LETTER

Screening new plant introductions for potential invasiveness: a test of impacts for the United States

Doria R. Gordon[1,2] & Crysta A. Gantz[2]

[1] The Nature Conservancy, University of Florida, P.O. Box 118526, Gainesville, Florida 32611, USA
[2] Department of Botany, University of Florida, P.O. Box 118526, Gainesville, Florida 32611, USA

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Correspondence
Doria R. Gordon, The Nature Conservancy and Department of Botany, University of Florida, P.O. Box 118526, Gainesville, Florida 32611 USA. Tel.: 352-392-5949; fax: 352-846-1344. E-mail: dgordon@tnc.org; cgantz@ufl.edu

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Abstract

The economic, health, and environmental costs of invasive plant species suggest the need for screening systems to reduce the probability of importing new harmful invaders. We assessed 105 plant species introduced to the United States since 1995 using the Australian Weed Risk Assessment system and a secondary screen to evaluate the proportion of species that would have been prohibited from import were such a screening system implemented. These tools are likely to result in correct decisions to accept or reject species of unknown invasive potential over 80% of the time. The species tested spanned temperate and tropical locations of origin and represented all vascular plant life forms with the exception of aquatic plants. We had insufficient data to complete assessment of 4% of the species. None of the remaining 101 species were predicted to become invasive: 88% were predicted to be noninvasive and 12% required further evaluation. On average, we required 8 hours to assess each species. These results, in combination with the savings incurred when likely invaders are identified and prohibited prior to import, suggest that this screening system could be implemented to protect the economy and environment and would be unlikely to significantly preclude opportunities for the horticultural industry.

Introduction

The economic, health, and environmental costs incurred by invasive species have resulted in increased calls for screening tools that distinguish and preclude import of new species with high probability of becoming invasive (e.g., National Plant Board 1999; Lodge *et al*. 2006; Smith *et al*. 2008). Several recent studies have examined approaches to predicting which plant species are likely to become invasive. While a variety of methods have been developed (e.g., Tucker & Richardson 1995; Reichard & Hamilton 1997; Frappier & Eckert 2003; Weber & Gut 2004; Widrlechner *et al*. 2004; Herron *et al*. 2007; Parker *et al*. 2007), a suite of studies has focused on the Australian Weed Risk Assessment system (hereafter WRA) either alone (Pheloung *et al*. 1999; Daehler *et al*. 2004; Kato *et al*. 2006; Gordon *et al*. 2008b) or in comparison (Daeher & Carino 2000; Jefferson *et al*. 2004; Křivánek & Pyšek 2006) with other methods. These tests have encompassed tropical and temperate, island and continental locations.

Where different methods have been compared, the WRA has generally been determined to be more accurate, particularly in identification of the species likely to invade and impact natural systems (Daeher & Carino 2000; Jefferson *et al*. 2004; Křivánek & Pyšek 2006). Further, the WRA addresses the full range of vascular plants, while some approaches (Tucker & Richardson 1995; Reichard & Hamilton 1997; Frappier & Eckert 2003; Widrlechner *et al*. 2004; Herron *et al*. 2007) address only woody species. Finally, the WRA appears to identify invaders and noninvaders with consistent accuracy (90% and >70%, respectively) across all geographies tested (Gordon *et al*. 2008a). The results suggest that species with unknown invasive potential are accurately accepted or rejected for import by the WRA over 80% of the time (Gordon *et al*. 2008a). Implementation of the WRA in Australia is predicted to save the country US$1.67 billion (AU$1.8 billion) over 50 years (Keller *et al*. 2007). Because of these combined results, the WRA is currently being tested in Japan (Nishida 2006), Italy (Crosti *et al*. 2007), and Canada (C. Wilson, Canadian Food Inspection Agency, pers. comm., 2008).

In the United States, calls for a greater focus on preventing the import of invaders have come from several organizations, including the National Plant Board (1999), National Invasive Species Council (2001), and Ecological Society of America (Lodge *et al*. 2006). Recognizing this need, the U.S. Department of Agriculture, Animal and Plant Health Inspection Service (USDA APHIS 2004) announced their intent to revise the plant quarantine regulation. However, any approach adopted must balance a precautionary approach with one that will not unduly or unnecessarily burden industries importing plant species, which contribute substantially to the U.S. agricultural economy. For example, the horticulture industry is the fifth largest agricultural commodity group in the United States (U.S. Department of Agriculture 2004) and is the fastest growing sector of agriculture (Hall *et al*. 2006). While we know that the vast majority of the plant species imported to new geographies have not become invasive, most of the invaders were initially introduced for horticultural purposes (Reichard & Hamilton 1997; Virtue *et al*. 2004; Mack 2005; Dehnen-Schmutz *et al*. 2007).

As a result, investigation of the potential impact of implementing a screening approach like the WRA on the U.S. horticulture industry seems timely. If research indicates that the majority of plants imported would not be restricted, conservationists, horticulturalists, regulators, and commercial interests alike may agree on a preventative approach. In Australia, between 1997 and 2007, 55% of all 3,300 species that were assessed were accepted, 21% required further evaluation, and 24% were rejected (Riddle *et al*. 2008). However, outcomes would be resolved for over 60% (Gordon *et al*. 2008a) of the species needing more evaluation if Australia implemented the secondary screen developed by Daehler *et al*. (2004). Past experience suggests that the majority of those species would be accepted for import using this screen (Gordon *et al*. 2008a).

In this project, we assessed 105 recently introduced plant species using the WRA to evaluate the proportion of species that might be prohibited from import were such a screening system implemented. While the difficulty of detecting extremely rare events (base rate effect, *sensu* Smith *et al*. 1999) suggests that we will reject a smaller number of species from a pool of 100 species than a pool of 1000, this work should provide an indication of the potential impact of a required screening system on importers. We worked with the botanical garden and horticulture communities to identify species that have been imported to the United States recently, to ensure that we were addressing species of interest to importing entities but whose invasive potential was not yet understood. Our intent was to mimic a pre-border risk assessment process in which novel species to the United States are screened for potential to become invasive prior to import.

Methods

Species selected

No comprehensive database of non-native species introduced to the United States or tracking of dates of new species imported currently exists. As a result, neither the identity nor rate of new introductions can easily be determined. Species identification for this research was completed with the help of botanical gardens and horticultural businesses that made their introduction data available: the Chicago Botanic Garden, Fairchild Tropical Botanic Garden, the U.S. Department of Agriculture (USDA) Subtropical Horticulture Research Station (MIA), and from the website of Plant Delights Nursery in North Carolina (www.plantdelights.com/About/intros.html). Additional species were identified from records from Heronswood Nursery in Kingston, Washington (Hinkley 1999).

In order to have at least 100 species for this assessment, we identified 105 species that had been imported to the United States (including Hawaii and Puerto Rico) since 1995 (Appendix 1). We assumed that we would have to eliminate some of the species because of insufficient data or because later information would indicate that they had been introduced earlier than 1995.

Only full species were considered for this assessment. The initial identification of species was based upon the acquisition date for the species provided by each organization or individual collector. We then removed species if they had duplicate accession records, were native to the United States, or were insufficiently identified. We searched the Internet and literature on each species, including several references on early plant introductions to the United States (e.g., Wilson 1913; Bailey 1949). Any species for which we found evidence of introduction earlier than 1995 were excluded from this study.

While it is possible that some of these species were introduced earlier, we located no such records. We also searched for but found no evidence of naturalization of any of the species in the United States. Assuming we have not missed any taxonomic synonyms, if some species were imported earlier they were either so infrequent or

Table 1 U.S. habitat-specific modifications for WRA questions 2.01, 2.04, 4.10, and 8.05.

WRA #	Question	Modification for the United States
2.01	Species suited to . . .	NAPPFAST Global Plant Hardiness Zones in the United States[a]
2.04	Native or naturalized in regions with . . .	an average of 11-60 inches of annual precipitation[b]
4.10	Grows on . . .	any soil order representing >5% cover in the United States[c]
8.05	Effective natural enemies present . . .	in the contiguous United States and Alaska

[a]Data from: http://www.nappfast.org.
[b]Data from: http://www.prism.oregonstate.edu/.
[c]Data from: http://soils.usda.gov/use/worldsoils/mapindex/order.html.

so unsuccessful that the species did not persist in the trade and any introduction must have been limited.

The species were selected to include a variety of growth forms, families, and regions of origin. Cultivars and varieties were not selected because of generally insufficient data available at the sub-species level. No aquatic plants were included because the horticultural sources we consulted did not include aquatic species in their lists. These efforts to include the described breadth of species from the sources consulted precluded a random sample of all species introduced; however, no other bias was incorporated into the list of species assessed. The species tested are representative of the pool of plant species introduced to the United States for horticultural purposes since 1995.

WRA implementation

The WRA uses 49 questions to develop scores for each species that correspond to outcomes of "accept" for import, "evaluate further", or "reject" because of potential for invasion in the region of concern (Pheloung *et al.* 1999). Each of the questions receives a score, ranging from −3 to 5 (most, −1 to 1), depending on the answer. While not all questions need scores to complete the WRA, a minimum of 10 questions distributed as specified must be answered. The scores for all answered questions are summed to determine a total score. If the total is greater than 6, the species has a high likelihood of becoming invasive (should not be introduced, or reject); a total of 1–6 indicates that further evaluation is necessary before a regulatory decision is possible; and a total less than 1 suggests the species is unlikely to be invasive (no restriction on introduction, or accept). These ranges for score interpretation were originally empirically determined (Pheloung *et al.* 1999) and have worked consistently in all subsequent tests (Gordon *et al.* 2008a).

We used clarified definitions of the WRA questions adopted by most of the previous developers or implementers of the WRA (Gordon *et al.* 2008c). Data used to address the 49 WRA questions were only from occurrences of the species outside of the United States. Exclusion of data from within the United States allows unbiased prediction of potential for invasiveness. Similarly, we did not affirm that propagules of the species are distributed intentionally by people (question 7.02), unless we had positive evidence of distribution elsewhere than the United States. We also used a secondary screen (Daehler *et al.* 2004) to help resolve decisions for species with the "evaluate further" outcome. This tool is a decision tree that includes a subset of three (herb or small shrub) to six (vine) WRA questions depending on the life form of the species (Daehler *et al.* 2004).

Four WRA questions, originally specific to the environments and climates of Australia, were modified for applicability to the United States (Table 1). For question 2.01, the global plant hardiness zone maps developed for a USDA APHIS Plant Pest Forecasting System (www.nappfast.org) were used to determine whether a species would be likely to survive in any of the United States hardiness zones based upon the documented native and naturalized distribution range of the species. If the distribution was limited to the tropics, the species received a climate match score of 1. All other species fell within the range of the United States hardiness zones (contiguous United States and Alaska) and received a climate match score of 2.

We obtained data for the WRA from reviews of the primary literature, invasive species references and websites for different regions of the world, horticultural and forestry references, floras, and online searches.

Analysis

We examined the correlation between score and number of questions answered to evaluate the influence of data availability on our results. We then used chi-square analysis with a Fisher's exact two-tailed test to evaluate any

Table 2 Summary of the WRA results for 101 vascular plant species introduced into the United States since 1995 by growth form.

Result	Total # species	Graminoid	Forb/ herb	Shrub	Vine/ liana	Tree
Accept	89	1	51	14	1	22
Evaluate Further	12	1	0	3	3	5
Reject	0	0	0	0	0	0

differences in results by plant growth form or region of nativity.

Results

Data availability

Of the 105 species identified, we had to eliminate four (or 4%) because of insufficient data availability. All results will be reported for the 101 species that we could fully assess. On average, we were able to answer 26 (range 21 to 33) of the 49 questions per species. The total score was independent of the number of questions answered for the species ($r = 0.12$, $P = 0.23$).

The 101 species include 53 herbaceous and 48 woody species in 59 families (Table 2, Appendix 1). Additionally, the species originate from many different biogeographic realms (Olson *et al*. 2001): 13% are native to Afrotropic, 4% to Australasia, 16% to Indo-Malay, 22% to Neotropic, and 35% to Palearctic (Table 3). Eleven species were native to two realms: 9% to the Indo-Malay and Paleoarctic, 1% to each of the Afrotropic and Indo-Malay, and Australasia and Indo-Malay (Appendix 1). These proportions reflect the regions of plant exploration of the organizations providing species accession data. While unevenly distributed, the breadth of life forms and biogeographic realms of origin suggest that results found here should apply across the range of vascular plant exploration activities.

Table 3 Summary of the WRA results for 99 vascular plant species introduced into the United States since 1995 by biogeographic realm (Olson *et al*. 2001). Two species (one accepted, one evaluate further) native to two unique realm combinations not included.

Result	Afro-tropic	Austra-lasia	Indo-Malay	Neo-tropic	Palearctic	Indo-Malay & Palearctic
Accept	11	4	14	19	31	9
Evaluate Further	2	0	2	3	4	0
Reject	0	0	0	0	0	0

We assessed the species in batches of approximately 10 each. Under those circumstances, we estimate that it took on average 8 hours per species for an experienced assessor to collect and evaluate the data necessary to address the 49 questions.

WRA results

None of the 101 species tested was rejected (i.e., predicted to become a harmful invader in the United States; Table 2, Appendix 1). Overall, 89 species (88%) were accepted as unlikely to become invasive. Initially 41 species (41%) required further evaluation (Appendix 1), but this number was reduced by 71% to 12 species after application of the secondary screen (Daehler *et al*. 2004; Table 2). All results reported are after implementation of the secondary screen.

While sample sizes were not equivalent, we found that the number of species accepted or requiring further evaluation differed by growth form ($\chi^2 = 26.55$, $P < 0.0001$; Table 2). The primary pattern explaining this difference was that 92% of the species requiring further evaluation were woody ($\chi^2 = 8.73$, $P = 0.0013$). In contrast, no pattern was detected in the outcome by biogeographic realm of origin ($\chi^2 = 2.04$, $P = 0.84$; Table 3).

Discussion

The primary finding of this research was that none of the species tested that were imported into the United States since 1995 would have been rejected had they been required to undergo screening with the WRA prior to import. The species spanned temperate and tropical locations of origin across all biogeographic realms and represented all vascular plant life forms with the exception of aquatic plants. While 12% of the species would require further investigation that might delay an import decision, this test suggests that the WRA would not have a substantial impact on the plant industry if this screening system were required for import of new species as it is in Australia and New Zealand.

The percentages found in this study, and particularly the lack of rejected species, need to be interpreted carefully given the known low probability that an imported species will become invasive. Williamson & Fitter (1996) estimated that 0.1% of species that are introduced become invasive. Other data suggest that this number is closer to 1% (Groves *et al*. 2003; Mack 2005). Regardless, the probability is low enough that if the WRA is accurately predicting likely invaders, we should not be surprised that none of the 101 species was rejected (Smith *et al*. 1999).

We do know that approximately 60% of species that naturalize but are not harmful invaders are also rejected by the WRA (Gordon *et al*. 2008a). While naturalization also has relatively low probability, the rates are potentially 10-fold higher (Williamson & Fitter 1996) than those for invasion: up to 10% (Groves *et al*. 2003; Virtue *et al*. 2004; Mack 2005; Dehnen-Schmutz *et al*. 2007) or higher (Caley *et al*. 2008). These proportions do not explain the higher rejection rate found by Australia in over a decade of assessment. However, given the number of species we tested, we had anticipated that roughly 5% of the species might have been rejected. In fact, none of these introduced species appear likely to become naturalized or invasive in the United States.

Further, any screening system must address potential opportunity costs of rejecting species that will not become invasive. Earlier tests of the WRA suggest that potentially 30% of species might be falsely rejected (Gordon *et al*. 2008a). Again, this test suggests that such lost opportunities will be rare, since no species were rejected.

The concern that implementing mandatory or voluntary screening will be impossible because of insufficient data on species new to the trade was not supported by our data. While the average number of questions answered (26) is lower than the roughly 35 reported for retroactive tests of species with longer history in their introduced ranges (Gordon *et al*. 2008b), we could run the WRA on all but 4% of the species tested with the WRA. Aside from assuring a breadth of growth forms and families, we did no sorting or exclusion of species that would suggest that these proportions would be different for any species proposed for import. The independence of total score from the number of questions answered seen here and in other studies (Daehler & Carino 2000; Kato *et al*. 2006; but see the weak relationship found by Daehler *et al*. 2004) also suggests that risk assessment will be feasible for most new species.

The average length of time we found necessary to assess a species is consistent with that reported previously for the WRA (Daehler & Carino 2000; Kato *et al*. 2006; Gordon *et al*. 2008b). The 1 to perhaps 2 days necessary to assess a species is shorter than the reported 2 to 8 weeks needed for the current U.S. risk assessment (Parker *et al*. 2007).

These results, in combination with earlier findings that identification and restriction of likely invaders prior to import would be less costly than controlling species once they have been released (Smith *et al*. 1999; Keller *et al*. 2007), suggest that implementation of this screening system would be cost-effective for the United States and other countries. While specific risk results will vary with the environmental conditions and biota of different countries, the consistent accuracy of the WRA in different regions (Gordon *et al*. 2008a) suggests that the patterns seen for screening plant species imports to the United States would likely be similar elsewhere.

In the United States both the plant quarantine regulations and the method for weed risk assessment are currently under revision to increase safeguards against importing new invaders. The intent of the current USDA revision is to initially identify and regulate new species for which evidence of pest risk is readily available. These species will be added to a new category of plants for planting, those that are "Not Authorized for Import Pending Pest Risk Analysis" (NAPPRA) (P. Lehtonen, USDA APHIS PPQ, pers. comm., 2008). While a substantial improvement to the current situation, restriction of screening to a limited group of species, rather than mandatory screening of all new species will likely result in the continued import of invasive species.

The USDA is considering a more comprehensive approach for the future, but is currently limited by data on those species that have already been imported into the United States: import data is only tracked by the USDA at the genus level (P. Lehtonen, USDA APHIS PPQ, pers. comm., 2008). As a result, the rate that new plant species are imported to the United States is not known. Other countries likely have similarly insufficient data on new species imports. An example that might indicate the scale of this rate for the United States is that the Midwest Plant Collecting Consortium imported 167 plant species from the Republic of Georgia over 2 years (Jefferson *et al*. 2004), 13 of which were novel species (B. Tankersley, pers. comm., 2008). Given that plant exploration for novel species by consortia or individuals is episodic rather than continuous, importation is likely on the order of tens of species per year. However, increasing global trade is enhancing opportunities for exploration and import of horticultural and other species (Perrings *et al*. 2002; Mack 2005).

A more comprehensive preventative approach would require development of a database of all species that have already been imported and a number of criteria that define those species. Such database development should be initiated now, to allow implementation of regulation requiring screening of all novel imports. However, even without this database, a screening system such as the WRA can clearly be used more proactively in countries both for prohibiting potentially harmful new introductions and for restricting the use of existing species before they have become invasive and are beyond effective management through preventative mechanisms (e.g., Barney & DiTomaso 2008).

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Appendix 1. Results for all 105 species introduced into the United States since 1995 assessed using the Australian Weed Risk Assessment modified for the United States. A conclusion followed by an asterisk indicates the use of the secondary screen (Daehler *et al*. 2004) for resolving species requiring further evaluation. If no conclusion exists, insufficient data were available to complete the WRA.

Scientific name	Biogeographic realm	Where collected	Family	Growth form	Score	Conclusion
Acalypha siamensis	Indo-Malay	?	Euphorbiaceae	Shrub	3	Accept*
Adansonia rubrostipa	Afrotropic	South Africa	Bombacaceae	Tree	−7	Accept
Adansonia suarezensis	Afrotropic	South Africa	Bombacaceae	Tree	−7	Accept
Adiantopsis chlorophylla	Neotropic	Argentina	Pteridaceae	Forb/herb	2	Accept*
Adiantum thalictroides	Neotropic	Argentina	Pteridaceae	Forb/herb	4	Accept*
Alloxylon flammeum	Australasia	Australia	Proteaceae	Tree	−2	Accept
Amorphophallus lambii	Indo-Malay	Thailand	Araceae	Forb/herb	2	Accept*
Angiopteris smithii	Indo-Malay	Indonesia	Angiopteridaceae	Forb/herb	N/A	
Aquilegia caucasica	Palearctic	Repub. Georgia	Ranunculaceae	Forb/herb	−1	Accept
Araiostegia pseudocystopteris	Indo-Malay; Palearctic	India	Davalliaceae	Forb/herb	3	Accept*
Ardisia nigrescens	Neotropic	Honduras	Myrsinaceae	Shrub	−1	Accept
Areca ridleyana	Indo-Malay	Malaysia	Arecaceae	Shrub	0	Accept
Arnebia pulchra	Palearctic	Repub. Georgia	Boraginaceae	Forb/herb	−1	Accept
Asarum delavayi	Palearctic	China	Aristolochiaceae	Forb/herb	0	Accept
Aspidistra patentiloba	Indo-Malay	China	Liliaceae	Forb/herb	2	Accept*

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Appendix 1. Continued.

Scientific name	Biogeographic realm	Where collected	Family	Growth form	Score	Conclusion
Aster oharai	Palearctic	Russia	Asteraceae	Forb/herb	−1	Accept
Bambusa lako	Indo-Malay	Indonesia	Poaceae	Graminoid	1	**Evaluate**
Bauhinia natalensis	Afrotropic	South Africa	Fabaceae	Tree	1	Accept*
Beesia calthaefolia	Indo-Malay; Palearctic	China	Ranunculaceae	Forb/herb	0	Accept
Bellevalia makuensis	Palearctic	Repub. Georgia	Hyacinthaceae	Forb/herb	N/A	
Berberis iberica	Palearctic	Repub. Georgia	Berberidaceae	Shrub	1	**Evaluate**
Besleria laxiflora	Neotropic	Honduras	Gesneriaceae	Shrub	−3	Accept
Carex ciliatomarginata	Palearctic	Japan	Cyperaceae	Graminoid	4	Accept*
Cerastium purpurascens	Palearctic	Repub. Georgia	Caryophyllaceae	Forb/herb	2	Accept*
Chione sylvicola	Neotropic	?	Rubiaceae	Tree	−2	Accept
Chloranthus sessilifolius	Indo-Malay; Palearctic	UK	Chloranthaceae	Forb/herb	1	Accept*
Chlorophytum saundersiae	Afrotropic	?	Liliaceae	Forb/herb	0	Accept
Chrysophyllum venezuelanense	Neotropic	Ecuador	Sapotaceae	Tree	−5	Accept
Chrysosplenium valdivicum	Neotropic	Chile	Saxifragaceae	Forb/herb	−1	Accept
Cicerbita prenanthoides	Palearctic	Repub. Georgia	Asteraceae	Forb/herb	−3	Accept
Cimicifuga brachycarpa	Palearctic	China	Ranunculaceae	Forb/herb	−2	Accept
Cladochaeta candidissima	Palearctic	Repub. Georgia	Asteraceae	Forb/herb	1	Accept*
Clematis hexapetala	Palearctic	Russia	Ranunculaceae	Forb/herb	4	Accept*
Colocasia heterochroma	Indo-Malay	China	Araceae	Forb/herb	3	Accept*
Combretum bracteosum	Afrotropic	?	Combretaceae	Tree	4	Accept*
Combretum ovalifolium	Indo-Malay	India	Combretaceae	Liana/shrub	2	**Evaluate**
Cotoneaster submultiflorus	Palearctic	China	Rosaceae	Shrub	2	**Evaluate**
Cupania cinerea	Neotropic	Colombia	Sapindaceae	Tree	1	**Evaluate**
Delonix decaryi	Afrotropic	South Africa	Fabaceae	Tree	1	Accept*
Dianthus cretaceus	Palearctic	Repub. Georgia	Caryophyllaceae	Forb/herb	−1	Accept
Dianthus imereticus	Palearctic	Repub. Georgia	Caryophyllaceae	Forb/herb	0	Accept
Dillenia reticulata	Indo-Malay	Malaysia	Dilleniaceae	Tree	−2	Accept
Dioscorea dodecaneura	Neotropic	?	Dioscoreaceae	Vine	2	**Evaluate**
Disporopsis jinfushanensis	Palearctic	China	Liliaceae	Forb/herb	0	Accept
Disporum megalanthum	Palearctic	China	Colchicaceae	Forb/herb	0	Accept
Epimedium chlorandrum	Palearctic	China	Berberidaceae	Forb/herb	−2	Accept
Faramea multiflora	Neotropic	Costa Rica	Rubiaceae	Shrub/tree	−2	Accept
Ficus destruens	Australasia	Australia	Moraceae	Tree	−2	Accept
Filipendula glaberrima	Palearctic	Russia	Rosaceae	Forb/herb	−2	Accept
Flacourtia montana	Indo-Malay	?	Flacourtiaceae	Tree	−2	Accept
Fritillaria caucasica	Palearctic	Repub. Georgia	Liliaceae	Forb/herb	2	Accept*
Geranium ruprechtii	Palearctic	Repub. Georgia	Geraniaceae	Forb/herb	3	Accept*
Gironniera parvifolia	Indo-Malay	Malaysia	Ulmaceae	Tree	−4	Accept
Grewia flavescens	Afrotropic; Indo-Malay	?	Tiliaceae	Tree	0	Accept
Hapaline benthamiana	Indo-Malay	?	Araceae	Forb/herb	1	Accept*
Hedera pastuchovii	Palearctic	Repub. Georgia	Araliaceae	Vine	3	**Evaluate**
Heliconia steyermarkii	Neotropic	Venezuela	Heliconiaceae	Forb/herb	−2	Accept
Ilex guayusa	Neotropic	Ecuador	Aquifoliaceae	Shrub	0	Accept
Iris caucasica	Palearctic	Repub. Georgia	Iridaceae	Forb/herb	2	Accept*
Kirkia acuminata	Afrotropic	Zimbabwe	Simaroubaceae	Tree	−2	Accept
Lespedeza liukiuensis	Palearctic	Japan	Fabaceae	Shrub	5	**Evaluate**
Livistona concinna	Australasia	Australia	Arecaceae	Tree	−3	Accept
Loxostylis alata	Afrotropic	?	Anacardiaceae	Tree	0	Accept
Mangifera griffithii	Indo-Malay	Indonesia	Anacardiaceae	Tree	−3	Accept
Mapania baldwinii	Afrotropic	Cote D'Ivoire	Cyperaceae	Forb/herb	−2	Accept
Massularia acuminata	Afrotropic	Cameroon	Rubiaceae	Tree/shrub	−2	Accept
Meehania montis-koyae	Palearctic	Japan	Lamiaceae	Forb/herb	−2	Accept
Musa sikkimensis	Indo-Malay	India	Musaceae	Monocot (shrub)	0	Accept
Muscari tenuiflorum	Palearctic	Repub. Georgia	Hyacinthaceae	Forb/herb	5	Accept*
Myrcia dichasialis	Neotropic	Peru	Myrtaceae	Tree	−2	Accept

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Appendix 1. Continued.

Scientific name	Biogeographic realm	Where collected	Family	Growth form	Score	Conclusion
Ocotea meziana	Neotropic	Costa Rica	Lauraceae	Tree	−4	Accept
Ornithogalum kochii	Palearctic	Repub. Georgia	Liliaceae	Forb/herb	2	Accept*
Papaver oreophilum	Palearctic	Repub. Georgia	Papaveraceae	Forb/herb	2	Accept*
Pavonia dasypetala	Neotropic	Honduras	Malvaceae	Shrub	−2	Accept
Persicaria microcephala	Indo-Malay; Palearctic	?	Polygonaceae	Forb/herb	0	Accept
Petraeovitex bambusetorum	Indo-Malay	Thailand	Verbenaceae	Vine/shrub	N/A	
Pinellia peltata	Indo-Malay	China	Araceae	Forb/herb	3	Accept*
Pittosporum rubiginosum	Australasia	Australia	Pittosporaceae	Shrub	−3	Accept
Polygonatum kingianum	Indo-Malay; Palearctic	China	Liliaceae	Forb/herb	1	Accept*
Protium glabrum	Neotropic	Honduras	Burseraceae	Tree	−4	Accept
Pseudodracontium harmandii	Indo-Malay	Thailand	Araceae	Forb/herb	0	Accept
Psychotria chiapensis	Neotropic	Costa Rica	Rubiaceae	Shrub/tree	−5	Accept
Pulsatilla violacea	Palearctic	Repub. Georgia	Ranunculaceae	Forb/herb	0	Accept
Pyrgophyllum yunnanensis	Palearctic	China	Zingiberaceae	Forb/herb	−2	Accept
Remusatia pumila	Indo-Malay; Palearctic?	?	Araceae	Forb/herb	4	Accept*
Rohdea watanabei	Indo-Malay; Palearctic	Taiwan	Liliaceae	Forb/herb	0	Accept
Rondeletia leucophylla	Neotropic	Mexico	Rubiaceae	Shrub/tree	−1	Accept
Scabiosa olgae	Palearctic	Repub. Georgia	Dipsacaceae	Forb/herb	−2	Accept
Schotia latifolia	Afrotropic	?	Fabaceae	Tree	3	**Evaluate**
Scilla rosenii	Palearctic	Repub. Georgia	Liliaceae	Forb/herb	1	Accept*
Silene pygmaea	Palearctic	Repub. Georgia	Caryophyllaceae	Forb/herb	−2	Accept
Siparuna pauciflora	Neotropic	Costa Rica	Monimiaceae	Shrub/tree	−2	Accept
Smilacina fusca	Indo-Malay; Palearctic?	Nepal	Ruscaceae	Forb/herb	0	Accept
Sonneratia caseolaris	Australasia; Indo-Malay	Australia	Sonneratiaceae	Tree	2	**Evaluate**
Spiraea mongolica	Palearctic	China	Rosaceae	Shrub	0	Accept
Strychnos toxifera	Neotropic	?	Loganiaceae	Liana	−2	Accept
Tabernaemontana sananho	Neotropic	Ecuador	Apocynaceae	Shrub	−2	Accept
Tecoma guarume	Neotropic	?	Bignoniaceae	Tree	1	**Evaluate**
Terminalia randii	Afrotropic	Zimbabwe	Combretaceae	Tree	2	**Evaluate**
Thelypteris beddomei	Indo-Malay; Palearctic	?	Thelypteridaceae	Forb/herb	2	Accept*
Tricyrtis affinis	Palearctic	Japan	Liliaceae	Forb/herb	4	Accept*
Tulipa karabachensis	Palearctic	Azerbaijan	Liliaceae	Forb/herb	1	Accept*
Tupistra nutans	Indo-Malay	India	Liliaceae	Forb/herb	−1	Accept
Voacanga thouarsii	Afrotropic	South Africa	Apocynaceae	Tree	0	Accept
Ziziphus chloroxylon	Neotropic	Jamaica	Rhamnaceae	Tree	N/A	

