Identifying invasive plant species: what plant propagators need to know about the science behind invasive plant assessment protocols©

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Abstract

Although only a very small number of introduced plant species ultimately become invasive in the United States, those that do can cause a number of harmful effects within our natural communities. Some of these invasive species are woody in nature (trees and shrubs), and these typically have a past or current horticultural connection. Thus, plant propagators of woody plant species need to remain informed of how plants are identified as invasive and which species are beginning to spread in their state. In this paper, I present additional reasons for why plant propagators should care about this issue, what they need to know about how states assess plant species as invasive, and newer issues involving cultivars that also provide unique opportunities for plant propagators. Ultimately, plant propagators are encouraged to become better engaged with efforts to assess invasive plants in their own state and to contribute to the dialog about invasive plant issues in the United States.

Keywords: assessment, cultivars, invasive species, woody

INTRODUCTION

Our world today is filled with an amazing diversity of cultivated plants, many of which are highly desired by the gardening public for traits such as flower or fruit color. Even from the earliest of times in the United States, plant explorers have been sent out throughout the world to gather seeds and cuttings of the most unusual, hardy, or sensational plants to cultivate and promote back home. More recently, global trade of commodities such as plants has become more the norm than the exception. As a result, over 25,000 plant species have been introduced to the United States since European settlement (Pimentel et al., 2005). In many cases, these plant introductions were accidental, such as when seeds hitchhike in ship ballast water or are carried along in imported soil. In other cases and especially with woody species, non-native plants have been purposely imported into the United States with the very best of intentions — whether it be promoting fireblight resistance in fruit trees in the Pacific Northwest, preventing soil erosion on road cuts in the South, or introducing fruiting shrubs for wildlife in the Northeast. Unfortunately, a small number of these non-native plants escape cultivation and spread to negatively impact natural areas across the United States, causing unforeseen and widespread effects (Sakai et al., 2001) that were never anticipated during the original introduction. These plants are known today as invasive species. According to the federal definition provided by President Clinton's Executive Order 13112, an invasive species is "an alien [non-native] species whose introduction does harm or is likely to cause economic or environmental harm, or harm to human health." In short, invasive plants can be thought of those plants that jump boundaries into natural areas, where they spread and eventually outcompete native plant species, negatively affect animals that live there, and/or alter natural ecosystem processes.

Scientists do recognize, however, that not every imported species will become invasive (Richardson and Rejmánek, 2011). Ecologists use the "Law of Tens" to talk about the potential for an imported species to spread. For example, if 1,000 plant species are imported

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into a new area, it is estimated that only 10% of those (100) may escape cultivation. Of those, only 10% will begin to establish (10) and of those, only 10% will ultimately become invasive (1 species) — and then usually only after a number of decades called a "lag period." Therefore, the term "non-native" is *not* equivalent to "invasive" because there can also be some non-native species that do not pose a threat to natural ecosystems. In addition, there may be some introduced species that are still in their lag period and have not yet shown any invasive tendencies. Furthermore, not all invasive species are non-native (despite the federal definition) as scientists recognize some native species, such as white-tailed deer, as invasive.

The fact that only a small proportion of all introduced species become problematic however, does not lessen the importance of the issue. Although it is difficult to put a dollar cost on invasive species, Pimentel et al. (2001, 2005) have estimated that invasive plant species cost at least $35 billion per year in the USA in reduced revenue from agriculture, forestry, recreation, control and removal costs, etc. Consequently, invasive species not only affect the integrity and ecology of our natural areas, but they are also quite financially costly for land managers and owners of federal, state, and private natural lands. In other words, invasive species are a concern that ultimately will affect everyone.

WHY SHOULD YOU CARE?

Why should plant propagators, especially those working with woody plants, care about invasive species? There are several reasons. First, the majority of woody invasive species have a horticultural connection in their current or past history. For example, 82% of 235 invasive woody species surveyed were used in horticulture at some point in time, even if they are no longer used today in that way (Reichard and White, 2001). These include shrub species such as Amur honeysuckle (*Lonicera maackii*) or common buckthorn (*Rhamnus cathartica*). Second, plant propagators often focus on specific traits during development because these are the traits desired most by gardeners. It turns out that these are the same traits that are found most often in invasive species (Sakai et al., 2001). For example, species that are invasive are most likely to have prolific flowering, high fruit production (often desired by gardeners for attracting wildlife), rapid growth, survival in diverse habitats, tolerance to stress, and have a history of multiple introductions. This last characteristic is important because many introductions may be necessary before a species can successfully establish within an area. For example, many European birds such as the European starling only established in the United States after they were imported and introduced multiple times to Central Park in New York City by a Shakespeare enthusiast who wanted to introduce all the birds found in Shakespeare's plays into the park (Ehrlich, 1989; Mirsky, 2008). For cultivated plants, multiple and repeated introductions typically occur as part of the large-scale production and distribution of ornamental plants to multiple points across the country. This aspect of commercial plants has been largely ignored by scientific researchers but undoubtedly plays a role in certain species invasions.

Finally, plant propagators should care about invasive plant species because it just makes good business sense. Although not as common as with herbaceous species, some woody plants can begin to seed within a landscape and become perceived as a pest species, appearing in places where it was not planted nor wanted (for example, Callery pear seedlings appearing in residential yards in southwestern Ohio). Over time, invasive plants can rapidly overwhelm a landscape aesthetically and ruin the ornamental novelty of the species so often desired by gardeners. Customers will not see the value in paying money for a plant that they can just dig up from their neighbors' yard or a park down the street. On a more positive note, plant propagators who pay attention to emerging species invasions can potentially increase their profits by anticipating future changes in product availability and offer alternatives (especially as invasives are becoming increasingly regulated in certain states). For example, breeders and propagators can begin developing sterile cultivars of species that show signs of invasiveness, thereby anticipate future demand for this type of product well before other competitors are even aware of the problem.

Will the invasive plant issue ever affect you as a plant propagator? The answer is most likely yes — if you work on woody species, you will probably encounter this issue during

your career. Highly popular ornamental plant species that are now considered invasive in one or more USA states include Japanese barberry (*Berberis thunbergii*), Norway maple (*Acer platanoides*), burning bush (*Euonymus alatus*), purple loosestrife (*Lythrum salicaria*) and Callery pear (*Pyrus calleryana*). Based on past history, it is highly likely that plant propagators today are currently developing species improvements and cultivars that will unintentionally become invasive in the future. What can be done now to prevent this from happening and ultimately help plant propagators continue to be successful in their businesses? But to even begin to answer this question, we must first ask: How do we even identify plants as invasive?

INVASIVE SPECIES ASSESSMENT PROTOCOLS

Whether a plant is labeled as invasive ultimately depends on where the plant falls along a gradient of invasion severity — in other words, "How abundant is the plant within the landscape?" and "What are the impacts of that plant within the natural ecosystem?" For example, the occasional solitary plant growing in a forest would usually escape the notice of most people and would not elicit any discussion of potential invasiveness. On the other end of the spectrum, an extensive carpet of a non-native species spread across an entire hillside with multiple, detrimental effects on surrounding plants and animals can easily be perceived as being invasive (especially if there are multiple reports of the same behavior in other locations). Where then, along this continuum, is a species first recognized by some authority as being "invasive"? This is where invasive species assessment protocols become important.

Many USA states have now adopted their own protocols and procedures for how to identify a plant species (or cultivar — more on this below) as invasive. The creation of a single, state-wide list of invasive plants is critical to prevent confusion among the general public in terms of which particular plants should be excluded from sale or at least closely regulated, and which plants should be promoted for gardening and other uses. Even more importantly, a single list is instrumental for green building councils who determine which plants are necessary for projects to get LEED certification, as well as for determining which plantings are permitted in developments that have adopted their own restrictions. Having a single recognized list also arguably levels the playing field for the nursery industry so that competition is fair and just among all of its members. It is important to remember, however, that the creation of a single statewide list does not preclude the creation of other regional lists by local parks and arboreta, but it does at least create some level of basic consistency across the state.

Invasive plant assessment on the state level is an ever-evolving process. Historically, invasive plant assessments in many states were quite casual, and often involved surveying land managers for the names of their most problematic species targeted for removal on their properties. The names of these plants were then combined together to form the invasive list for that particular state. However, over the last few years, many states have moved towards adopting more scientifically rigorous protocols. For example, the first list of invasive plants in Ohio was created in 2000 by surveying land managers across the state. Unfortunately, the nursery industry was inadvertently excluded from this conversation even though some of the listed species were of nursery importance. So when the Ohio Invasive Plants Council (OIPC) realized that the invasive plant list needed to be updated to recognize new invaders (such as lesser celandine, *Ficaria verna* [syn. *Ranunculus ficaria*]), the organization created an entire new assessment process that would be objective, transparent, and based on scientific data. The nursery industry was specifically invited to be a part of this process (in both the creation of the protocol as well as its implementation), as were representatives from research, land managers from local parks, state lands, and federal lands, non-profit organizations, and the general public. The final assessment protocol and its policy of implementation ultimately were approved by the leadership of the OIPC and the Ohio Nursery and Landscape Association (ONLA). Today, periodic assessments in Ohio are conducted by a five-person team, which includes two representatives suggested by the ONLA and approved by the OIPC. Other states as well have been purposely reaching out to engage nursery professionals, plant breeders, propagators, and horticulturalists in their invasive

plant assessment processes.

Many states have or are forming their own assessment protocols, and there are several generalizations that can be made. First, many protocols can be classified into two types, depending on the purpose of the resulting list for a particular state (Buerger et al., 2016). On one hand, species are identified as invasive purely for educational or informative reasons (for example, currently in Indiana, Michigan, and Ohio), while on the other hand, a plant species may be listed as invasive for purposes of regulation (Illinois, Minnesota, Wisconsin, Connecticut). Educational protocols usually rank assessed species as Invasive, Not Very Invasive (or similar wording), or Need More Information, and these protocols often involve a point system. In contrast, regulatory protocols classify assessed species as Needing Some Regulation (Prohibited, Restricted, etc.), No Regulation, or Need More Information and these are often based on committee discussions using a non-point system or decision tree (or in some states, a point system is only used to guide the initial committee discussions). Second, the size and composition of the committee typically conducting these plant assessments varies by state (ranging from 5 members in Ohio to many more members in Wisconsin, depending on the species that is discussed). In contrast to the past, most states now increasingly recognize the horticultural industry and plant propagators as critical members of the assessment process and include them in discussions. For example, the Midwest Invasive Plant Network (MIPN) has been engaging various members of the green industry over the past 3 years with their Invasives in the Trade Working Group.

Assessments for various states typically consist of a mix of questions, some of which aim to predict whether a plant will invade. This is especially true for protocols developed for regulation purposes, as their intent is often to prevent future plant invasions (in contrast to just identifying plants that are already established invaders). The questions in the protocols for different states can generally be grouped together into at least five major categories (Buerger et al., 2016):

1) Current Distribution. These questions are designed to assess how widespread is the plant within natural areas locally, regionally, and sometimes even nationally. Plants growing in dense numbers within natural areas across regions where they were not planted will achieve a score or generate the most points that indicate the strong possibility that the plant may be invasive. In contrast, plants that are limited in number or not yet present within a given state may generate a low score for this particular set of questions. Some states also include questions about the distribution of the plant in surrounding areas or nearby states (if the plant is not yet present outside of cultivation in the state in question). This is critical because research has indicated that the best predictor of invasiveness in plants is whether the plant is invasive in a nearby location or similar habitat (Reichard and Hamilton, 1997; Kolar and Lodge, 2001; NAS, 2002).
2) Establishment and Expansion Capability. Plants that are most likely to be identified as invasive typically are those that are experiencing rapid expansion across multiple environments (or have the potential to do so). In some cases, these plants may have already established in a location and are just now showing early signs of spread or are otherwise already beginning to expand geographically. Questions within this category often refer to the biological characteristics of plants, such as seed production, vegetative spread, and seed dispersal ability (Sakai et al., 2001).
3) Ecological Impacts. This series of questions are motivated by the fact that some invasive plants have larger negative impacts on natural ecosystems than other plant species. The highest scores for these questions are often given to plants that outcompete native plants, reduce survival and reproduction of animal species, and negatively impact ecosystem processes such as nutrient cycling, fire regimes, and forest succession. This type of information is documented most often in the scientific literature for invaders widely distributed across their introduced range.
4) Socio-Economic and Cultural Impacts. A subset of states (such as Michigan and Florida) also consider the economic contribution of the assessed species as part of their normal assessment process. Most often this refers to the role of the species in

horticulture, or its potential or current use as feed for cattle, biofuels, or other means of generating financial income within the state. Essentially, the "invasiveness" of a species is downgraded slightly if its removal from industry would cause undue financial hardship on state residents or industries. Consequently, this category of questions is most prevalent in states whose goal is to regulate invasive species. In other states (such as Ohio), the economic importance of a species is not included in the assessment as it is considered separate from explaining why a species may be biologically invasive.

5) Prevention, Control, and Management. Several states acknowledge the importance of control and management costs of assessed plants. In this case, plants that are most difficult to remove from natural landscapes generate the highest assessment scores. As with the socio-economic questions, this category is not used in some state protocols because the cost of invasive removal is not considered by itself to be a biological reason why a plant may become invasive on its own. In many cases, however, land managers find this category of questions to be extremely helpful in prioritizing their management plans.

Regardless of the categories of questions above, most state protocols require evidence to support each answer. Ideally, this would consist of a scientific study published in the peer-reviewed literature. In some cases, this involves documentation of the occurrence of a plant in natural areas, using mapping sources such as BONAP (http://www.bonap.org), USDA PLANTS database (http://plants.usda.gov/java/; note that the "I" species notation here indicates "Introduced", and not "Invasive"), or EDDMapS (https://www.eddmaps.org). Ultimately, effective protocols must yield answers and final assessments that are easily understandable, transparent, and clearly based on scientific evidence in order to be convincing to a broad range of constituents.

THE CULTIVAR QUESTION

As more states develop assessment protocols, there is increasing focus on the role of cultivars in species invasions (see for example, Knight et al., 2011) and how they should be dealt with in the assessment process. Although there is not yet general consensus, many states currently group cultivars with the parental species. In this case, if a given plant species is assessed as invasive, all known cultivars are also listed as invasive, unless shown otherwise. In other words, cultivars are "presumed guilty unless proven innocent." In other states, cultivars are assessed separately from the original species, either using the same protocol (as in Ohio) or a separate protocol developed specifically for cultivars (Florida, Indiana, and New York). In Ohio, this process is particularly difficult because of the frequent lack of biological information regarding specific cultivars in the scientific literature.

An important challenge to the assessment of cultivars often involves the identification of escaped individuals. Are escapees the cultivar itself (usually rare), offspring of cultivars planted nearby, offspring from seeds dispersed from naturalized populations that were initiated by seeds of cultivars, or are they members of the parental species? Although escapees are typically identified through morphological traits such as growth form or leaf color and shape, this can be deceptive in some cases and genetic methods remain the best way to conclusively verify the identity of escaped individuals. For example, individuals of Japanese barberry (*Berberis thunbergii*) are sometimes found in natural areas, but their ornamental origin has been questioned because wild plants produce green leaves, lacking the red/purple coloration of most popular cultivars. However, it has since been shown using greenhouse crosses that a proportion of offspring of purple cultivars can indeed produce green leaves (Lehrer et al., 2006a; Lehrer and Brand, 2010). Even more importantly, an individual plant can shift from producing purple to green leaves during a single growing season, depending on the amount of light available (Lehrer and Brand, 2010). Furthermore, genetic tests of wild individuals have confirmed their cultivar parentage (Lubell et al., 2009), and Japanese barberry cultivars are known to produce seed (Lehrer et al., 2006b) that germinate and grow in natural conditions (Lubell and Brand, 2011) with their offspring capable of also producing seed in woodlands (Brand et al., 2012). Consequently, the identity

of escaped individuals in natural areas must be examined carefully because wild individuals may not morphologically resemble their cultivar parent. A straightforward way to overcome the difficulty of determining which cultivars have or will contribute to invasive populations is to determine if a cultivar is capable of producing viable seeds or other propagules that can disperse away from the maternal plant.

An additional concern for cultivar assessment is the potential for different cultivars of certain plant species to cross-fertilize one another, creating hybrids and potentially triggering invasive populations. This has been seen, for example, in Callery pear (*Pyrus calleryana*) trees in which any given cultivar is self-incompatible (such as 'Bradford', 'Chanticleer', or 'Autumn Blaze') but the combination of cultivars (or a cultivar and its rootstock) together results in cross-fertilization and seed production (Culley and Hardiman, 2007; Culley et al., 2011). Thus an individual cultivar is technically not invasive, but the species is invasive because of the different cultivars that are produced and distributed together across the county (Culley and Hardiman, 2009). Similarly, popular cultivars of *Lythrum virgatum* such as 'Morden Pink' and 'Morden's Gleam" (often sold as alternatives to the highly invasive *L. salicaria*) are now known to produce seeds following cross-pollination with each other or with introduced *L. salicaria* growing nearby (Lindgren and Clay, 1993; Amon et al., 2007). This highlights the fact that cultivars cannot be examined in isolation of one another but they must be grown together in an array of genotypes to best determine which may have any potential to spread.

More recently, researchers and plant breeders have begun to focus on the development of low fecundity ("sterile") cultivars that may serve as practical alternatives to highly invasive, but ornamentally popular plant species (e.g., Callery pear, Japanese barberry, etc.). This is most important in states with invasive plant regulation but it also provides a way in which ornamental plant breeders can be perceived as being environmentally friendly. However, the concept of sterility is still debated by researchers – such as whether sterility is permanent or transient, and whether seed sterility is sufficient or whether pollen sterility is also important. In addition, vegetative growth is rarely addressed in cultivars and could be important, especially for plants that disperse by vegetative fragments growing near waterways where water dispersal is common. Scientific studies have shown that even cultivars with very low seed production can still potentially trigger an invasion (Knight et al., 2011). However, most researchers agree that a permanent, completely sterile plant may not be realistic in the long term. For example, some states, such as Oregon where butterfly bush (*Buddleja davidii*) is regulated, define sterility as less than 2% seed production in order for cultivars be approved for statewide sale. In other words, this level of seed production is viewed as an acceptable level of risk in the state. Many states in the Midwestern USA are now working together to best define the concept of sterility for cultivars and what would be an acceptable standard.

CONCLUSIONS

In order to remain profitable, plant propagators need to remain cognizant of invasive plant assessment in their state, especially for ornamental plant species or cultivars that are just beginning to spread but have already been determined to be invasive in other states. There are many opportunities for plant propagators to become actively involved in the discussion of and specifically, the assessment of invasive plants. A good starting point is to contact the invasive plant council (sometimes known as the exotic pest council) in their state, if such a council exists and is active. If a plant propagator lives in the midwestern United States, a good resource is also the Midwest Invasive Plant Network MIPN; see http://www.mipn.org). Many of these organizations would like to engage plant propagators and breeders in their discussions, in recognition of that fact that woody invaders in particular often have a past or current horticultural use. There is also increasing recognition that we all have a common interest in protecting our natural resources and working together to create practical ways to reduce the harmful impacts of invasive species in our communities. Horticulturists need to also engage in these discussions so that they can be part of solutions that allow them to remain commercially viable while effectively reducing

current and future species invasions. One proactive approach is for plant breeders and propagators to begin to develop sterile cultivars so that they can be well positioned to offer alternatives if the associated species is identified as invasive in the future. Other solutions may also be found if plant propagators actively engage in discussions with land managers, academic researchers, and other interested parties who recognize that they all have a common interest – to reduce species invasions in our natural communities.

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