire to attract pollinators, support wildlife, and promote biodiversity can also influence decision-making in gardening (Goddard et al. 2013; Home et al. 2019). The evolutionary history shared between native plants and local fauna creates ecological relationships that are important for biodiversity conservation (Tallamy 2007). Gardens can serve as important corridors for native plant species (Doody et al. 2010; Staude 2024), yet the potential disconnect between gardeners' appreciation for biodiversity and their knowledge of plant origin may limit such conservation efforts. Alien origin is a criterion for a plant to be considered invasive (IUCN 2025), and this aspect is often emphasised in governmental agency communications with garden owners regarding invasive plants (Swedish Environmental Protection Agency 2025). Alongside origin, other factors such as species-specific traits, cultivation history, propagule pressure, and climate matching between source and recipient regions also contribute to predicting invasion risk (van Kleunen et al. 2018). However, garden owners may regard origin as relatively unimportant compared to functional or aesthetic traits (Qvenild et al. 2014). There have been reports from Africa, continental Europe and the USA that laypeople, in general, are unable to distinguish native species from alien ones (McKinney 2006; Lindemann-Matthies 2016; Shackleton and Shackleton 2016; Seboko et al. 2024).

Effective control of invasive species requires knowledge of appropriate management techniques (Niemiec et al. 2016) and social acceptance of control methods, particularly when they involve controversial approaches such as herbicide use and lethal removal (Sharp et al. 2011; Olszańska et al. 2016), while preventing further dispersal necessitates safe disposal methods (Krajšek et al. 2020). Selecting the most suitable control measures for a specific situation requires an understanding of the invasive plant's dispersal pathways. To the best of our knowledge, no study has so far investigated which methods domestic garden owners use in their control of invasive plant species. Moreover, knowledge about garden owners' plant preferences, knowledge of dispersal pathways and which control methods garden owners perceive as effective not only informs about the perceived effectiveness of management methods but also provides valuable insights for developing more targeted communications and support for invasive plant management in private gardens across a wider geographical context.

Against this review, we hypothesise that:

Hypothesis 1a Garden owners prioritise cultivation qualities over geographical origin

Hypothesis 1b Garden owners prioritise biodiversity-supporting abilities over geographical origin

Hypothesis 2 Garden owners with personal experience of invasive species in their gardens have a higher awareness of dispersal pathways than those without such experience

Hypothesis 3 The management methods used by garden owners to manage invasive plants correlate positively with the perceived effectiveness of the used management methods

Method

Data

Preparatory work before conducting a survey included a scoping literature review, influence diagrams and explorative, semi-structured interviews with garden owners (n = 14) from the three biosphere reserves (Palmér et al. 2023). This approach aligns with Persson et al. (2018), integrating local knowledge into scientific research, which emphasises the importance of exploratory engagement with stakeholders to understand local contexts and practices, in this case, garden owners, to identify relevant topics before formal data collection (the main survey). The preparatory work facilitated the integration of practical experience from gardeners with theoretical knowledge from domain experts by recognising potential knowledge gaps between these different perspectives.

A survey was distributed to approximately 6000 randomly selected domestic gardeners, specifically domestic garden owners, in the three biosphere reserves located in different bio-climatic regions of Sweden: Voxnadalen, Lake Vänern Archipelago and Mount Kinnekulle, and Blekinge Archipelago (UNESCO 2025) (Fig. 1). These biosphere reserves encompass areas of high biodiversity values with mixed land uses, and the surveyed gardens were situated within the buffer and transition zones rather than within the strictly protected areas. The postal invitations included a link to a web-based questionnaire hosted by Netigate (2025). The respondents were

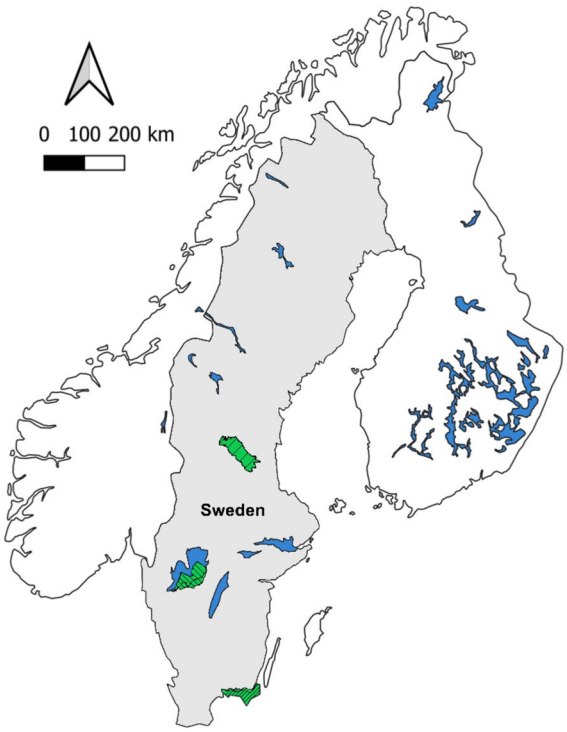

Fig. 1 Location of included study areas in Sweden. Voxnadalen (the northernmost), Lake Vänern Archipelago and Mount Kinnekulle (central) and Blekinge Archipelago (the southernmost). Adapted from Palmér et al. (2023). Made with Natural Earth

informed of the objectives of the study, that participation was entirely voluntary, and that no questions were compulsory to answer, in a postal cover letter. The survey as well as the cover letter were formulated in Swedish. The survey was deployed on October 22 and remained open until December 7 in 2020 and generated 990 responses.

The subsequent survey comprised 24 questions focusing on invasive species, their effect on biodiversity, and how they are expected to be impacted by climate change. All species included in this study are assessed to have a severe impact according to a national risk assessment of invasive species in Sweden and are among the most common invasive plant species in the country (Strand et al. 2018; SLU Artdatabanken 2025). Six invasive plant species were used in the questionnaire: butterfly bush (*Buddleja davidii* Franch.), Himalayan balsam (*Impatiens glandulifera* Royle), garden lupin (*Lupinus polyphyllus* Lindl.), Japanese knotweed (*Reynoutria japonica* Houtt.), rugosa rose (*Rosa rugosa* Thunb.), and lilac *(Syringa vulgaris* L.). However, *Buddleja davidii* was omitted from the present study due to inadequate cold tolerance in the northernmost study area, making it hard to compare between study areas. The order of the species was randomised when presented in the questionnaire. The complete questionnaire is provided in Palmér et al. (2023).

This study analysed four questions from the questionnaire, each containing multiple sub-questions, with the 32 sub-questions treated as individual variables in the analysis. These concerned knowledge level of plant dispersal pathways, management practices, garden owners' perceived effectiveness of management practices, and preferred qualities when choosing plants for gardens. In addition, the variables municipality and gardening interest were included in the analysis. Most respondents (95%) reported knowing what invasive means at the beginning of the survey. After the question concerning the definition in the survey, a definition was given so that everyone who answered the subsequent questions was aware of the definition. Only responses from garden owners with at least one invasive plant species growing in their garden were included in the present study (n = 743). For the test of the hypothesis concerning management methods, making use of responses to Q3 and Q4 in Table 1, only respondents who had taken measures to control invasive species in their gardens were included (n = 328).

Statistical analysis

To test the hypotheses that garden owners prioritise cultivation qualities and biodiversity supporting abilities over geographical origin, a Friedman test was used to assess differences in the median ranks across sub-questions concerning plant preference in Q1 (Table 1). Following a significant Friedman test result, pairwise comparisons were performed using the Conover post hoc test with adjustments for multiple comparisons according to Bonferroni. Kendall's *W* was calculated as the effect size measure.

To test the hypothesis that garden owners with personal experience of invasive species have higher awareness of dispersal pathways, knowledge of the primary dispersal pathway (Q2) was categorised for each of the included species (Online resource Text 1) and analysed using a two-sided test of proportions to

Table 1 Questions analysed in the present study, with abbreviations used in the paper

Number	Question	Response option
Q1	What is important to you when choosing plants for your garden? - That the plant possesses the right traits for the growing site (variable *habitat suitability*) - That the plant is hardy (variable *hardiness*) - Availability in nurseries (variable *availability in nurseries*) - The appearance of the plant (variable *plant aesthetics*) - That the plant produces food (variable *food production*) - That the plant spreads in the garden (variable *spreading*) - That the plant does not spread in the garden (variable *non-spreading*) - That the plant is good for pollinators (e.g. bees, bumble bees and butterflies) (variable *pollinator support*) - That the plant is beneficial for biodiversity (variable *biodiversity beneficial*) - That the plant is alien (variable *alien origin*) - That the plant is Swedish (variable *Swedish origin*)	Not at all important (0) 1 2 3 Very important (4)
Q2	Do you know how the following plants are primarily dispersed? - Himalayan balsam, *Impatiens glandulifera* - Garden lupin, *Lupinus polyphyllus* - Japanese knotweed, *Reynoutria japonica* - Rugosa rose, *Rosa rugosa* - Lilac, *Syringa vulgaris*	Road transport Translocation of soil Birds Wind Water Root suckers Other Do not know
Q3	Have you or anyone else used the following invasive species control measures in your garden? - Digging - Burning - Hot water - Hand weeding - Cutting - Salting - Covering - Chemical substances	Yes, always Often Rarely No, never Do not know
Q4	According to you, are the following invasive species control measures effective? - Digging - Burning - Hot water - Hand weeding - Cutting - Salting - Covering - Chemical substances	Yes, always Often Rarely No, never Do not know
Q5	In what municipality do you live?	A list of 21 municipalities subsequently aggregated into three study areas, Voxnadalen, Lake Vänern Archipelago and Mount Kinnekulle and Blekinge Archipelago
Q6	How interested in gardening are you?	Not interested (0) 1 2 3 Very interested (4)

determine group differences. Cramér's V was calculated as the effect size measure.

To test the hypothesis that management methods correlate positively with perceived effectiveness, Spearman's rank correlation analysis was conducted to evaluate the relationship between reported use and the effectiveness of each management method (Q3, Q4), with "I do not know" responses excluded prior to analysis, as they cannot be meaningfully ordered within the ordinal scale for rank correlation. The Spearman's rank correlation coefficient (ρ) served as the effect size measure.

Variables for study area (based on municipality) (Q5) and gardening interest (Q6) were analysed using the Kruskal Wallis test for Q1, Q3 and Q4, followed by Dunn's post hoc test with Bonferroni correction when significant. Effect sizes were assessed using eta-square (η^2). For Q2, Pearson's χ^2 was used to examine associations between study area, gardening interest and correctly identified dispersal pathways, followed by a pairwise test of proportions with continuity correction when the overall test was significant. Effect sizes were assessed using Cramér's V. To check for co-variation between the ordinal variables study area and gardening interest, Goodman–Kruskal γ and Somers' D were used.

The open-source software R Project for Statistical Computing v 4.3.2 was used to analyse the data (R Core Team 2023). All analyses were performed using the car (Fox and Weisberg 2019), DescTools (Signorell 2024), dunn.test (Dinno 2024), stats (R Core Team 2023), PMCMRplus (Pohlert 2024), rstatix (Kassambara 2023) and vcd (Meyer et al. 2024) packages in R. Visualisations, including graphs, were created with the ggplot2 (Wickham 2016) and dplyr (Wickham 2023) packages. For all statistical tests, the significance level (α) was set at 0.05.

Results

Hypothesis 1a *Garden owners prioritise cultivation qualities over geographical origin.*

A Friedman test revealed a statistically significant difference in the ranking across factors ($\chi^2(8) = 2483$, $p < 2.2e{-}16$, Kendall's $W = 0.51$), indicating that respondents rated certain factors as consistently more important than others when choosing plants for their gardens (Q1) (Fig. 2). The variables *plant aesthetics*, *habitat suitability*, *hardiness*, *availability in nurseries* and *non-spreading*, showed similarly high median rankings. Both origin-related factors were ranked significantly lower. *Swedish origin* had a median ranking of 2, while *alien origin* had a median ranking of 0 (not important at all). In the pairwise comparisons (Conover post hoc test), all four factors ranked least important were significantly different from each other, and all other included variables (Fig. 2, Online resource Table 1).

Habitat suitability of plants was rated as more important by respondents with a strong interest in gardening than those with lower interest, indicating a significant association between gardening interest

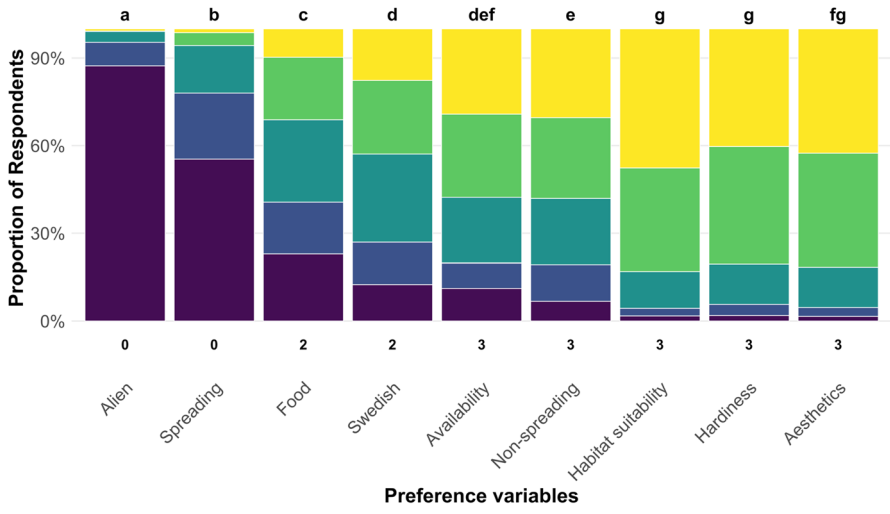

Fig. 2 Importance ratings for how Swedish garden owners rate cultivation qualities and geographical origin, Q1 in Table 1. Letters = statistical groups. Numbers under the bars indicate median rank (sorted by median importance). 4 very important (yellow), 3 (green), 2 (turquoise), 1 (blue), 0 not important (dark blue)

and the value placed on *habitat suitability*. No significant co-variation was found between the study areas and gardening interest (Goodman–Kruskal $\gamma = 0.080$, Somers' $D = 0.052$). In the northernmost study area (Voxnadalen), respondents placed significantly higher importance on plant *hardiness* compared to respondents in the southern Blekinge archipelago. Voxnadalen respondents also showed a stronger preference for native *Swedish* plants than respondents from the other study areas. Both Voxnadalen respondents and respondents with a strong gardening interest valued *food production* plants highly (Online resource Table 2).

Hypothesis 1b *Garden owners prioritise biodiversity-supporting abilities over geographical origin.*

A Friedman test revealed a statistically significant difference in the rankings across biodiversity-supporting abilities ($\chi^2(3) = 1231$, $p < 2.2\text{e-}16$, Kendall's $W = 0.675$). A post hoc Conover test showed that all included variables were rated significantly differently (Online resource Table 3). *Pollinator support* was ranked as the most important variable, followed by *biodiversity beneficial*, *Swedish* origin and *alien* origin (Fig. 3).

There was a general tendency in all three study areas to find *pollinator support* important, but respondents from Blekinge archipelago were significantly more likely to find pollinators important than respondents from Lake Vänern Archipelago and Mount Kinnekulle (Online resource Table 4). Respondents with strong gardening interest were more likely to see both *biodiversity beneficial* and *pollinator support* as important than respondents with less strong interest.

Hypothesis 2 *Garden owners with personal experience of invasive species in their gardens have a higher awareness of dispersal pathways than those without such experience.*

Respondents who had *Impatiens glandulifera*, *Reynoutria japonica, Rosa rugosa* or *Syringa vulgaris* in their gardens were significantly more likely to know how these species are dispersed than those who did not (Online resource Table 5). The awareness of dispersal characteristics was positively correlated with gardening interest (Online resource Table 6). Respondents who were very interested in gardening consistently reported better knowledge of dispersal for all the included species. A geographical difference was found for *Reynoutria japonica* where garden owners in Blekinge archipelago reported a higher knowledge level than garden owners in Voxnadalen and Lake Vänern Archipelago and Mount Kinnekulle. An opposite pattern was found for *Impatiens glandulifera* where respondents in Blekinge reported a lower knowledge level than garden owners in Voxnadalen and Lake Vänern Archipelago and Mount Kinnekulle.

Hypothesis 3 *The management methods used by garden owners to manage invasive plants correlate*

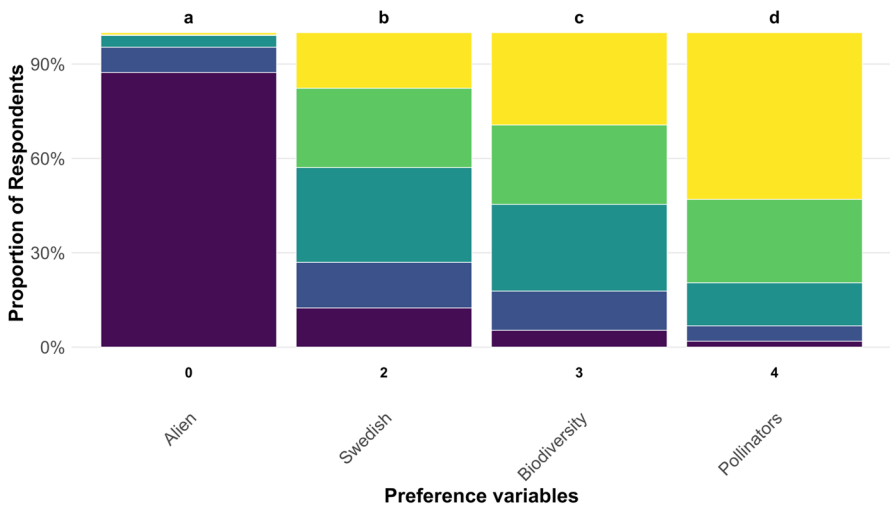

Fig. 3 Importance ratings of biodiversity-supporting abilities and geographical origin by Swedish garden owners, Q1 in Table 1. Letters = statistical groups ($p < 0.05$). Numbers under the bars indicate median rank (sorted by median importance). 4 very important (yellow), 3 (green), 2 (turquoise), 1 (blue), 0 not important (dark blue)

positively with the perceived effectiveness of the used management methods.

Results of the Spearman rank correlation tests showed that each of the management actions was significantly positively correlated with the perceived effectiveness of the management methods ($p < 0.001$ for all management actions) (Online resource Table 7). Sample sizes for these correlations ranged from 82 (management method *Water*) to 270 (management method *By hand*) (Online resource Table 8).

For management actions, the methods *hand weeding*, *cutting* and *digging* were frequently used (median response: "often"), and *hand weeding* and *digging* were often perceived as effective. However, *burning*, *chemical substances*, *salt* and *hot water* were not frequently used, and *salt* and *hot water* were rarely considered effective (Fig. 4).

Respondents in Voxnadalen were significantly more likely to report never having used *chemical substances* than those in Lake Vänern Archipelago and Mount Kinnekulle, or in Blekinge Archipelago. They were also more likely to perceive these substances as not effective (Online resource Table 9).

Discussion

In this study, we surveyed garden owners across three biosphere reserves (Voxnadalen, Lake Vänern Archipelago and Mount Kinnekulle, and Blekinge Archipelago) in different bioclimatic conditions in Sweden (Fig. 1). We hypothesised that garden owners would prioritise practical plant characteristics and biodiversity benefits over geographical origin, that direct experience with invasive species would increase awareness of dispersal pathways and that management methods use would correlate with perceived effectiveness.

Hypothesis 1a *Garden owners prioritise cultivation qualities over geographical origin.*

Most factors concerning practical plant characteristics, such as plant aesthetics, hardiness, and habitat suitability, were ranked highly, suggesting that garden owners find several factors important when selecting plants for their gardens. Origin was constantly perceived as less important than other included variables. The relatively low rankings of Swedish origin, especially in comparison to practical attributes like hardiness and plant aesthetics, suggest that gardeners are less likely to consider plant origin as a key factor in their decisions. However, while native origin was not considered very important, alien origin was consistently ranked as unimportant, suggesting that garden owners neither specifically select nor avoid plants based on their origin. Based on these results, the hypothesis, stating that garden owners prioritise practical plant characteristics over the values associated with plant origin, was corroborated.

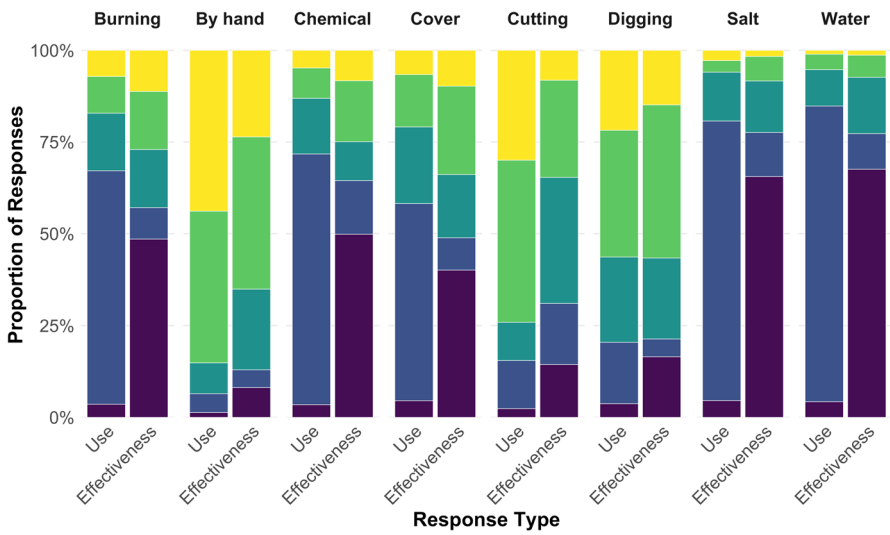

Fig. 4 Proportions of Swedish garden owner responses to management method used and perceived effectiveness of these methods. Always (yellow), often (green), rarely (turquoise), never (blue), do not know (dark blue)

That Swedish garden owners in this study valued plant aesthetics highly aligns with Shackleton and Shackleton (2016), who found that gardeners in South Africa appreciated the aesthetic qualities of invasive plants even while recognising the potentially problematic ecological impacts. The practical cultivation considerations correspond with the findings from Kendal et al. (2012), who noted that gardeners in Australia, in addition to aesthetic appearance, also prioritise practical considerations such as hardiness and habitat suitability in their plant selection process. The findings also align with Qvenild et al. (2014), who observed that gardeners in Norway frequently do not consider whether plants are native or alien when gardening, and Šiftová (2021), who observed that Czech gardeners also ranked using native plants as one of their lowest priorities in garden maintenance. In Mexico, the proportion of native species in domestic gardens has been seen to vary along the urban–rural gradient (Poot-Pool et al. 2015). However, these studies represent a limited geographical scope and may not capture the full range of gardening motivations across different cultural and socioeconomic contexts globally.

Results also align with the findings that spreading plants are most often seen as not preferred (Saltszman et al. 2016). Furthermore, the Swedish garden owners' general disregard of growing plants for food is consistent with Clayton (2007), where food production was ranked as less important than other gardening activities among gardeners in Ohio, USA. It is, however, in contrast with Šiftová (2021), who found food production to be the most common gardening activity in Czechia. Research on domestic gardens from Cuba (Wezel and Bender 2003) and Mexico (Blanckaert et al. 2004) suggests that food security can be an important motivation, highlighting the need for diverse geographical perspectives in understanding gardeners and their relationships to their gardens. These divergent findings concerning food production underscore that gardening practices and preferences are not necessarily universal but can reflect cultural and geographical contexts, economic conditions and gardening traditions.

Hypothesis 1b *Garden owners prioritise biodiversity-supporting abilities over geographical origin.*

Pollinator support and biodiversity were ranked as more important than origin, which was ranked as unimportant. Since origin was consistently ranked as of lower importance, the hypothesis was corroborated.

These findings align with McKinney (2006), who found that many garden owners are positive towards species diversity, although they do not possess knowledge of the species' geographical origin. This disconnect is important to acknowledge, as plant origin may affect local and regional flora conservation and biodiversity support, particularly given the role of gardens in native plant dispersal and conservation (Doody et al. 2010; Staude 2024).

Geographical differences and gardening interest

Garden owners in the northern study area Voxnadalen found plant hardiness and Swedish origin more important than other participants. This could be a reflection of the region's climatic challenges, with a mean annual temperature that is 3–4° C lower than for the southernmost study area (Blekinge archipelago) (SMHI 2025b). The preference may be because native local plant material is adapted to harsher climates and the limited availability of cold-tolerant plant material. Local environmental variables, including regional climate conditions, have previously been shown to influence plant selection preferences and landscape management decisions (Avolio et al. 2015; Larson et al. 2016). The prevalence of *Lupinus polyphyllus* in Voxnadalen may also have heightened local awareness of invasive alien species. This aligns with findings from Palmér et al. (2023), showing that garden owners in this region were more proactive in managing invasive plants.

Garden owners from this northernmost study area, Voxnadalen, and those with a strong interest in gardening valued food-producing plants more highly. This tendency may reflect regional differences in gardening traditions, with rural or semi-rural areas, such as Voxnadalen, being more prone toward self-sufficiency and food cultivation.

Beyond these geographical patterns, gardening interest significantly influences how garden owners valued habitat suitability, pollinator and biodiversity support. The association between a strong gardening interest and greater horticultural knowledge and practical experience has also been observed in Great

Britain (Loram et al. 2011). Additionally, gardening engagement has been found to correlate with increased awareness of and greater motivation to support local biodiversity (Goddard et al. 2013).

Understanding these variations in gardening priorities is important for developing communication strategies that align with different gardeners' values and motivations. Given that co-evolutionary relationships between local flora and fauna play an important role in biodiversity conservation (Tallamy 2007), there appears to be a need for more effective communication about the ecological benefits of native plants. However, strategies that focus on communicating plant origin alone may not be effective in motivating garden owners to manage invasive species. While our findings suggest that garden owners do not prioritise plant origin in their selection decision, it is important to acknowledge that the relationship between gardener preferences and invasive species management is more nuanced than simply promoting native plants. The horticultural industry plays a crucial role in determining which plants are available to gardeners, and in many regions, the majority of plants sold are alien species, with limited native options available in the trade (van Kleunen et al. 2018). Only a minority of alien species become invasive, and many alien species provide various benefits, though these positive contributions are frequently overlooked in invasiveness risk assessments (Vimercati et al. 2020). From an invasive species management perspective, the priority should be on avoiding the cultivation of plants with invasive traits rather than avoiding alien species altogether. Overall, the results underscore the complexity of garden owners' decision-making, where practical cultivation concerns and biodiversity-supporting factors often take precedence over plant origin.

Hypothesis 2 *Garden owners with personal experience of invasive species in their gardens have a higher awareness of dispersal pathways than those without such experience*

A significant association between presence and awareness of dispersal pathways was found for the four species *Impatiens glandulifera, Reynoutria japonica*, *Rosa rugosa* and *Syringa vulgaris*. Since the association was not found for the entire group of species, the hypothesis that garden owners with personal experience of invasive species in their gardens have a higher awareness of dispersal pathways than those without such experience, was partially corroborated.

In addition to seed dispersal, three of the species where positive associations were found, *Reynoutria japonica*, *Rosa rugosa* and *Syringa vulgaris*, all have distinct root suckering dispersal. That garden owners with these species in their garden had significantly better knowledge level of dispersal is likely due to that the local impact of root suckering is relatively easy to detect. The dispersal source is often apparent even to individuals without specialised expertise in botany. In clonal dispersal, the offspring are genetically identical to the parent plant (Oborny and Bartha 1995), making identification straightforward. In contrast, seed dispersal tends to occur over longer distances (Traveset et al. 2014), and the source of dispersal may be less apparent. Seed dispersal is furthermore typically sexual, resulting in offspring that may exhibit some degree of morphological variation from the parent plant. It should be noted that *Lupinus polyphyllus* is a very common invasive species in Sweden (Tyler et al. 2015), and the lack of significant association between this species and personal experience in one's own garden may be because it is widely recognised by a large proportion of the population (Palmér et al. 2023).

This variation in garden owners' knowledge of the dispersal pathways among species supports Verbrugge et al. (2013), who found that risk communication on invasive species benefits from regional and species-specific information. Similarly, Persson et al. (2018) suggest that effective sustainability solutions can be enhanced when they draw on both scientific evidence and local knowledge, as site-specific observations can reveal important patterns not captured by broader scientific approaches alone. It should be noted that species identification skills varied among respondents, particularly for *Impatiens glandulifera*, *Reynoutria japonica* and *Rosa rugosa*. Poor plant identification may contribute to knowledge gaps about dispersal pathways. Prinbeck et al. (2011) identified that for gardeners, specific and localised information about invasive species and their prevention was critical for overcoming barriers to behavioural change, emphasising the need for clear, targeted guidance rather than general information.

Garden owners with a greater interest in gardening showed higher levels of knowledge of dispersal pathways. This aligns with previous studies indicating that gardening experience and interest are associated with greater ecological knowledge and engagement (Goddard et al. 2013). These findings suggest that targeting communication efforts toward less engaged garden owners might help bridge knowledge gaps in invasive species management.

Hypothesis 3 *The management methods used by garden owners to manage invasive plants correlate positively with the perceived effectiveness of the used management methods.*

When it comes to management methods, a significant positive correlation was observed across all management methods. As positive correlations for the use and perceived effectiveness were found for all included methods, the hypothesis was corroborated.

Methods that were most frequently used, such as hand weeding and digging, were also those most commonly seen as effective. In contrast, methods such as burning, the use of chemicals, salt, and hot water were used less frequently and respondents more often indicated they did not find them effective or did not know how effective these methods were (Fig. 4).

The acceptance of manual methods such as digging while being sceptical against chemical use is consistent with Olszańska et al. (2016), who found the same pattern among representatives from the general public and nature conservationists in Poland. However, the low use of chemical substances is in contrast with Varga-Szilay et al. (2024), where more than 60% of Hungarian gardeners reported using pesticides of some form, in their gardens.

The results from our study, moreover, suggest a potential gap between the perceived and actual effectiveness of certain management actions, such as covering the ground and the use of hot water. Covering the ground can be effective when properly implemented, though success rates vary depending on application methods, species and duration (Martin et al. 2020; Dusz et al. 2021), and the use of hot water can achieve very high control rates for some invasive species when applied correctly (Oliver et al. 2020). These methods may be less understood or less accessible to garden owners, or they may be seen as more labour-intensive, expensive, or environmentally harmful.

This finding emphasises the need for communications on invasive species management that take into account which methods garden owners perceive as being effective. Methods that are perceived as effective (e.g., hand weeding and digging) may be even more widely adopted or even more effective if garden owners are provided with additional training or resources on how to improve their efficacy, whereas methods perceived as less effective may require re-evaluation or adjustment in practice. For instance, ground covering effectiveness could be enhanced by providing guidance on appropriate materials, proper application methods and the duration of time required for successful outcomes.

We suggest that a deeper understanding of how personal experience affects garden owners' decisions is essential to designing effective communication and interventions. A targeted approach will help bridge knowledge gaps and empower garden owners to make informed decisions about planting, cultivation, and management of invasive species.

Conclusion

The findings from this study reveal that plant aesthetics, practical plant characteristics and biodiversity-supporting benefits were consistently ranked higher than plant origin. This suggests a possible disconnect in communication between expert recommendations, emphasising origin, and the garden owners' priorities and practices. However, the relationship between plant origin awareness and invasion management is complex. Effective invasion prevention requires both addressing the limited availability of native plants in the horticultural trade and focusing management efforts on species with demonstrated invasion potential rather than all alien species. Regional differences in gardening priorities, influenced by climatic conditions and local invasive species presence, further emphasise the need for targeted communications.

Awareness of invasive species dispersal pathways was high for species with obvious and localised dispersal methods, such as root suckering. This points to the importance of information about less apparent dispersal pathways to enhance public understanding.

Garden owners tended to use and perceive as effective the manual management methods that were most accessible and familiar, such as hand weeding and digging, while more labour-intensive or costly methods were less favoured. This reflects a need to balance practicality and ecological effectiveness when advising on invasive species management.

These findings highlight the complexity of garden owners' decision-making processes and the importance of communication that meets the needs of the garden owners' priorities and perceptions. By bridging the gap between expert knowledge and used gardening practices, efforts to promote sustainable gardening and invasive species management can become more impactful and widely adopted.

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Data availability Data will be made available on reasonable request.

Declarations

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