Ranking Nonindigenous Weed Species by Their Potential to Invade the United States

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Ranking Nonindigenous Weed Species by Their Potential to Invade the United States

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Because of the large number of potentially invasive species, and the time required to complete weed risk assessments (WRAs) with the use of the current, mandated system in the United States, species need to be prioritized for assessment and possible listing as Federal Noxious Weeds. Our objective was to rank the potential invasiveness of weedy or pest plant species not yet naturalized in the United States. We created a new model of invasiveness (hereafter the U.S. weed-ranking model) based on scoring factors within four elements: (1) invasiveness potential, or likelihood to exhibit invasive behavior; (2) geographic potential, or habitat suitability; (3) damage potential, or likely impact; and (4) entry potential, or likelihood to be introduced. The ranking score was the product of the four elements. We scored 250 species satisfactorily, from a list of 700 +. We analyzed model sensitivity to scoring factors, and compared results to those from a WRA model for Hawaii. For species not in cultivation in the United States, the top 25 species included a mix of annuals, perennials, sedges, shrubs, and trees. Most had exhibited invasive behavior in at least several other countries. Because of greater entry potential scores, the highest-scoring species were weeds in cultivation. Twenty-nine such species, out of 44 total, had scores greater than the highest scoring species not in cultivation. In comparison to the Hawaii WRA model, correlation and regression analyses indicated that the U.S. weed-ranking model produced similar, but not exact, results. The ranking model differs from other WRAs in the inclusion of entry potential and the use of a multiplicative approach, which better suited our objectives and United States regulations. Two highly ranked species have recently been listed as Federal Noxious Weeds, and we expect most top-tier species to be similarly assessed.
Key words: Invasive, exotic weeds, invasiveness model, weed risk assessment.

The flora of the contiguous United States and Alaska includes at least 17,000 exotic plants (Flora of North America Editorial Committee 1993a, 1993b), large numbers of which were introduced deliberately. Many of those have become important agricultural crops, and others have not significantly affected either agriculture or natural habitats. In contrast, approximately 500 species have become serious weeds of agriculture (Pimentel et al. 2000), and others have invaded natural habitats and replaced the native vegetation (e.g., Westbrooks 1998). Moreover, invasive species are the second greatest threat to biodiversity (native species) after habitat loss (Wilcove et al. 1998). Because of the economic and environmental costs of pest plants and other invasive species, U.S. government agencies were mandated in Executive Order 13112 (1999) to "mitigate the adverse effects of invasive pests that would harm agricultural, managed and natural ecosystems." Excluding all further plant introductions would most simply safeguard the United States against plant invasions, but that would be neither practical nor legal under current World Trade Organization and other international agreements.

Currently, 90 individual species and six complete genera of serious weeds on the Federal Noxious Weed List are prohibited entry into the United States (USDA-APHIS-PPQ 2006). Listing is the first and most important component of our exclusion policy because it requires importers to avoid deliberate or accidental importation. Candidate species must each be assessed as to whether or not they are likely to become invasive in the United States (USDA-APHIS-PPQ 2004a). These weed risk assessments (WRAs) (USDA-APHIS-PPQ 2004b) may take from 2 to 8 wk, generally, for risk analysts to produce. Although some people advocate the use of a screening tool, such as the Australian WRA (Pheloung et al. 1999), to make efficient regulatory decisions about plant imports (Keller et al. 2007), U.S. regulations currently require us to use a different approach (USDA-APHIS-PPQ 2004a). Given that, prioritizing species to identify those most likely to be listed as Federal Noxious Weeds and ensure that our WRA and listing processes work as efficiently as possible would be very helpful.

Most researchers agree that accurately predicting species invasiveness is very difficult without experimentation in the target habitat, partly because of the wide range of characteristics demonstrated by successful invaders (Goodwin et al. 1999; Newsome and Noble 1986; Roy 1990). For example, numerous studies have identified plant traits for predicting invasiveness in particular species (e.g., Reichard and Hamilton 1997; Richardson et al. 1994) but those characters have often been unreliable when extrapolated to other species or situations (Lonsdale and Smith 2001; Rejmanek and Richardson 1996; Smith et al. 1999). The scientific consensus is that no traits for plant invasiveness are universal (Williams et al. 2002).

Appraisal of species demonstrating invasiveness in the United States emphasizes those difficulties: Out of 123 invasive, problematic species in the United States (Cox 1999; Skinner et al. 2000), only 33 (27%) had been listed in Holm et al. (1979) as being serious or principal weeds elsewhere, and 27 (22%) were unlisted. That may largely be due to the agricultural bias of Holm et al. (1979), but some non-agricultural weeds have also failed to demonstrate invasiveness in their native habitats. For example, purple loosestrife (*Lythrum salicaria* L.) has been a serious environmental problem in the United States (Westbrooks 1998), but was not a "serious" or "principal" weed in Holm et al. (1979), and is recorded as weedy in only 10 countries. In other words, some plants only demonstrate invasive behavior after introduction to a new territory, often after a lag phase (Kowarik 1995). Some reasons for unexpected invasive behavior may be release from natural enemies in their native habitats (Mitchell and

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Table 1. Character descriptions, scoring (points), and criteria that are summed to estimate the invasive potential of plant species in the new ranking model.

Character	Points[a]	Criteria/rationale
Country weediness reports	3 each	= occurrence at "serious" level in Holm et al. (1979)
	2 each	= occurrence at "principal" level
	1 each	= any lower level
Other weediness reports	3 each	= occurrence as a serious weed, per country
Invasiveness elsewhere	10	= category 3 of invasive behavior in Binggeli et al. (1998), OR on the list of worst invasive species in Lowe et al. (2004), OR shows invasive behavior outside natural range
	5	= invasive weed in South Africa or prohibited in Australia
	3	= on other weed lists in New Zealand, South Africa, or Australia
Vegetative reproduction	3	= spreads vegetatively by rhizomes, stolons, etc.
Aquatic	5	= free-floating or fully submerged
	3	= otherwise adapted to aquatic conditions
Vine	3	= vines, spreading, climbing or scrambling plants
Seed production	1 to 3	a function of estimated annual production
Seed or spore size	3	= less than 1 mm
	2	= 1 to 2 mm
	1	= 2 to 3 mm
	0	> 3 mm
Dormancy	2	= dormancy or flexible germination strategy
Dispersal	3	= special dispersal structures, e.g., pappus, edible fruits, or burrs
	2	= aquatic species likely to be spread by water
	1	= known to have average dispersal ability
	0	= known to have very low dispersal ability
Inconspicuousness	1	= grass, sedge, or similar species (non–broad-leaved species)
Tolerances	2 each	Shade/drought/pest/frost/fire
Unpalatable	2	Escapes herbivory
Responds to rising CO_2	2	Increased growth rates

[a] If no criteria are met the score is zero.

Power 2003), or rapid evolutionary adaptation (Muller-Scharer et al. 2004). Regardless, some invasive behavior is probably unpredictable.

Still, to optimize assessments of possible noxious weeds, trying to rank species by potential invasiveness is reasonable. Weed risk assessment tools to date have typically been designed to predict whether or not a particular species will become invasive (Daehler et al. 2004; Pheloung et al. 1999). Our objective was to develop a model to rank plant species for their potential to be introduced and damage either agricultural or natural ecosystems in the United States. We focused on species that had already demonstrated invasive behavior elsewhere, which has been a reasonably consistent, useful indicator (Daehler et al. 2004; Kolar and Lodge 2001). To quantify potential invasiveness, we devised a scoring system, the U.S. weed-ranking model, based on previous WRA systems and the scientific literature on plant invasiveness. The U.S. weed ranking model is a unique, multiplicative model that includes factors that have generally proven useful in other models. The project was a collaborative effort between the Weed Science Society of America (WSSA) and the Center for Plant Health Science and Technology (CPHST) of the United States Department of Agriculture (USDA).

Materials and Methods

Plant Species. To develop a list of pest plants to rank, we first selected ca. 450 species in Holm et al. (1977) that were not yet naturalized in the United States but were classified as serious or principal weeds in at least one other country. Notably, most of the 200 world's worst weeds in Holm et al. (1977) already occur in the United States. To offset the authors' bias toward agricultural weeds and include recent literature, ca. 250 more species were added from other sources, the most important of which listed serious environmental pest plants that invade natural vegetation (e.g., Binggeli et al. 1998; Weber 2003). Other sources included country lists of noxious or "declared" weeds (Klein 2002), E-mail and Internet forums, and the weed science literature. We found about 730 species not naturalized in the United States with documented potential to be invasive.

We found, however, that distinguishing between species not yet known to occur in the United States and those reportedly being cultivated or available from horticultural sources was important. Possibly listing species not in cultivation is fairly straightforward, but species in cultivation may have commercial value, in particular, which could make listing more complicated. This information was captured in the model as entry potential (EP; see below).

Model Development. The model was based on the four following elements: entry potential, EP; invasive potential, IP; geographic potential, GP; and damage potential, DP. Except for GP, each element had several factors, which were scored as explained below. The ranking score R was the product of the four elements. Multiplicative models are a standard, well-studied approach for calculating ecological indices, but its use here was unique because WRA screening models have usually been additive or statistical (above). We think it was appropriate and logical because the four elements are largely independent of each other, and because model scores would approach zero if any element (particularly EP) approached zero—which is different from additive models.

As in other WRA screening models, point valuations here were arbitrary. These have usually been determined subjectively, with little justification, by researchers (e.g., Pheloung et al. 1999). We assigned point valuations for each model factor (Tables 1 and 2) based upon values for similar factors in other WRA systems, and invasiveness research. Factors that affected valuation included the quality of the information (e.g., Holm et al. 1979 = high quality), and the apparent relative contribution of the factor to the risk of invasiveness

Table 2. Factors, scoring, and criteria applied for the damage potential of plant species.

Character	Points	Criteria/rationale
Competitive to crops	0 to 0.2	Species in no/few/many crops and pastures
Cost/difficulty of control	− 0.1 to 0.1	Easy to difficult to control
Effects on fire regime	0.1	Flammable, or propagules have greater survival
Changes vegetation	0.2	Alters or replaces natural vegetation
Health hazard to livestock	0.1	For example, toxic, thorny
Health hazard to man	0.1	For example, toxic, benefits mosquitoes
Nitrogen-fixing	0.1	Possible growth advantage, or tolerance of low fertility areas
Obstructs water flow/use	0 to 0.2	Level of obstructiveness
Pest/disease interactions	− 0.1 to 0.1	Host of beneficial (negative) or pest (positive) species/pathogens
Reduces value of produce	0.1	For example, contaminates produce, interferes with operations
Related to genetically modified crop	0.1	For example, likely to acquire herbicide resistance

(e.g., under DP, changes vegetation > *N*-fixing). Furthermore, model testing (below) ensured that we understood the effects of our point valuations well, and probably better than for other WRA methodologies.

Invasive Potential, IP. Invasive potential was a critical element in the model, because it set the base value for invasiveness of a species, which was then modified by the scores for GP, DP, and EP. The factors considered under IP included the number of countries in which a species has naturalized, whether a species has been labeled a serious weed (Binggeli et al. 1998; Holm et al. 1979; Lowe et al. 2004), reproductive strategies, aquatic or vine habit, and dispersal ability (Table 1). Factor scores were summed to give the value of IP.

Geographic Potential, GP. The default score for GP was 1. This factor represents the likelihood of a species being able to spread throughout much of the United States. Here, however, we only reduced GP to 0.8 for species expected to have a very restricted ecological range in the United States, which were species restricted to coastal, saline, desert, or strictly lowland tropical conditions. We chose that level of reduction (20%) as an amount that would significantly but not overwhelmingly affect scores. More complex climate mapping was considered, but the current technology would have been difficult to apply efficiently to hundreds of species. A significant factor in that decision was the paucity of data available for most of the species. In addition, the United States has such a wide variety of climate and habitat types, a large decrease in GP would likely only have been justified for species with extremely limited potential distributions.

Damage Potential, DP. The default value of DP was also equal to 1. It was increased by 0.1 for each detrimental character, such as competitiveness with crops, hazards to humans or livestock, known vectoring of pests or diseases, or difficulty of control (Table 2). The value was reduced by 0.1 for species that were readily controlled.

Entry Potential, EP. The default score for EP was 0, and the maximum possible value was 1, which was given if we found evidence that a species was currently being or had been cultivated in the United States, as indicated by the following: Hortus Third (L. H. Bailey Hortorium 1976); literature searches; availability on U.S.-based horticultural Web sites; automated Internet searches with the Agricultural Internet Monitoring System (USDA-APHIS and CIPM 2006); and other on-line information [e.g., distribution data and links to other sources on the PLANTS Web site (USDA NRCS 2004)].

We considered that every species here might be accidentally introduced as a contaminant (e.g., in seed for propagation or on vehicles returned from overseas). The value for accidental introduction was increased by 0.1 if the species was present in China, which is an increasing trade partner with many potential weeds adapted to a temperate climate, or in bordering Mexico. In addition, up to 0.2 was added if the seeds were difficult to detect. Some species might also be deliberately introduced (+ 0.1 to 0.2) for food, medicinal, ornamental, or other reasons. Therefore, for species not known to be in cultivation, entry potential ranged from 0.2 to 0.7, where the maximum value represented a species that was (1) difficult to detect in seed lots, (2) naturalized in either Mexico or China, and (3) that might be deliberately introduced.

Scoring. All species in the database were first scored on a partial basis for IP. Based on the results of those searches and scores, species with very low scores (i.e., little available information) were excluded, and full searches and scoring were then done for several hundred remaining species. Preliminary searches indicated how much information was available for a species, and we thought it was very unlikely that many species with low preliminary scores would ultimately rank highly. Not all species could be scored satisfactorily, due to the lack of or difficulty of finding relevant information. We excluded species from the final rankings and analysis, for example, if we found no information about DP. Overall, we found sufficient information to generate scores for about 250 species, 44 of which were in cultivation in the United States.

Model Testing. To better understand the model, we analyzed correlations between the four main elements above, including semipartial correlations (SAS 2006) to assess the relative contributions of each element to R. We also did a model-sensitivity analysis to determine which elements and factors within those elements most affected the R score. We started with baseline scores of IP = 51 (i.e., maximum scores for each characteristic, except that extra countries = 3), GP = DP = 1, and EP = 0.7, which gave baseline R = 35.7. Then we sequentially increased single factor values by 25%, which allowed comparisons across factors. Sensitivity was assessed as the percent change of the new value, R', from R (i.e., $R'/35.7$ - 1). Lastly, we assessed the effects of deleting single factors under IP on the rankings of the top 100 species not in cultivation in the United States.

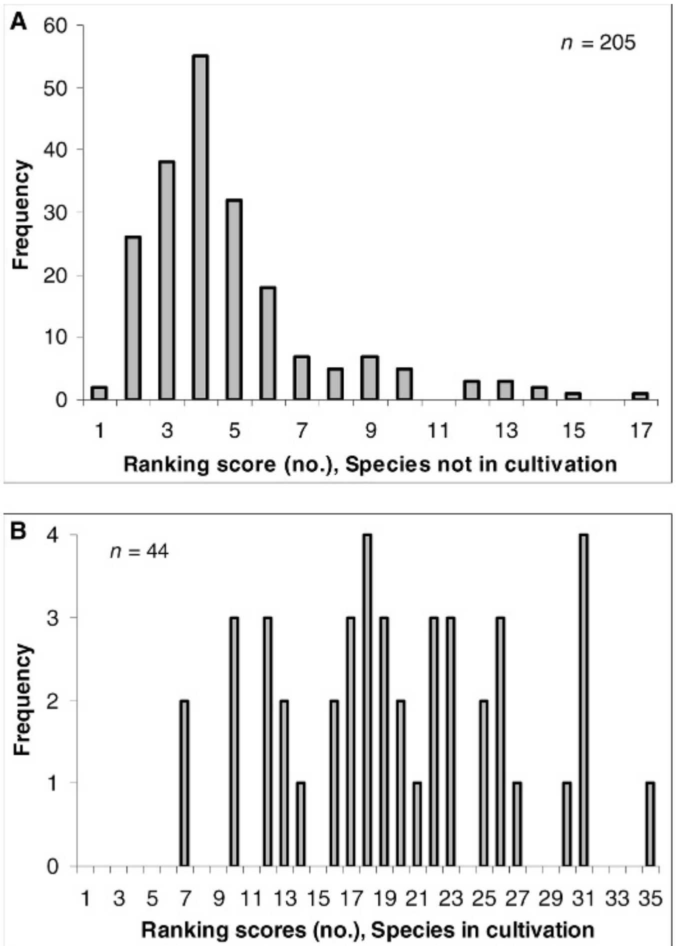

Figure 1. Frequency histograms of overall ranking scores (R) for species either (A) not known to be present in the United States or (B) reported to be in cultivation.

Model Comparison to Independent Results. Our objective in this test was to compare scores from the U.S. weed-ranking model to independent scores from a previously tested ranking or scoring system. Unfortunately, we found no existing model scores for a sufficient number of species on our list. For example, our list contained only a few species that had been evaluated with the Australian WRA (Biosecurity Australia 2005). Therefore, we used results from the Hawaii WRA system (Daehler and Carino 2000), which, according to experts, performed well at differentiating between pest and nonpest plants (Daehler et al. 2004). This model had published scores for more than 500 species (Daehler and Denslow 2006), with scores ranging from 29 to -13. Eleven species appeared on our list and were automatically included in the test. We determined R scores for an additional 20 species on the Hawaii WRA list, giving a total of 31 species scores for comparison. Because extreme scores can strongly influence comparisons, we chose the 20 species using stratified random selection across the range of scores. We used information from our own literature searches and from the Hawaii WRA to score the species. Using the Hawaii WRA information simplified the search process but did not compromise the test because some important factors in the ranking model were unique (e.g., country weediness reports, EP factors). Finally, for the purposes of the test, we ignored cultivation status in the United States and just scored EP based on the standard factors (accidental introduction, difficulty of detection, etc.).

We compared model rankings using rank-order correlation in SAS[1] (SAS 2006), which was most important to our objectives, and raw scores with linear regression (Neter et al. 1990; SAS 2006). We checked regression results with the use of residual analysis (Neter et al. 1990) and the Anderson-Darling normality test (SAS 2006), and made appropriate transformations to meet regression assumptions.

Results and Discussion

Plant Species Rankings. *Species Not in Cultivation in the United States*. For the 205 scored species not in cultivation in the United States, R ranged from 0.66 to 16.8, with a mean of 4.83, and a median of 4.2. The distribution of scores was skewed to the right (Figure 1A; skewness = 1.9). The top three species had scores of 16.8 to 14, and the score for the 25th-ranked species was 7.7 (Table 3, Appendices A and B). The top-ranked species were fairly heterogeneous, including sedges, shrubs, trees, aquatics, and toxic species. Two common characteristics among most of the top-ranked species were Asian origin or naturalization (Table 3), and scores of 10 points for "invasiveness elsewhere" (Table 1).

For these species, IP scores ranged from 2 to 35, the mean was 12.0, and the median value was 11.0. Two species had IP = 35: antelope grass [*Echinochloa pyramidalis* (Lam.) Hitchc. & Chase] and seedbox [*Ludwigia hyssopifolia* (G. Don) Exell], and narrow-leaved ragwort (*Senecio inaequidens* DC.) had a score of 34. Those 3 species all ranked in the top 10 overall (Table 3).

Values for DP ranged from 1 to 1.6. Three species had DP = 1.6: drooping cassinia (*Cassinia arcuata* R.Br.), Barth's rice (*Oryza barthii* A. Chev.), and camphor bush (*Tarchonanthus camphoratus* L.). The most cited factor under DP (Table 2) was "competitiveness to crops" (175 times), followed by "changes vegetation" (86) and "cost/difficulty of control" (63). The damage-reducing factor "ease of control" was cited 17 times. The following five factors were cited for only one to five species, indicating the difficulty of finding good information about them: "related to genetically modified crop," "reduces value of product," "pest/disease interactions," "human health hazard," and "changes fire regime."

Finally, values for EP ranged from 0.2 to 0.6, with a mean of 0.34; no species got the maximum score of 0.7 for noncultivated species. Scores for GP were fixed at either 1.0 or 0.8 (see above), with a mean of 0.98. We did not modify enough GP scores for it to have a strong effect on rankings. Only 4 of the top 40 species were given GP values of 0.8, and those were assigned because species were closely associated with either seashore/sandy areas (e.g., seashore centipede grass, *Ischaemum muticum* L.), or very arid or wet habitats.

The simple correlation between IP and R was 0.87, and simple correlations with R were 0.37 for DP, and 0.36 for EP. The squared semipartial correlation—which indicates the value of including a particular variable in the model—between R and IP was 0.76, compared to 0.16 for EP, and only 0.02 for DP. Both simple and semipartial correlations between R and GP were very small. Thus, IP most affected R scores, EP moderately affected scores, and DP and GP had minor effects. When we excluded GP from the calculation of R (i.e., $R' =$

Table 3. Twenty-five highest-ranking weed species not in cultivation in the United States by score, with scientific names, common names, descriptive notes, and distribution.

Rank[a]	Score	Scientific name	Common name	Description	Distribution (origin/naturalized regions)
1	16.8	*Echinochloa pyramidalis* (Lam.) Hitchc. & Chase	Antelope grass	Semiaquatic, robust, rhizomatous perennial	Africa (Asia, Australia, Europe, South and Central America)
2	15.4	*Ludwigia hyssopifolia* (G. Don) Exell apud A.R. Fernandes	Seedbox, primrose willow	Erect marshy or aquatic annual herb	Worldwide (Pacific)
3	14.0	*Rubus alceifolius* Poir.	Giant bramble	Thorny tropical and subtropical shrub	Southeast Asia
4	13.7	*Lygodium flexuosum* (L.) Sw.	Maidenhair creeper	Rhizomatous, perennial, climbing fern from	Southeast Asia
5	13.4	*Actinoscirpus grossus* (L. f.) Goetgh. & D. A. Simpson	Giant bulrush	Robust rhizomatous, perennial, tropical sedge	Southeast Asia
6	13.2	*Sagittaria pygmaea* Miq.	Pygmy arrowhead	Rhizomatous aquatic, temperate/ subtropical	East Asia
7	12.9	*Hakea salicifolia* (Vent.) B. L. Burtt	Willow-leaved hakea	Shrub or small tree, well-suited to Mediterranean climate	Australia (Europe, New Zealand, South Africa)
8 (tie)	12.4	*Ligustrum robustum* (Roxb.) Blume	Tree privet	Woody shrub	Asia
8	12.4	*Wikstroemia indica* C. A. Mey.	Tiebush, Indian stringbush	Tropical and subtropical shrub, invades forests	Asia, Australia (Indian Ocean islands)
10	12.2	*Senecio inaequidens* DC.	Narrow-leaved ragwort	Perennial herb, wide range of habitats and soils	Africa (Europe)
11	10.2	*Cestrum laevigatum* Schltdl.	Inkberry bush, poison berry	Evergreen tree in wide range of coastal habitats	South America (South Africa)
12	9.9	*Cyperus aromaticus* (Ridley) Mattf. & Kukenthal	Navua sedge	Sturdy perennial sedge, weed of grasslands and wetlands	Africa, Pacific
13 (tie)	9.7	*Eupatorium macrocephalum* (Less.) DC.	Pompom weed	Rhizomatous perennial	Central America, South America
13	9.7	*Gomphrena celosioides* Mart.	Bachelor's button, prostrate globe-amaranth	Toxic, prostrate, often annual weed, especially in dry crops	South America (Africa, Asia, Australia)
15	9.6	*Cyanotis axillaris* (L.) D.Don	–	Perennial herb, mainly prostrate; wetter sites	Asia, Australia (Africa)
16	9.2	*Chrysanthemoides monilifera* (L.) Norl.	Boneseed, bitou bush, Higgin's curse	Woody, bushy shrub in disturbed sites; forms dense stands	Africa (Australia, Europe)
17 (tie)	9.0	*Desmostachya bipinnata* (L.) Stapf	–	Rhizomatous, perennial C_4 grass of dry areas	Africa, Asia
17	9.0	*Ischaemum muticum* L.	Seashore centipede grass	Leafy, scrambling, perennial grass	Asia
19 (tie)	8.6	*Impatiens parviflora* DC.	Small balsam	Competitive ruderal in forest gaps; forms dense stands	Asia (Europe)
19	8.6	*Pycreus flavidus* (Retz.) T. Koyama	–	Vigorous sedge in rice and wetlands, temperate and subtropical	Asia and Europe
19	8.6	*Potamogeton distinctus* A. Benn.	Roundleaf pondweed	Aquatic, well-adapted to dry seasons and cultivation; rice weed	Asia
19	8.6	*Isachne globosa* (Thunb.) Kuntze	Swamp millet	Tropical perennial grass	East and South Asia
23	8.4	*Cyperus exaltatus* Retz.	–	Robust, tillering perennial sedge in moist/wet areas; widely adapted	Africa, Asia, Australia, South America
24	7.8	*Acroceras zizanioides* (Kunth) Dandy	Acrocillo	Tropical perennial grass	Asia, Africa, and Central America
25	7.7	*Tarchonanthus camphoratus* L.	Camphorwood	Large shrub or small tree; forms dense thickets; difficult to control	Africa, Asia

[a] Tie = scores equal to the tenth.

IP × DP × EP), the simple correlation between R and R' was still 0.99. Although GP was the least useful element here, it probably has the greatest potential to affect scores of the species for which relevant biological information exists, but only if it can be more easily estimated for dozens of species.

Comparing the top 100-ranked species in four tiers of 25 species, the mean R score for species in tier 1 was 1.7 times greater than that for species in tier 2, and 2.4 times greater than that for species in tier 4. Species in the first tier had the greatest means for all of the elements IP, EP, and DP (Table 4). Moreover, the greatest differential between tiers was between the top tier and the second tier, with an average decrease of 27% for IP, 12% for EP, and 4% for DP. From top to bottom tier, the greatest decline in a single element was for IP, by almost half, followed by EP, at about 25%. Within IP, the largest differences between tiers were for "country weediness reports," "invasiveness elsewhere," "other weediness reports," "vegetative reproduction," and "dispersal" (Table 5). Species with smaller seeds seemed moderately more likely to be ranked higher. Few differences over tiers were seen for the other factors under IP. In particular, aquatic or viny species did not seem more likely to be ranked higher (Table 5). Lastly, we stress that this analysis merely described which model factors contributed the most to R scores—albeit for a large number of species—and are not general findings about weediness traits.

Species in Cultivation in the United States. For the 44 species in cultivation, R scores ranged from 6.5 to 34.8, with a mean of 19.3, and a median of 19.2. The roughly uniform distribution of R scores (Figure 1B) was probably because relatively few of these species were satisfactorily scored. Scores for IP ranged from 0 to 30, with a mean of 15.5. Mean DP was 1.3, with a range from 1 to 1.5.

Table 4. Mean model scores by ranked tiers of 25 plant species not in cultivation in the United States for total score, *R*, and the following individual elements: IP, invasive potential; DP, damage potential; and EP, entry potential. Also given is the absolute change (Δ) from the tier above.

	R		IP		DP		EP	
Rankings	Mean	Δ	Mean	Δ	Mean	Δ	Mean	Δ
1 to 25	10.8	–	21.6	–	1.34	–	0.40	–
26 to 50	6.5	4.3	15.7	5.9	1.28	0.06	0.35	0.05
51 to 75	5.1	1.4	12.8	2.9	1.29	−0.01	0.34	0.01
76 to 100	4.5	0.7	11.9	0.9	1.25	0.04	0.32	0.01
Mean	6.7		15.5		1.29		0.35	

Table 5. Mean model scores for factors within IP, invasive potential, for species not in cultivation in the United States, by ranked tiers of 25 species, showing point values given (pts).

	Weediness reports	Invasiveness elsewhere	Other reports	Vegetative reproduction	Aquatic	Vine	Seed size	Dispersal
Ranks	0/1/2/3 pts each	0/3/5/10 pts	3 pts each	0/3 pts	0/3/5 pts	0/3 pts	0/1/2/3 pts	0/1/2/3 pts
1 to 25	3.75	8.47	4.29	1.75	1.25	0.27	1.60	2.32
26 to 50	3.04	6.23	3.00	1.23	1.04	0.14	1.60	1.96
51 to 75	1.83	6.36	3.00	0.86	1.50	0.27	1.52	1.64
76 to 100	1.92	4.60	3.00	1.04	1.17	0.50	1.32	1.46
Mean	2.64	6.91	3.56	1.23	1.24	0.30	1.51	1.85

Twenty-nine species in cultivation (Table 6, Appendix A) had *R* scores greater than 16.8, which ranked them above all species not in cultivation. Over both groups, 39 of the top 50 ranked species were species in cultivation, and all 44 ranked in the top 100. Mean *R* of 19.3 for species in cultivation was about four times greater than for species not in cultivation (4.8). Despite that, we found no significant difference between the two groups in mean DP ($P > 0.05$). Mean IP was significantly greater for species in cultivation ($P < 0.05$), but only by 29% (15.5 vs. 12.0). The biggest difference between the two groups of species was in EP, where the mean for cultivated species (1.0, by definition) was about three times greater than that for species not in cultivation (0.34 $\pm$ 0.01). Consequently, mean IP $\times$ mean EP was 15.5 ($= 15.5 \times 1$) for species in cultivation, and 4.1 ($= 12.0 \times 0.34$) for species not in cultivation.

We think the overall rankings for species in cultivation appropriately represented the greater risk from species already present in the United States but not yet naturalized. Most invasive plant species were originally introduced deliberately, and cultivated as crops or ornamentals (e.g., Groves et al. 2005; Westbrooks 1998). Many of those species had no prior record of weedy or invasive behavior. In contrast, because of documented invasive behavior the species here were all credible threats to ecosystems in the United States.

Model Testing. *Sensitivity Analysis*. Model *R* scores were most affected by GP and DP, which each changed *R* by 25%. That was expected given the multiplicative model and that the default values of both modifiers were equal to 1. The second most important scoring items were three + 0.2-point items under EP, "accidental introduction," "deliberate introduction," and "difficulty of detection." Each of these changed *R* by 7%. Thus, the four most important scoring items were in elements that modified IP, rather than in IP itself, despite their low score values relative to some factors in IP. In contrast, for (unweighted) additive WRA models the simple prediction is that model sensitivity will be greatest to the highest-scoring items.

The most important item under IP was "invasiveness elsewhere," which had the greatest score (up to 10 points) and affected *R* by 5%. One source for this factor (Binggeli et al. 1998) focuses upon woody tropical and subtropical species, which might have indicated potential bias, but out of 13 species in the top 20 given scores of 10, only 3 were based upon Binggeli et al. (1998). "Aquatic species," a 5-point factor, affected *R* by only 2%, whereas all other 3- and 2-point items affected *R* by only 1%. Finally, the absolute effect in this test of being a species in cultivation in the United States—i.e., EP increasing from 0.7 to 1—was a 43% increase in *R* (as expected, since $1/0.7 = 1.43$).

We also determined model sensitivity to the deletion of single scoring factors under IP. The factor "invasiveness elsewhere" (above) was by far the most important factor affecting the rankings of the top 100 species. The average absolute change in rankings after deleting it was 21 places, and 9 species rankings changed by more than 25 places. Thus, the *R* scores of several species were very dependent on their score in that category. Other important factors included "country weediness reports" (mean change of 11 places), "aquatic species" (9.3 places), "vegetative reproduction" (8.9 places), and "dispersal" (8.6 places). The following factors had almost no impact on the top 100 rankings, perhaps because of a lack of information: "frost tolerant" (1 place), "insect/disease tolerant" (0.3 places), and "responds to rising CO_2" (0.3 places).

Comparison to Hawaiian WRA Results. Comparing the 31 species' scores for the U.S. weed ranking model and the Hawaiian WRA, a highly significant, positive Spearman rank-order correlation of 0.78 was found ($P < 0.001$; Figure 2A). A linear regression of *R* scores on Hawaiian WRA scores did not meet normality assumptions (by residuals and Anderson-Darling test, $P = 0.05$). After $\log_e$-transforming the *R* scores, the regression on the Hawaiian WRA scores was positive and highly significant ($P < 0.001$, adjusted $R^2 = 0.67$; Figure 2B). Therefore, the U.S. weed-ranking model produced scores and rankings that were similar to the Hawaiian WRA. Although not as good as a predictive test,

Table 6. Scientific and common names, and model scores for the 30 highest-ranked species in cultivation in the United States.

Rank	Score	Scientific name(s)	Common name(s)
1	34.8	*Senecio angulatus* L.f.	Cape ivy
2	31.2	*Limnocharis flava* (L.) Buchenau	Sawah lettuce
3 (tie)	30.8	*Cestrum elegans* (Brongn. ex Neumann) Schltdl. (*C. purpureum*)	Red cestrum
3	30.8	*Gymnocoronis spilanthoides* DC.	Senegal tea plant
3	30.8	*Melianthus major* L.	Honey flower
6	29.9	*Crassula helmsii* A. Berger	Swamp stonecrop
7	27.0	*Litsea glutinosa* (Lour.) C.B. Robinson	Indian laurel
8	26.0	*Hiptage benghalensis* (L.) Kurz	Hiptage
9 (tie)	25.8	*Hakea gibbosa* (Sm.) Cav.	Hairy hakea
9	25.8	*Hakea sericea* Schrad. & J.C.Wendl.	Silky hakea
11	25.2	*Homalanthus populifolius* Graham	Queensland poplar
12	24.7	*Onopordum acaulon* L.	Stemless thistle
13	23.4	*Asparagus africanus* Lam.	Ornamental asparagus
14	22.8	*Salvinia cucullata* Roxb. ex Bory	Water fern
15	22.5	*Rotala rotundifolia* (Buch.-Ham. ex Roxb.) Koehne	Dwarf rotala
16 (tie)	22.4	*Lygodium scandens* (L.) Sw.	Climbing fern
16	22.4	*Pinus patula* Schiede ex Schlecht. & Cham.	Mexican weeping pine
18	21.6	*Nymphaea alba* L.	Platter dock, white water lily
19	20.8	*Marsilea crenata* Presl	Pepperwort, water clover
20	20.4	*Acacia karroo* Hayne	Sweet thorn, karroo thorn
21	20.4	*Regnellidium diphyllum* Lindm.	Water clover
22 (tie)	19.2	*Nymphaea nouchali* Burm. f.	Lotus lily, water lily
22	19.2	*Senecio glastifolius* L.f.	Holly-leaved senecio
24	18.7	*Echinopsis spachiana* (Lem.) Friedrich & G.D. Rowley	Golden torch cereus, torch cactus
25	18.2	*Rhamnus alaternus* L.	Italian buckthorn
26 (tie)	18.0	*Juncus prismatocarpus* R.Br.	Jointed/branching rush
26	18.0	*Miscanthus nepalensis* (Trin.) Hack.	Himalayan fairy grass
26	18.0	*Polygala myrtifolia* L.	Myrtle-leaf milkwort
29	16.9	*Furcraea hexapetala* (Jacq.) Urban	Cuban hemp
30 (tie)	16.8	*Hakea drupacea* (C. F. Gaertn.) Roem. & Schult.	Sweet hakea
30	16.8	*Cyperus laxus* Lam.	Diffused flatsedge

this comparison did provide more confidence in model results, given the expert testing that the Hawaiian WRA has already undergone (Daehler et al. 2004).

This did not mean, however, that the models are equivalent. For example, the distribution of ranking model scores (Figure 1A) was more skewed than the Hawaiian WRA scores (not shown). Moreover, some rankings were quite different. For example, the highest-ranking species in the Hawaiian WRA ranked only 5th in our model, and the 3rd-highest-ranked species in our model was only ranked 13th in the Hawaii WRA (Figure 2B). Below we discuss other important differences between the models; these can significantly affect scores and rankings.

Other WRA models ultimately will be judged by whether or not admitted species demonstrated invasive behavior. The U.S. weed-ranking model differs in that accuracy may be judged by whether or not high-ranked species are listed as Federal Noxious Weeds, or if low-ranking species were consistently not candidates for listing. Species receiving High or Medium-High risk ratings in the full WRA process are eligible for listing (USDA-APHIS-PPQ 2004a). Listing decisions may not solely depend on biology and risk, however; factors such as the economic value of species in cultivation may also need to be considered. Therefore, the best test of the U.S. weed-ranking model is probably whether or not high-ranking species become eligible for listing, and if low-ranking species do not.

Model Development, Use, and Comparison. *General Modeling Issues*. One might ask, "Why create a new weed ranking model when other tested WRA screening tools already exist?" Most importantly, U.S. regulations differ from those of Australia, in particular, and barring a change in policy we must use the current WRA method and not a screening tool. Second, WRA screening tools typically do not account for the likelihood of introduction because they were designed to assess proposed imports, which are certain to be introduced if allowed. Many potentially invasive species on our lists are *not* commercial, and therefore accounting for entry potential was critical. Because of this, we feel our model more completely assesses potential risk.

Our main objective, ranking species by potential invasiveness, was another key difference from other WRA models. Using a model to rank species for assessment is a simpler proposition—and has less serious consequences—than using a model to determine whether or not to allow species to enter. The latter required Pheloung et al. (1999) to set decision thresholds empirically; these have been adopted "as is" by later users (e.g., Daehler et al. 2004). In our approach no thresholds needed to be defined and the ranking itself was the output. We are confident that the ranking differences between species were meaningful: Top 10 species are more likely to be High-Risk species than those ranked 11 to 20, which are much more likely to be High-Risk species than those ranked lower than 100, etc. Still, we recognize that scores were biased by available information, a caveat that applies to all WRA models.

Another important conceptual difference was the use of a multiplicative rather than an additive model. The practical effect was that *R* scores would approximate zero if the value of any element neared zero. Therefore, a species known to have very low EP would likely rank low regardless of IP score. This was better for our particular objective, because first assessing weed species scoring highly in all elements seemed preferable. In the Australian and Hawaii WRAs, scores were additive and most questions were weighted equally (0 or $\pm$ 1 point)

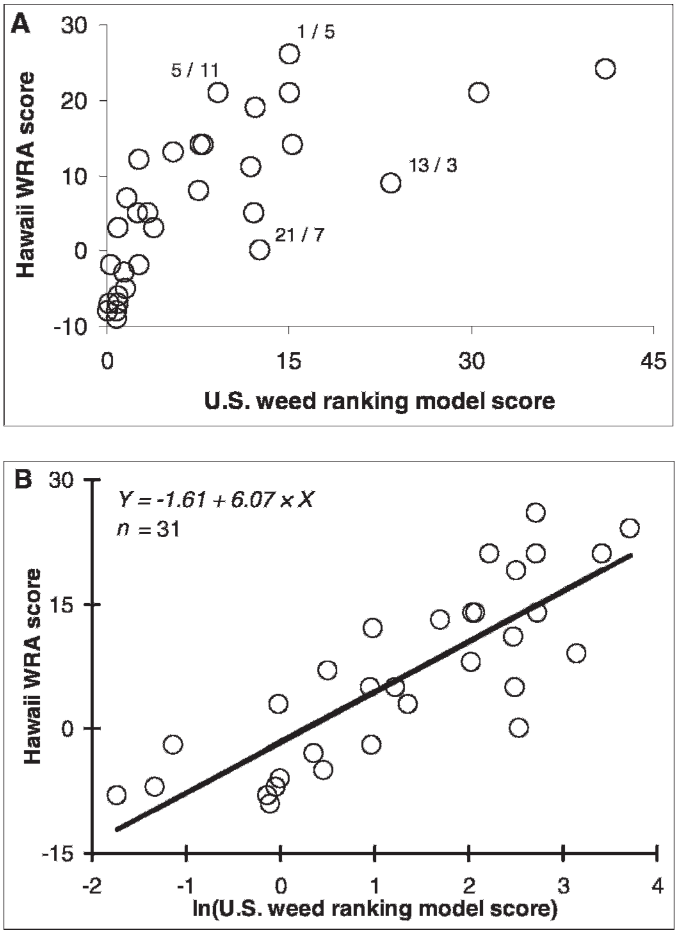

Figure 2. Comparison of (A) untransformed ranking model scores, and (B) log$_e$-transformed ranking model scores ($P < 0.0001$, adjusted $R^2 = 0.67$) with previously published scores from the Hawaii WRA for the same plant species. In (A), labels (*x*/*y*) near selected points indicate species ranks in the Hawaii WRA (*x*) and in the U.S. weed-ranking model (*y*).

(Daehler et al. 2004; Pheloung et al. 1999). Consequently, a species could score negatively or very low in habitat suitability yet still be rejected if enough points were accumulated in other factor areas. This approach may be appropriate, depending on the system and its intent. For the reasons above, we think the multiplicative model was best suited to prioritization for the current United States WRA system and regulations.

Factors scored in the U.S. weed-ranking model were reported to correspond to invasiveness, or have been included in other WRA or invasiveness models. Thirty-three different factors were included, compared to 49 questions in the Australian and Hawaiian WRAs (Daehler et al. 2004; Pheloung et al. 1999). We used fewer scoring factors in part because, for example, we had only one dispersal score, whereas the Australian and Hawaiian WRAs have eight questions about dispersal. Although the factors in the models were similar, we grouped them differently in the U.S. weed-ranking model. For example, undesirable traits and dispersal mechanisms were both part of "Biology/Ecology" in the Australian WRA (Pheloung et al. 1999), whereas we placed undesirable traits within DP, and the dispersal factor within IP. This probably has no effect on scores in the Australian WRA, but it clearly affects scoring in our model because of the different valuations (weightings) given to the four elements.

We recognize that some overlap, or correlation, probably exists between the four elements in our model. For example, a species may have been designated as a "weed elsewhere" (IP) because of some damage it caused (DP). This problem probably exists for all assessment tools, however. For example, the Hawaiian and Australian WRAs have questions about both whether or not a species is an agricultural weed, and whether or not it has undesirable traits, such as being parasitic. One reason to ask for similar information in different ways is that the information may be available in one form (e.g., known to be parasitic) but not the other (e.g., not formally named as an "agricultural weed"). The Australian WRA specifically has more questions to limit the number of "Evaluate further" results (Pheloung et al. 1999). We think that the four elements in our model best described the invasion process or pathway for our system, and that we minimized overlap through careful placement of factors within those elements.

For many species, scores for some important factors were missing. For the 205 species not in cultivation we scored a mean of 13.1 factors, and on average 8.7 of those were for IP. Some factors were inherently limited because sources such as Holm et al. (1977) and Binggeli et al. (1998) included a limited number of species. We think we overcame those limitations by using independent references about invasive behavior outside the area of origin (e.g., "other weediness reports" and "invasiveness elsewhere"). Using only reliable scientific or internet sources was important. Still, scores and rankings were inevitably affected by the amount of available data and the amount of time spent searching for it. These problems exist for all WRAs or ranking models. The most difficult information to find here included pest and disease interactions, dormancy behavior, drought and frost tolerance, and reaction to increasing levels of carbon dioxide.

Scoring of Model Elements. As noted above, we rarely modified the default GP score here, and only reduced GP by 20% when we did. Geographic suitability was also coarse and subjective in other WRA models (Daehler et al. 2004; Pheloung et al. 1999). Using climate-matching techniques is being considered as a means of quantifying this element, but we do not yet know if the time required to find and use the required information would be worthwhile in this project. The United States has areas of most climatic and ecological types, and the existence of relatively smaller areas of special habitat could be more important for some species than much larger cultivated or natural areas. It could be argued that we should have decreased GP more for purely tropical species, but we decided not to because of the value and uniqueness of tropical areas in the United States (e.g., Florida Keys, Hawaii as a "hot spot" for endemic species).

Currently, EP equals 1.0 for all species already in cultivation in the United States. This could be modified by how widely a species has been distributed. Many ornamentals could be present on thousands of sites, others on very few, and the likelihood of encountering a suitable habitat would be greater for more widespread ornamentals. At present, however, the data for this refinement do not exist.

For species not already present in the United States, the likelihoods of deliberate or accidental introduction are generally much less than 1. Scoring for deliberate entry depends on a subjective estimate of the interest in importing species for ornamental, medicinal, or other use. The risk of accidental introduction depends mainly on the volume and type of traffic between infested countries and the United States. The most likely means of accidental introductions of pest plants is probably as a seed contaminant. Little is known about the likelihood of accidental introduction of pest plants via other pathways, such as passengers carrying seeds on shoes or clothing, but it does occur (e.g., Whinam et al. 2005).

Application of the Model Rankings. The rankings from the U.S. weed-ranking model have begun to be put to use. For example, we created fact sheets for the top 50 species not in cultivation, and some of the species in cultivation. We hope those will be available for public use this year via the WSSA Web site (http://www.wssa.net).

Our primary objective was to prioritize species for full WRAs to identify candidates for listing as Federal Noxious Weeds. To date, full WRAs have been done for three highly ranked species. Narrow-leaved ragwort, the 10th-ranked species of those not in cultivation, was listed as a Federal Noxious Weed by APHIS on June 14, 2006. Listing will also be proposed by APHIS for stemless thistle (*Onopordum acaulon* L.), the 12th-ranked species in cultivation, in the next proposed amendment of the noxious weed regulations. In the third case, a WRA was done for antelope grass (Fowler 2002), the highest-ranked species not in cultivation (Table 3), before this model analysis was complete. In that WRA, antelope grass was rated High Risk for "consequences of introduction," as reflected by a high IP score here of 35 points. It rated only Low Risk for "likelihood of introduction," however, and therefore was not a candidate for listing with an overall rating of Low Risk. This apparent mismatch between model and WRA results highlights two important facts. First, information for the ranking model may be quite general, whereas more specific information is often required and used in the WRA. For example, based on distribution and seed size we scored antelope grass in the model for seed contamination of commodities, whereas in the WRA it could not be established that antelope grass was likely to contaminate seeds of commodities actually imported into the United States (e.g., rice). Second, although we know of no specific instance in this case, both model and WRA results are subject to change as new information becomes available. Still, the results from both the ranking model and the WRA agree that if a Moderate Risk rating for "likelihood of introduction" can be justified, antelope grass should be a prime candidate for listing.

We hope that creating the list of weeds in cultivation in the United States will encourage industry to appraise the commercial value of high-ranked species, compared to the potential for economic loss. Some may be good candidates for listing and regulation because they have little commercial value, or because the potential damage is so great. The nursery industry could try to voluntarily reduce how many outlets make risky species available for sale (e.g., Anonymous 2002; Florida Nursery, Growers & Landscape Association 2005), but whether or not that approach can be effective remains to be seen (Caton 2005; Moss and Walmsley 2005).

In addition, the species rankings have been used to support ongoing efforts to revise the plants-for-planting regulations (7CFR §319.37). The proposed revisions would establish a new category of "Not Authorized for Import Pending Pest Risk Analysis," or NAPPRA, which could include both pest plants and plant hosts of quarantine pests. Some highly ranked species from our project have been added to a preliminary NAPPRA list of pest plant species. APHIS would conduct full WRAs for NAPPRA species after other countries request exports of the species to the United States (P. Lehtonen, personal communication).

This ranking model may be particularly useful for states that must allocate scarce resources to the management and eradication of invasive weeds. That use, however, would likely increase the importance of accounting for GP, while obviating the utility of EP, because the weeds have presumably already naturalized in the state.

Finally, the rankings have been used to help select species for the Cooperative Agricultural Pest Survey (CAPS). Consequently, one species, stemless thistle, was on the CAPS list of targeted species for both 2006 and 2007 (USDA-APHIS 2006). The CAPS program is aimed at early detection of adventive pests, including plants, for earlier, more effective management and control efforts (USDA-APHIS 2005).

Sources of Materials

[1] SAS version 9.1, SAS Institute Inc., 100 SAS Campus Drive, Cary, NC 27513-2414.

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Appendix A. Synonyms of species listed in tables in the article.

Scientific name	Synonyms
Acroceras zizanioides	*Panicum zizanioides* Kunth
Actinoscirpus grossus	*Scirpus grossus* L.f.
Berkheya rigida	*Stobaea rigida* Thunb.
Chrysanthemum myconis	*Coleostephus myconis* (L.) Reichenb.f.
Cirsium acarna	*Picnomon acarna* (L.) Cass.
Cordia curassavica	*C. macrostachya* R. & Schult. *C. cylindrostachya* R. & Schult.
Crassula helmsii	*Tillaea recurva* (Hook. f.) Hook. f.
Cyanotis axillaris (L.) Sweet.	*C. axillaris* (L.) D. Don
Cyperus aromaticus	*Kyllinga polyphylla* Willd. ex Kunth
Cyperus exaltatus	*C. racemosus* Heyne
Demostachya bipinnata	*Briza bipinnata, Eragrostis cynosuroides*
Eleocharis dulcis	*Scirpus tuberosus* Roxb.
Eupatorium macrocephalum	*Campuloclinum macrocephalum*. (Less.) DC.
Fimbristylis globulosa	*Scirpus globulosus* Retz.
Fuirena glomerata	*F. ciliaris* (L.) Roxb. *Scirpus ciliaris* L.
Gnaphalium affine	*G. multiceps* Wall. ex DC. *G. luteoalbum* (L.) var. affine
Gomphrena celosioides	*G. decumbens* auct non Jacq.
Hakea drupacea	*Conchium drupaceum* C. F. Gaertn. *Hakea suaveolens* R.Br.
Hakea salicifolia	*H. saligna* (Andr.) Knight
Hypericum triquetrifolium	*H. crispum* L.
Hyptis brevipes	*H. acuta* Benth.
Isachne globosa	*I. australis* R.Br.
Launaea cornuta	*Sonchus cornutus* Hochst. ex Steud. *S. exauriculatus* O. Hoffm.
Litsea glutinosa	*L. sebifera* Pers.
Ludwigia hyssopifolia	*Jussiaea linifolia* Vahl.
Ludwigia prostrata	*L. diffusa* Buch.-Ham. *Jussiaea prostrata* Lev.
Nymphaea alba	*Castalia alba* (L.) Wood
Nymphaea nouchali	*N. stellata* Willd.
Ottochloa nodosa	*Panicum nodosum* Kunth.
Potamogeton distinctus	*P. franchetii* A. Benn. & Baag
Pycreus flavidus	*P. globosus* Retz.
Trichodesma zeylanicum	*Borago zeylanica* Burm. f.
Wikstroemeria indica	*W. viridiflora* Meissn.

Appendix B. Species not in cultivation in the United States ranked from 26 to 50, with scientific names, common names, descriptions, regions and model scores.

Rank	Score	Scientific name	Common name	Description	Region
26 (tie)	7.6	*Cordia curassavica* (Jacq.) R. & Schult.	Black sage	Shrub, invasive in Mauritius	Central America
26	7.6	*Launaea cornuta* (Oliv. & Hiern.) C. Jeffrey	Wild lettuce	Rhizomatous perennial weed of crops & waste lands	South and East Africa
28	7.5	*Fuirena ciliaris* (L.) Roxb.	Umbrella grass	Sedge; wet grasslands, river banks, pond margins, and rice fields	Tropical Africa, Asia, Australia
29	7.4	*Phyllanthus maderaspatensis* L.	Canoe weed	Erect/spreading subshrub; medicinal uses	Madagascar, Australia
30 (tie)	7.0	*Digitaria ternata* (A. Rich.) Stapf	Black-seed fingergrass	Widespread, successful crabgrass; reproduces by seed and vegetatively	Africa, Australia, Europe, Mexico, South America
30	7.0	*Polygonum thunbergii* Sieb. & Zucc.	Knoterid	Thorny scrambling weed of wet places and rice crops	Asia
32	6.9	*Mollugo pentaphylla* L.	Mollugo	Weed in cultivated areas and open grasslands, at low and medium altitudes; medicinal uses	Asia, Australia
33 (tie)	6.6	*Eleocharis kuroguwai* Ohwi	Kuru-guwai	Rhizomatous, perennial weed of rice and wet places	Asia
33	6.6	*Chrysanthemum myconis* L.	Margarita amarilla	Weed of waste places	Mediterranean
33	6.6	*Gnaphalium affine* D.Don	Jersey cudweed	In Japan, a lowland weed of waste ground and cultivated fields; hillsides and arid ground in China; medicinal uses	South and East Asia
36 (tie)	6.3	*Berkheya rigida* (Thunb.) Bol. & Wall.	Augusta thistle, African thistle	Rhizomatous weed of grasslands, naturalized in Australia	South Africa
36	6.3	*Cineraria lyrata* Cron	African marigold	Herbaceous weed in wheat	Australia, South Africa
36	6.3	*Cyperus teneristolon* Mattf. & Kuk.	–	Perennial sedge with both rhizomes and stolons; important weed of highland crops in E Africa	Africa, Australia
39 (tie)	6.2	*Hybanthus attenuatus* (Humb. & Bonpl. ex Schult.) Schulze-Menz	Western green-violet	Weed of disturbed and cultivated areas; weedy in a wide range of crops	South America
39	6.2	*Ottochloa nodosa* (Kunth) Dandy	Slender panic grass	Perennial in disturbed areas, fields and plantations; forage	Africa, Asia, Australia
39	6.2	*Berberis glaucocarpa* Stapf	Great barberry	Spiny shrub, available as an ornamental	South Asia
39	6.2	*Myoporum tenuifolium* G. Forst.	Manatoka, false sandalwood	Invasive tree	Australia, South Africa
43 (tie)	6.1	*Limnophila heterophylla* Benth.	Purple mudwort	Aquatic weed, available as an ornamental	South and Southeast Asia
43	6.1	*Picnomon (Cirsium) acarna* (L.) Cass.	Soldier thistle	Spiny annual herb; weed of roadsides, banks, waste areas, and sometimes crops and pastures	Eurasia
43	6.1	*Cassinia arcuata* R. Br.	Drooping Cassinia, Sifton bush	Invasive shrub, early colonizer of disturbed areas	Australia
46	6.0	*Ludwigia prostrata* Roxb.	Climbing seedbox	Vigorous weed of rice and wet places	South, Southeast, and East Asia
47 (tie)	5.9	*Acacia hockii* De Wild.	–	Perennial shrub or small-to-medium tree of savannahs; prohibited in Australia	Africa
47	5.9	*Potamogeton schweinfurthii* A. Benn.	Pondweed	Submerged freshwater aquatic; aquarium trade plant	Africa
49	5.8	*Oryza barthii* A. Chev.	Wild rice, Barth's rice	Annual grass in savannah woodlands; tolerates flooding and deep water	
50	5.7	*Austroeupatorium inulaefolium* (Kunth) R. M. King & H. Rob.	Austroeupatorium	Perennial herb/shrub; moist spots in disturbed forest and roadsides; serious weed in plantations/orchards	Southeast Asia, South America