

## REVIEW ARTICLE

## State of the science and challenges of breeding landscape plants with ecological function

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Exotic plants dominate esthetically-managed landscapes, which cover 30–40 million hectares in the United States alone. Recent ecological studies have found that landscaping with exotic plant species can reduce biodiversity on multiple trophic levels. To support biodiversity in urbanized areas, the increased use of native landscaping plants has been advocated by conservation groups and US federal and state agencies. A major challenge to scaling up the use of native species in landscaping is providing ornamental plants that are both ecologically functional and economically viable. Depending on ecological and economic constraints, accelerated breeding approaches could be applied to ornamental trait development in native plants. This review examines the impact of landscaping choices on biodiversity, the current status of breeding and selection of native ornamental plants, and the interdisciplinary research needed to scale up landscaping plants that can support native biodiversity.

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## INTRODUCTION

Recent ecological studies have found that landscaping choices can affect biodiversity in urbanized areas.<sup>1–5</sup> The impact of land use practices in esthetically-managed landscapes of the United States was summarized in a US Environmental Protection Agency report,<sup>6</sup> which noted:

- the widespread replacement of millions of acres of native vegetation with primarily non-native ornamental plants in managed landscapes is a growing problem for the organisms that depend on native plants for food, shelter, and places to rear their young;
- many studies have documented the negative effect that non-native plants can have on the abundance and diversity of insect herbivores;
- if ornamental plants cannot serve as food for the same number and diversity of herbivores, the energy available for food webs decreases.

Non-native or exotic plants can be defined as plant species that evolved someplace other than where they have been introduced. Native plants, in contrast, share an evolutionary history with regional insects and other organisms. The observations of Erlich and Raven,<sup>7</sup> with further modification,<sup>8</sup> have led to an understanding of plant and insect co-evolution in which the adaptation of insects to plant defenses plays an important role. Landscaping primarily with exotic plant species would be expected to be detrimental to insect herbivores that have adapted to native plant hosts<sup>9</sup> and recent studies support this hypothesis.<sup>1,2,10,11</sup> Changes caused by exotic plants to the abundance and diversity of insects, and the birds that consume them, are discussed in the following section. The impact of exotic landscaping plants on other native taxa is less well studied. The spread of invasive exotic plants, however, has been linked to a decline in the diversity of reptiles, spiders and mycorrhizal fungi.<sup>12–15</sup> Invasive exotic plants can affect native species through food-web dynamics or by less predictable mechanisms.<sup>16</sup>

To conserve biodiversity in urbanized areas, the increased use of native plant species in designed landscapes has been advocated by conservation groups and US federal and state agencies. This includes NGOs such as the National Wildlife Federation, the Audubon Society and the Native Conservancy and government agencies such as the EPA, the USDA and the DOT. The implementation of this goal on an effective scale faces several hurdles. There are over 32 million hectares of esthetically managed land in the United States, including urban and suburban landscapes<sup>17</sup> and highway corridors.<sup>18</sup> The developed area of the United States is projected to increase by nearly 80% in the first quarter of this century,<sup>19</sup> adding millions more hectares of landscaping. The amount of land managed for esthetics is similar in scale to the land in corn cultivation (37M ha in 2014)<sup>20</sup> or in all US national and state parks (40M ha).<sup>21</sup> Increasing native plant landscaping to 30%, for example, of the managed landscape would require a significant expansion of what is now a niche market.

A major challenge to scaling up the use of native species in landscaping is in providing ornamental plants that are both ecologically functional and economically viable. Similar to environmental restoration with native plants, attention should be paid to genetic diversity and local adaptability.<sup>22</sup> Unlike environmental restoration, though, native plants must be introduced into managed landscapes through a market system in which landscaping plants that meet consumer demand are delivered profitably by the horticulture industry. Ecological function, cost-effective production and ornamental traits are qualities desired in native landscaping material that are potentially conflicting. The scale-up of landscaping plants that can support biodiversity would benefit from interdisciplinary research in genetics, ecology, and economics.

## EFFECTS OF EXOTIC PLANTS ON INSECT AND BIRD ABUNDANCE AND DIVERSITY

The prevalence of exotic plants in a landscape may alter the number of ecologically important insects, as well as the composition of

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insect populations. In the northeastern United States, a comparison of suburban yards landscaped with native or exotic plants found that exotic plants reduced the abundance and diversity of lepidopteran insects.<sup>1</sup> A study of urban vegetation in Singapore determined that lepidopteran diversity correlated directly with the percentage of native plants.<sup>2</sup> Field trials confirmed the negative impact of exotic plants on specialist and generalist lepidopteran numbers<sup>10</sup> and found a similar effect on insects of other taxa and feeding guilds.<sup>11,23,24</sup> A study in which old-field plant communities were manipulated found that insect species richness was reduced on exotic plants, although insect abundance was similar on native and exotic plants.<sup>25</sup> While the effects of exotic plants on insects may differ between studies, the geographic origin of introduced plants was found to change insect community structure.

Invasive exotic plants can also alter insect populations.<sup>26–28</sup> This is relevant to ornamental plants since many exotic species that have become invasive in the United States were introduced for landscaping purposes.<sup>29</sup> Field studies have found that invasive exotic plants can shift the insect population from large, specialist insects (e.g., lepidoptera) to small, generalist insects (e.g. dipteran midges), significantly reducing insect biomass.<sup>26</sup> Some invasive exotic plants, such as honeysuckle (*Lonicera maackii*), may increase insect species richness and numbers by creating a more complex vegetative structure.<sup>30</sup> Separately, honeysuckle was found to cause a decrease in caterpillar abundance that was moderated when there was higher tree diversity and more intact forest cover.<sup>31</sup> Habitat fragmentation and homogeneity are common features of urban landscapes and they may mediate the effects of exotic plants on insect herbivores.

Studies have indicated that several life-history attributes of insects may be altered due to exotic plants. Insect size, egg load and attraction to mates were reduced, and developmental period was longer on exotic species.<sup>32,33</sup> Native pollinators may visit abundant exotic plants more frequently, thus lowering pollination of native plants.<sup>34</sup> Lower feeding damage on exotic than on native plants has been reported, perhaps due to lower nutrient quality.<sup>35,36</sup> An exotic plant with foliage that is toxic to caterpillars can be a dead-end host for a native butterfly species.<sup>37</sup> This may allow exotic plant species to escape herbivory, and persist and spread on the landscape. Overall, while exotic plants can provide certain ecological services,<sup>25,30,38</sup> their ability to support native insects is limited in many ways.

Changes in insect quality and quantity can affect higher trophic levels through food web interactions. As argued by Tallamy,<sup>9</sup> nearly all terrestrial birds in North America rear their young on insects, with food being a major limitation to breeding success.<sup>39,40</sup> Two studies on the ecological impacts of plant origin, discussed previously with regard to insects, also examined effects on bird populations.<sup>1,2</sup> In suburban Pennsylvania yards landscaped with exotic plants, a reduction in bird abundance and diversity correlated with the decrease in lepidopteran populations.<sup>1</sup> Both avian and lepidopteran species richness varied directly with the percentage of native shrubs and trees in urban vegetation of Singapore.<sup>2</sup> The presence of native landscaping plants was found to have a positive effect on native bird abundance and diversity in urbanized areas across different environments.<sup>3–5,41</sup> Lepidoptera and birds have served as surrogate taxa in biodiversity studies because they are environmentally sensitive and relatively easy to measure.<sup>1,42</sup> The corresponding changes in native lepidopteran and avian populations could be causative (fewer caterpillars make birds forage elsewhere) or correlative (exotic plants negatively affect butterflies and birds independently).

#### CURRENT STATUS OF THE BREEDING AND SELECTION OF NATIVE ORNAMENTAL PLANTS

A niche market has developed in the United States for native ornamental plants that provide wildlife support, as well as local adaptability. The single largest venture directed at this market is the

American Beauties™ program, a partnership between the National Wildlife Federation and two wholesale nurseries.<sup>43</sup> The program distributes native landscaping plants to independent garden centers and landscapers in the northeastern United States. Over 350 plant species are provided through this system, including native perennials, grasses, vines, trees and shrubs. In addition, Armitage<sup>44</sup> describes more than 400 native ornamental plants, primarily herbaceous species, that can be ordered directly from local nurseries in the United States.

Native plants for ornamental horticulture generally come from breeding, genotype selection or open-pollinated seed. Within the American Beauties™ inventory, approximately 35% of the plants are named cultivars and 65% are propagated genotypes of native species. North American plant species have been selected or bred for flowering, architecture, foliage and disease-resistance traits, although not to extent of exotic ornamentals. For example, native plant genotypes have been selected that exhibit early flowering (e.g., *Potentilla fruticosa* 'KM01')<sup>45</sup> or double flowers (e.g., *Cercis canadensis* 'Flame').<sup>46</sup> From an open-pollination breeding program, an oak leaf hydrangea genotype (*Hydrangea quercifolia* 'Snow Queen') was identified that had low, compact form and abundant, showy blooms.<sup>47</sup> Controlled pollination was used to develop a bee-balm genotype (*Monarda didyma* 'Sugar Lace') with a modified branching pattern and powdery mildew resistance.<sup>48</sup> Through the interspecific hybridization of *Baptisia australis* and *B. bracteata*, a false indigo genotype (*Baptisia* × *bicolor* 'Starlite') was produced that had early and abundant flowering.<sup>49</sup>

Most breeding and selection of North American plant species for ornamental traits has been conducted by private sector programs, including some in Europe.<sup>45,48</sup> Native perennial plants for mid-western US landscapes have been bred at the Chicago Botanic Garden using wild collected germplasm and cultivated plants from nursery sources.<sup>50</sup> Genera targeted in this program include *Asclepias* (milkweed), *Baptisia* (false indigo), *Echinacea* (purple coneflower), *Liatris* (blazing star) and *Penstemon* (beardtongue). Public breeding programs at US universities have developed horticultural traits in native plants of genera such as *Aronia* (chokeberry),<sup>51</sup> *Cercis* (redbud),<sup>52</sup> *Cornus* (dogwood),<sup>53</sup> *Penstemon*<sup>54</sup> and *Vaccinium* (blueberry).<sup>55</sup>

#### ECOLOGICAL SERVICES AND ADAPTABILITY OF NATIVE ORNAMENTAL PLANTS

Many native landscaping plants available in the horticultural trade are vegetatively-propagated genotypes that have been selected or bred for ornamental characteristics. There is little information about whether native ornamental cultivars can provide the same ecological services as their parent species. One study compared two cultivars of ninebark (*Physocarpus opulifolius*) and a local genotype (Minnesota, USA) as hosts for the ninebark beetle (*Calligrapha spiraeae*), a specialist herbivore.<sup>56</sup> Controlled-feeding experiments found significant differences in feeding preference between the local ninebark and the purple-leaved cultivar 'Monlo', but not between the local ninebark and the yellow-leaved cultivar 'Dart's Gold'. Leaves of 'Dart's Gold' and the local ninebark had at least fourfold less anthocyanins, a potential feeding deterrent, than the purple leaves of 'Monlo'. These results indicate that while native cultivars can support specialist insects, this may vary with the ornamental trait.

Field studies comparing the effect of native plant cultivars and ecotypes on insect populations are being conducted at two botanical gardens in the United States, the Mt Cuba Center (Delaware)<sup>57</sup> and the State Botanical Garden of Georgia (James Affolter, pers. comm.). At the US National Arboretum, a field study is in progress that compares the impact of native and exotic ornamentals on predatory insects (e.g., parasitic hymenoptera).<sup>58</sup> The range over which a native cultivar can provide an ecological service, such as food-web support, has not been investigated. Scaling up the use of



Half of consumers in the same study purchased ornamentals based on plant traits, not plant origin or invasive potential.<sup>76</sup> Traits of ornamental plants that are popular with consumers include extended flowering, novel floral morphology (e.g., double flowers), compactness, and disease-resistance. 'Knockout' roses, 'Encore' azaleas and 'Endless Summer' hydrangeas are examples of top-selling exotic cultivars in the United States that have one or more of these characteristics. Some of the native ornamental species that are currently available have been selected for traits such as double flowers,<sup>46</sup> reduced stature<sup>47</sup> and foliage color.<sup>56</sup> Further development of native ornamentals with flowering, architecture or drought-tolerance<sup>77</sup> traits may be a strategy to increase native plant use among a large segment of the consumer market.

### ACCELERATED BREEDING OF ORNAMENTAL TRAITS IN NATIVE PLANTS

Molecular breeding could be used to accelerate the development of native plants species with ornamental traits. Molecular markers have been used with ornamental plants primarily to identify cultivars, conduct pedigree analysis and study germplasm variability.<sup>78</sup> Markers have also been developed in a few cases for breeding traits such as disease resistance in roses<sup>79</sup> and flowering time in chrysanthemum.<sup>80</sup> For native ornamental plants, marker-assisted selection has the potential to accelerate cultivar development, particularly for woody species. Woody plants are an important target because (i) they have the highest wholesale value in the US ornamental plant market,<sup>81</sup> and (ii) the hosts for the greatest diversity of lepidopteran species are native woody species.<sup>82</sup>

Molecular markers have been generated for a limited number of ornamental species that are native to North America. This may be due in part to the current cost of marker development relative to the market size of a native species. Amplified fragment length polymorphism (AFLP) and simple sequence repeat (SSR) markers were developed to identify cultivars and lines of flowering dogwood (*Cornus florida*).<sup>83,84</sup> The genetic diversity and population structure of *C. florida* were assessed using SSR markers.<sup>85</sup> A genetic linkage map of *C. florida* was constructed<sup>86</sup> and potential quantitative trait loci for red foliage were identified.<sup>87</sup> SSR markers were examined in redbud (*Cercis canadensis*) in order to determine pedigree and the applicability of molecular markers to breeding.<sup>88,89</sup> AFLP analysis was used to determine the genetic diversity and degree of introgression among several deciduous azalea species (*Rhododendron* sp.).<sup>90</sup> In another woody ornamental, chokecherry (*Prunus virginiana*), a major quantitative trait loci for disease resistance was identified using AFLP and SSR markers.<sup>91</sup> Saturated linkage maps<sup>92</sup> and a genome sequence database<sup>93</sup> have been developed for other *Prunus* species and other Rosaceae members that could be used in ornamental trait development. Among herbaceous North American species, genetic diversity has been examined in *Coreopsis leavenworthii* with AFLP markers<sup>94</sup> and in *Helianthus annuus* with both anonymous SSRs<sup>95</sup> and gene-specific EST-SSRs.<sup>96</sup>

To take advantage of the genetic variation present in native plant populations, reverse genetic approaches could be employed that have been used for forestry<sup>97</sup> and agricultural<sup>98,99</sup> species. Strategies such as EcoTILLING or BRDA (breeding with rare defective alleles) use genetic screening to identify defective alleles of genes known to play major roles in the control of qualitative traits. Allelic variation has been detected in coding sequences by several screening methods, including DNA nuclease assays, high-resolution melting analysis and next-generation sequencing.<sup>99</sup> The genetic screening of 100–800 accessions from germplasm collections has identified defective variants of genes leading to targeted traits. Examples include improved lignin quality in black poplar (*Populus nigra*),<sup>97</sup> virus resistance in pepper (*Capsicum* sp.)<sup>100</sup> and improved oil quality in rapeseed (*Brassica napus*).<sup>101</sup>

There are several ornamental traits controlled by recessive genes that could be targeted in native plants. Many of the novel flowering and architecture phenotypes that have been obtained by traditional breeding are due to defective alleles of single genes.<sup>102</sup> For example, floral timing has been modified in several plant species by selecting for natural *TERMINAL FLOWER1* (*TFL1*) mutations. *TFL1* represses the transition from vegetative to reproductive growth in the shoot meristem. In perennial plants such as rose (*Rosa hybrida*) and woodland strawberry (*Fragaria vesca*), *TFL1* mutations cause continuous flowering.<sup>103</sup> In annual crop plants, such as tomato and soybean, determinate varieties were developed through selection for defective alleles of *TFL1* orthologs.<sup>104,105</sup> Floral structure has been modified by selecting for mutations of *AGAMOUS* (*AG*), a transcription factor that regulates floral organ identity. A consequence of the loss of *AG* function is the homeotic conversion of stamens to petals to produce 'double flowers'. Natural mutations of *AG* orthologs are responsible for double flowers in varieties of ornamental cherry, morning glory and anemone.<sup>106–108</sup>

Novel architectural traits, such as reduced stature and increased branching, have been obtained from the loss of function of particular genes. Plant stature has been altered by selection for mutations in genes for gibberellic acid biosynthesis or signaling. Natural and induced mutations in *GIBBERELLIN 20-OXIDASE* (*GA20ox*) of rice led to semi-dwarf varieties that played a critical role in the Green Revolution.<sup>109</sup> Semi-dwarf phenotypes have been induced in crop species such as apple and tomato through the knockdown of *GA20ox* expression<sup>110,111</sup> and in hybrid poplar through the overexpression of *GA INSENSITIVE* (*GAI*).<sup>112</sup> Plant branching patterns can be altered by changes in the expression of *BRANCHED1* (*BRC1*) or *TEOSINTE BRANCHED1* (*TB1*), two closely related transcription factors that repress axillary bud growth. Reduced branching due to *TB1* overexpression was critical to maize domestication;<sup>113</sup> conversely, the knockout of *BRC1* expression in Arabidopsis and tomato causes increased branching.<sup>114,115</sup> Similar to *TFL1*, *AG* and *GA20ox* mutations in different plant species, the loss of function of *BRC1* resulted in the same phenotype in diverse plants. The discovery of natural mutations in candidate genes like these could lead to ornamental traits in native plant species.

Research in model species may be useful for the identification of other genes that play major roles in ornamental traits. For example, peach (*Prunus persica*) is a model Rosaceae species<sup>116</sup> that could be used to study flowering genes in woody plants. Peach has complete, autogamous flowers that are produced after a relatively short juvenile period (2–3 years) and a small, sequenced, diploid genome (227 Mb). Although gene transfer in peach is not practical, flowers can be fertilized with mutagenized pollen to generate M1 mutants;<sup>117,118</sup> non-chimeric M1 populations would allow early screening for mutations in targeted genes by TILLING or next-generation sequencing. In addition to the known flowering genes that have been characterized in peach,<sup>119–125</sup> floral morphology traits have been identified.<sup>126,127</sup> Peach flowers can be large and showy or small with curved petals (non-showy), with the 'showy' flower phenotype (*sh/sh*) segregating as a recessive, monogenic trait. *Sh* has been mapped to peach linkage group 1.<sup>128</sup> Knowledge of the peach *Sh* sequence and function could potentially be applied through EcoTILLING to obtain novel floral morphology in native ornamental *Prunus* species (e.g., *P. virginiana*, *P. serotina*, *P. americana*).

Other strategies that could be used to develop ornamental traits in native plants include interspecific hybridization and polyploidization.<sup>129</sup> Interspecific hybridization can occur naturally, an example being hybrid azaleas produced by the North American species *Rhododendron prunifolium* and *R. arborescens*. Spatial, temporal, or biological barriers, however, usually prevent interspecific hybridization. Pre- and post-fertilization barriers can be overcome by a range of methods, including pollination techniques, ovule and embryo rescue, and polyploidization.<sup>129</sup> Controlled crosses with

stored pollen were used to hybridize the North American natives *Franklinia alatamaha* and *Gordonia lasianthus* for woody ornamental development.<sup>130</sup> Polyploidization has been induced in order to restore fertility in interspecific crosses, e.g., native azalea hybrids.<sup>131</sup> Ornamental traits have also been developed directly through polyploidization, such as increased flower size in the North American species *Phlox subulata*.<sup>132</sup> Genetic transformation or genome editing may be a more direct means to obtain certain traits, but such approaches are rarely economically viable for ornamental plants.<sup>81</sup>

During ornamental trait development in native plant species, the trait and the source material should be chosen to maintain ecological and adaptive functions. A purple foliage trait, for example, could reduce food-web support. For environmental restoration, local provenances are usually the best adapted material, although exceptions to the 'local is best' guideline may increase with climate change.<sup>133,134</sup> The success of molecular markers for detecting the adaptive potential of native plant species has been mixed. For example, AFLP markers did not to reveal population differentiation related to local adaptation for three herbaceous perennial species native to Minnesota,<sup>135</sup> whereas AFLP markers could delineate local seed collection zones for a native Australian tree species.<sup>137</sup> Next-generation sequencing technology is being examined as a means to measure adaptive variation for restoration ecology, as well as the effect of outbreeding on local gene pools.<sup>136</sup> Whether there is sufficient regional genetic diversity in native species for breeding new traits needs to be determined. Ideally, ecological services provided by new ornamental cultivars of native species (e.g., native herbivore support) would be examined at a regional level.

## CONCLUSIONS

It has been argued that the origin of a plant species has no bearing on whether it poses an ecological risk,<sup>38,138,139</sup> although this is not a conclusion shared by many conservation biologists.<sup>149</sup> Exotic plants have a complex effect on biodiversity in urban areas.<sup>140</sup> Because new species are introduced into urban landscapes more rapidly than native species disappear, local biodiversity can remain high.<sup>141,142</sup> The reduction of native shrub and tree cover, however, can alter the composition of native populations; ground-foraging bird species, for example, are favored over birds that are canopy foragers.<sup>41</sup> Urbanization also tends to select for the same synanthropic species in different cities.<sup>142,143</sup> Consequently, while diversity may remain high within a locality ( $\alpha$ -diversity), the diversity between localities ( $\beta$ -diversity) is reduced.<sup>2</sup> The result of this trend is biotic homogenization.<sup>141,142</sup> To maintain native biodiversity in urban landscapes, the cultivation of native plant species has been recommended.<sup>5,143–146</sup>

The extent to which native species need to be incorporated in esthetically managed landscapes to provide ecological services is not known. Small-scale additions of native ornamental plants in New York city community gardens did not increase beneficial insect richness.<sup>147</sup> In contrast, landscaping with native shrubs and ground cover was found to increase the abundance and diversity of butterflies and birds in residential yards in Pennsylvania.<sup>1</sup> Suburbs of Canberra had significantly higher bird species richness when native trees made up more than 30% of the streetscape vegetation.<sup>4</sup> This was assumed to be due to the increased foraging resources provided by native trees. To manage biodiversity in urban environments, residential landscapes should be considered as patches of interconnected habitat that can link other green spaces (e.g., parks, remnant forests).<sup>148</sup> A proposal has been made to replace half the landscaping devoted to grass lawn in the United States with native plants,<sup>149</sup> which would be equivalent to about 25% of the esthetically managed landscape.

To scale up native plants in landscaping to the 30% range will require that current constraints to their use be addressed.

Stakeholder surveys have found that the availability of native plants is a major limitation to increasing their use in landscaping.<sup>43,65–68</sup> If native ornamentals were made more available through mainstream supply chains, it would likely be as a few selected genotypes of each species. This raises several interrelated questions, such as: what is the genetic diversity needed in a native plant species to provide ecological services regionally? What is the number of genotypes that can be provided profitably for regional markets? Is there sufficient genetic diversity within regionally appropriate germplasm for breeding ornamental traits?

Ecological objectives, including improved adaptation and sustainability, are receiving greater consideration in plant breeding.<sup>150</sup> The development of native plants with ornamental traits could be accelerated using molecular breeding approaches, although the current market size of native landscaping plants may be insufficient to justify their cost. However, as ornamental shrubs and trees alone have an annual wholesale value of approximately \$3 billion in the United States,<sup>81</sup> molecular breeding would be feasible if native species made up a larger part of that market. Tools from restoration ecology can be applied to address the genetic appropriateness of native plant material. Environmentally defined regions such as ecoregions or seed transfer zones may be useful as a platform for integrating economic, ecological and genetic research on native ornamental plants (Figure 1). An interdisciplinary approach could help resolve competing demands for ecological function, cost-effective production and consumer appeal in native landscaping plants.

## COMPETING INTERESTS

The authors declare no conflict of interest.

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## REFERENCES

- Burghardt KT, Tallamy DW, Shriver WG. Impact of native plants on bird and butterfly biodiversity in suburban landscapes. *Conserv Biol* 2008; **23**: 219–224.
- Chong, KY, Teo S, Kurukulasuriya B, Chung YF, Rajathurai S, Tan HTW. Not all green is as good: different effects of the natural and cultivated components of urban vegetation on bird and butterfly diversity. *Biol Conserv* 2014; **171**: 299–309.
- Lerman SB, Warren PS. The conservation value of residential yards: linking birds and people. *Ecol Appl* 2011; **21**: 1327–1339.
- Ikin K, Knight E, Lindenmayer DB, Fischer J, Manning AD. The influence of native versus exotic streetscape vegetation on the spatial distribution of birds in suburbs and reserves. *Divers Distrib* 2013; **19**: 294–306.
- Paker Y, Yom-Tov Y, Alon-Mozes T, Barnea A. The effect of plant richness and urban garden structure on bird species richness, diversity and community structure. *Landscape Urban Plan* 2014; **122**: 186–195.
- Kramer MG. *Our built and natural environments: a technical review of the interactions among land use, transportation, and environmental quality*. Washington, DC: EPA, 2013. EPA report 231K13001, pp. 38–40.
- Erlach PR, Raven PH. Butterflies and plants: a study in coevolution. *Evolution* 1964; **18**: 586–608.
- Janz N. Ehrlich and Raven revisited: mechanisms underlying codiversification of plants and enemies. *Annu Rev Ecol Evol Syst* 2011; **42**: 71–89.
- Tallamy DW. Do alien plants reduce insect biomass? *Conserv Biol* 2004; **18**: 1689–692.
- Burghardt KT, Tallamy DW, Phillips C, Shropshire KJ. Non-native plants reduce abundance, richness, and host specialization in lepidopteran communities. *Ecosphere* 2010; **1**: 1–22.
- Burghardt KT, Tallamy DW. Plant origin asymmetrically impacts feeding guilds and life stages driving community structure of herbivorous arthropods. *Divers Distrib* 2013; **19**: 1553–1565.
- Martin LJ, Murray BR. A predictive framework and review of the ecological impacts of exotic plant invasions on reptiles and amphibians. *Biol Rev* 2011; **86**: 407–419.
- Mgobozi MP, Somers MJ, Dippenaar-Schoeman AS. Spider responses to alien plant invasion: the effect of short- and long-term *Chromolaena odorata* invasion and management. *J Appl Ecol* 2008; **45**: 1189–1197.

- 14 Hawkes CV, Belnap J, D'Antonio C, Firestone MK. Arbuscular mycorrhizal assemblages in native plant roots change in the presence of invasive exotic grasses. *Plant Soil* 2006; **281**: 369–380.
- 15 Mummy DL, Matthias CR. The invasive plant species *Centaurea maculosa* alters arbuscular mycorrhizal fungal communities in the field. *Plant Soil* 2006; **288**: 81–90.
- 16 DeVore JL, Maerz JC. Grass invasion increases top-down pressure on an amphibian via structurally mediated effects on an intraguild predator. *Ecology* 2014; **95**: 1724–1730.
- 17 Tallamy DW. *Bringing Nature Home: How You Can Sustain Wildlife with Native Plants*. Portland, OR: Timber Press, 2007.
- 18 Callicot JB, Lore GK. *The nature of roadsides and the tools to work with it*. Washington, DC: FHWA, 1999. Federal Highway Administration Publication FHWA-EP-03-005.
- 19 Alig RJ, Kline JD, Lichtenstein M. Urbanization on the US landscape: looking ahead in the 21st century. *Landscape Urban Plan* 2004; **69**: 219–234.
- 20 USDA National Agricultural Statistics Service. Washington, DC: USDA ERS, 2014.
- 21 Nickerson C, Ebel R, Borchers A, Carriazo F. *Major uses of land in the United States, 2007*. Washington, DC: USDA ERS, 2011. USDA Economic Research Service EIB-89.
- 22 McKay JK, Christian CE, Harrison S, Rice KJ. How local is local?—a review of practical and conceptual issues in the genetics of restoration. *Restor Ecol* 2005; **13**: 432–440.
- 23 Ballard M, Hough-Goldstein J, Tallamy D. Arthropod communities on native and nonnative early successional plants. *Environ Entomol* 2013; **42**: 851–859.
- 24 Perre P, Loyola RD, Lewinsohn TM. Insects in urban plants: contrasting the flower head feeding assemblages on native and exotic hosts. *Urban Ecosys* 2011; **14**: 711–722.
- 25 Cook-Patton, SC, Agrawal, AA. Exotic plants contribute positively to biodiversity functions but reduce native seed production and arthropod richness. *Ecology* 2014; **95**: 1642–1650.
- 26 Heleno RH, Ceia RS, Ramos JA, Memmott J. Effects of alien plants on insect abundance and biomass: a food-web approach. *Conserv Biol* 2008; **23**: 410–419.
- 27 Hengstum T, Hoftman DA, Oostermeijer JGB, Tienderen PH. Impact of plant invasions on local arthropod communities: a meta-analysis. *J Ecol* 2014; **102**: 4–11.
- 28 Bezemer TM, Harvey JA, Cronin JT. Response of native insect communities to invasive plants. *Annu Rev Entomol* 2014; **59**: 119–141.
- 29 Reichard SH, White P. Horticulture as a pathway of invasive plant introductions in the United States. *BioScience* 2001; **51**: 103–113.
- 30 Loomis JD, Cameron GN. Impact of the invasive shrub Amur honeysuckle (*Lonicera maackii*) on shrub-layer insects in a deciduous forest in the eastern United States. *Biol Invasions* 2014; **16**: 89–100.
- 31 Stireman JO, Devlin H, Doyle AL. Habitat fragmentation, tree diversity, and plant invasion interact to structure forest caterpillar communities. *Oecologia* 2014; **176**: 207–224.
- 32 Keeler MS, Chew FS. Escaping an evolutionary trap: preference and performance of a native insect on an exotic invasive host. *Oecologia* 2008; **156**: 559–568.
- 33 Forister ML, Scholl CF. Use of an exotic host plant affects mate choice in an insect herbivore. *Am Nat* 2012; **179**: 805–810.
- 34 Dietzsch AC, Stanley DA, Stout JC. Relative abundance of an invasive alien plant affects native pollination processes. *Oecologia* 2011; **167**: 469–479.
- 35 Cappiccino N, Carpenter D. Invasive exotic plants suffer less herbivory than non-invasive exotic plants. *Biol Lett* 2005; **1**: 435–438.
- 36 Lieurance D, Cipollini D. Exotic *Lonicera* species both escape and resist specialist and generalist herbivores in the introduced range in North America. *Biol Invas* 2013; **15**: 1713–1724.
- 37 Sands DPA. Conserving the Richmond birdwing butterfly over two decades: where to next? *Ecol Manage Restor* 2008; **9**: 4–16.
- 38 Davis, M. Do native birds care whether their berries are native or exotic? *No. BioScience* 2011; **61**: 501–502.
- 39 Nagy, LR, Holmes RT. Food limits annual fecundity of a migratory songbird: an experimental study. *Ecology* 2005; **86**: 675–681.
- 40 Granbom M, Smith, HG. Food limitation during breeding in a heterogeneous landscape. *The Auk* 2006; **123**: 97–107.
- 41 Chace JF, Walsh JJ. Urban effects on native avifauna: a review. *Landscape Urban Plan* 2006; **74**: 46–69.
- 42 Blair, RB. Birds and butterflies along an urban gradient: surrogate taxa for assessing biodiversity? *Ecol Appl* 1999; **9**: 164–170.
- 43 Brzuszek RF, Harkess RL. Green industry survey of native plant marketing in the southeastern United States. *HortTechnology* 2009; **19**: 168–172.
- 44 Armitage AM. *Armitage's Native Plants for North American Gardens*. Portland, OR: Timber Press, 2006.
- 45 Skelley K. *Potentilla fruticosa* 'KM01'. US Plant Patent application 20140026268, 2014.
- 46 Anonymous. A double-flowered redbud (*Cercis canadensis* var. plena). *Missouri Bot Garden Bull* 1935; **23**: 77–78.
- 47 Flemer W. *Hydrangea quercifolia*. US Plant Patent 4458, 1979.
- 48 Oudshoorn HG. Monarda plant named 'Sugar Lace'. US Plant Patent 22918, 2012.
- 49 JR. Baptisia plant named 'Starlite'. US Plant Patent 19971, 2009.
- 50 Ault J. Breeding and development of new ornamental plants from North American native taxa. *Acta Hort* 2003; **624**: 37–42.
- 51 Brand M. Aronia: native shrubs with untapped potential. *Arnoldia* 2010; **67**: 14–25.
- 52 Werner DJ, Snelling LK. Cercis plant named 'Ruby Falls'. US Plant Patent 22097, 2011.
- 53 Windham MT, Trigiano RN, Witte WT. Dogwood tree named 'Kay's Appalachian Mist'. US Plant Patent 13098, 2002.
- 54 Lindgren DT, Schaaf DM. Penstemon: a summary of interspecific crosses. *HortScience* 2007; **42**: 494–498.
- 55 NeSmith DS, Ehlenfeldt MK. 'Summer Sunset<sup>TM</sup>': a new ornamental blueberry. *HortScience* 2011; **46**: 1560–1561.
- 56 Tenczar EG, Krischik VA. Effects of new cultivars of ninebark on feeding and ovipositional behavior of the specialist ninebark beetle, *Calligrapha spiraeae* (Coleoptera: Chrysomelidae). *HortScience* 2007; **42**: 1396–1399.
- 57 Native plant partnership: UD, Mt. Cuba Center research how native plants contribute to healthy ecosystems. Newark, DE: University of Delaware; 7 July 2014. Available at <http://www.udel.edu/udaily/2015/jul/healthyecosystems070714.html> (accessed 12 November 2014).
- 58 Greenstone MH, Olsen RT, Buffington ML et al. Insect natural enemies in ornamental urban landscapes: parasitic hymenoptera in native and exotic residential-scale plots. In: Proceedings of the 24th USDA Interagency Research Forum on Invasive Species; 8–11 January; Annapolis, MD, USA. USDA: Washington, DC, USA, 2013, p. 32.
- 59 Omernik JM. Ecoregions of the conterminous United States. *Ann Assoc Am Geog* 1987; **77**: 118–125.
- 60 Bower A, Clair BS, Erickson V. Generalized provisional seed zones for native plants. *Ecol Appl* 2010; **24**: 913–919.
- 61 Vogel KP, Schmer MR, Mitchell RB. Plant adaptation regions: ecological and climatic classification of plant materials. *Rangeland Ecol Manage* 2005; **58**: 315–319.
- 62 Miller SA, Bartow A, Gisler M, Ward K, Young AS, Kaye TN. Can an ecoregion serve as a seed transfer zone? Evidence from a common garden study with five native species. *Restor Ecol* 2010; **19**: 268–276.
- 63 Johnson GR, Sorensen FC, St Clair JB, Cronn RC. Pacific Northwest forest tree seed zones: a template for native plants? *Native Plants J* 2004; **5**: 131–140.
- 64 Hall CR, Hodges AW, Palma MA. Sales, trade flows and marketing practices within the US nursery industry. *J Environ Hort* 2011; **29**: 14–24.
- 65 Kauth PJ, Perez HE. Industry survey of the native wildflower market in Florida. *HortTechnology* 2011; **21**: 779–788.
- 66 Hooper VH, Endter-Wada J, Johnson CW. Theory and practice related to native plants. *Landscape J* 2008; **27**: 127–141.
- 67 Brzuszek RF, Harkess RL, Mulley S. Landscape architects' use of native plants in the southeastern United States. *HortTechnology* 2007; **17**: 78–81.
- 68 Brzuszek RF, Harkess RL, Kelly L. Survey of Master Gardener use of native plants in the southeastern United States. *HortTechnology* 2010; **20**: 462–466.
- 69 Heywood V. Conservation and sustainable use of wild species as sources of new ornamentals. *Acta Hort* 2001; **598**: 43–53.
- 70 Cooper, CB, Dickinson J, Phillips T, Bonney R. Citizen science as a tool for conservation in residential ecosystems. *Ecol Soc* 2007; **12**: 11.
- 71 van Heezik, YM, Dickinson KJM, Freeman C. Closing the gap: communicating to change gardening practices in support of native biodiversity in urban private gardens. *Ecol Soc* 2012; **17**: 34.
- 72 Hinson RA, Paudel KP, Velastegui M, Marchant MA, Bosch DJ. Understanding ornamental plant market shares to rewholesaler, retailer, and landscaper channels. *J Agr Appl Econ* 2012; **44**: 173–189.
- 73 Norcini J. *Native plants: an overview*. Tampa, FL: Florida Coop. Ext. Serv., Inst. Food Agr. Sci., Univ. Florida, 2006. ENH1045.
- 74 Helfand GE, Sik Park J, Nassauer JI, Kosek S. The economics of native plants in residential landscape designs. *Landscape Urban Plan* 2006 **78**: 229–240.
- 75 Yue C, Hurley TM, Anderson N. Do native and invasive labels affect consumer willingness to pay for plants? Evidence from experimental auctions. *Agric Econ* 2011; **42**: 195–205.
- 76 Yue C, Hurley T, Anderson NO. Heterogeneous consumer preferences for native and invasive plants: evidence from experimental auctions. *HortScience* 2012; **47**: 1091–1095.
- 77 Stanton KM, Mickelbart MV. Maintenance of water uptake and reduced water loss contribute to water stress tolerance of *Spiraea alba* Du Roi and *Spiraea tomentosa* L. *Hort Res* 2014; **1**: 14033.

- 78 Arús P. Molecular markers for ornamental breeding. *Acta Hort* 2000; **508**: 91–98.
- 79 Debener T, Byrne DH. Disease resistance breeding in rose: current status and potential of biotechnological tools. *Plant Sci* 2014; **228**: 107–117.
- 80 Zhang F, Chen S, Chen F *et al*. Genetic analysis and associated SRAP markers for flowering traits of chrysanthemum (*Chrysanthemum morifolium*). *Euphytica* 2011; **177**: 15–24.
- 81 Dobres MS. Barriers to genetically engineered ornamentals: an industry perspective. In: *Floriculture, Ornamental and Plant Biotechnology*. East Sussex: Global Science Books, 2008: 1–14.
- 82 Tallamy DW, Shropshire KJ. Ranking lepidopteran use of native versus introduced plants. *Conserv Biol* 2009; **23**: 941–947.
- 83 Smith NR, Trigiano RN, Windham MT *et al*. AFLP markers identify *Cornus florida* cultivars and lines. *J Am Soc Hort Sci* 2007; **132**: 90–96.
- 84 Wadl PA, Wang X, Trigiano AN *et al*. Molecular identification keys for cultivars and lines of *Cornus florida* and *C. kousa* based on simple sequence repeat loci. *J Am Soc Hortic Sci* 2008; **133**: 783–793.
- 85 Hadziabdic D, Fitzpatrick BM, Wang X *et al*. Analysis of genetic diversity in flowering dogwood natural stands using microsatellites: the effects of dogwood anthracnose. *Genetica* 2010; **138**: 1047–1057.
- 86 Wang X, Wadl PA, Rinehart TA *et al*. A linkage map for flowering dogwood (*Cornus florida* L.) based on microsatellite markers. *Euphytica* 2009; **165**: 165–175.
- 87 Wadl PA, Saxton AM, Wang X *et al*. Quantitative trait loci associated with red foliage in *Cornus florida* L. *Mol Breeding* 2011; **27**: 409–416.
- 88 Rinehart TA, Robert NT, Phillip AW *et al*. Characterization of twelve microsatellite markers for the native redbud tree (*Cercis canadensis*). *Mol Ecol Resources* 2010; **10**: 751–754.
- 89 Wadl PA, Trigiano RN, Werner DJ, Pooler MR, Rinehart TA. Simple sequence repeat markers from *Cercis canadensis* show wide cross-species transfer and use in genetic studies. *J Am Soc Hort Sci* 2012; **137**: 189–201.
- 90 Chappell M, Robacker C, Jenkins TM. Genetic diversity of seven deciduous azalea species (*Rhododendron* spp. section Pentanthera) native to the eastern United States. *J Am Soc Hortic Sci* 2008; **133**: 374–382.
- 91 Wang H, Walla JA, Magnusson VA, Zhong S, Dai W. Construction of genetic linkage maps and QTL mapping for X-disease resistance in tetraploid chokecherry (*Prunus virginiana* L.) using SSR and AFLP markers. *Mol Breeding* 2014; **34**: 143–157.
- 92 Dirlewanger E, Graziano E, Joobeur T *et al*. Comparative mapping and marker-assisted selection in Rosaceae fruit crops. *Proc Natl Acad Sci USA* 2004; **101**: 9891–9896.
- 93 Jung S, Ficklin SP, Lee T *et al*. The Genome Database for Rosaceae (GDR): year 10 update. *Nucleic Acids Res* 2014; **42**: D1237–D1244.
- 94 Czarnecki DM, Rao MN, Norcini JG, Gmitter FG, Deng Z. Genetic diversity and differentiation among natural, production, and introduced populations of the narrowly endemic species *Coreopsis leavenworthii* (Asteraceae). *J Am Soc Hort Sci* 2008; **133**: 234–241.
- 95 Tang S, Knapp SJ. Microsatellites uncover extraordinary diversity in native American land races and wild populations of cultivated sunflower. *Theor Appl Genet* 2003; **106**: 990–1003.
- 96 Pashley CH, Ellis JR, McCauley DE, Burke JM. EST databases as a source for molecular markers: lessons from *Helianthus*. *J Heredity* 2006; **97**: 381–388.
- 97 Vanholme B, Cesarino I, Goeminne G *et al*. Breeding with rare defective alleles (BRDA): a natural *Populus nigra* HCT mutant with modified lignin as a case study. *New Phytol* 2013; **198**: 765–776.
- 98 van Nocker S, Gardiner SE. Breeding better cultivars, faster: applications of new technologies for the rapid deployment of superior horticultural tree crops. *Hort Res* 2014; **1**: 14022.
- 99 Till BJ. Mining genetic resources via ecotilling. In: Tuberosa R, Graner A, Frison E (ed.) *Genomics of Plant Genetic Resources*. Dordrecht: Springer, 2014: 349–365.
- 100 Ibañez VP, Canizares J, Nuez F. EcoTILLING in *Capsicum* species: searching for new virus resistances. *BMC Genomics* 2010; **11**: 631.
- 101 Wang NA, Shi L, Tian F *et al*. Assessment of *FAE1* polymorphisms in three *Brassica* species using EcoTILLING and their association with differences in seed erucic acid contents. *BMC Plant Biol* 2010; **10**: 137.
- 102 Olsen KM, Wendel JF. A bountiful harvest: genomic insights into crop domestication phenotypes. *Annu Rev Plant Biol* 2013; **64**: 47–70.
- 103 Iwata H, Gaston A, Remay A *et al*. The TFL1 homologue K5N is a regulator of continuous flowering in rose and strawberry. *Plant J* 2012; **69**: 116–125.
- 104 Pnueli L, Carmel-Goren L, Hareven D *et al*. The SELF-PRUNING gene of tomato regulates vegetative to reproductive switching of sympodial meristems and is the ortholog of CEN and TFL1. *Development* 1998; **125**: 1979–1989.
- 105 Tian Z, Wang X, Lee R *et al*. Artificial selection for determinate growth habit in soybean. *Proc Natl Acad Sci USA* 2010; **107**: 8563–8568.
- 106 Liu Z, Zhang D, Liu D, Li F, Lu H. Exon skipping of AGAMOUS homolog PrseAG in developing double flowers of *Prunus lannesiana* (Rosaceae). *Plant Cell Rep* 2013; **32**: 227–237.
- 107 Nitasaka E. Insertion of an En/Spm-related transposable element into a floral homeotic gene DUPLICATED causes a double flower phenotype in the Japanese morning glory. *Plant J* 2003; **36**: 522–531.
- 108 Galimba KD, Tolkin TR, Sullivan AM, Melzer R, Theißen G, Di Stilio VS. Loss of deeply conserved C-class floral homeotic gene function and C-and E-class protein interaction in a double-flowered ranunculid mutant. *Proc Natl Acad Sci USA* 2012; **109**: 2267–2275.
- 109 Ashikari M, Sasaki A, Ueguchi-Tanaka M *et al*. Loss-of-function of a rice gibberellin biosynthetic gene, GA20 oxidase (GA20ox-2), led to the rice ‘green revolution’. *Breeding Sci* 2002; **52**: 143–150.
- 110 Bulley SM, Wilson FM, Hedden P, Phillips AL, Croker SJ, James DJ. Modification of gibberellin biosynthesis in the grafted apple scion allows control of tree height independent of the rootstock. *Plant Biotechnol J* 2005; **3**: 215–223.
- 111 Xiao J, Li H, Zhang J *et al*. Dissection of GA 20-oxidase members affecting tomato morphology by RNAi-mediated silencing. *Plant Growth Regul* 2006; **50**: 179–189.
- 112 Elias AA, Busov VB, Kosola KR *et al*. Green revolution trees: semidwarfism transgenes modify gibberellins, promote root growth, enhance morphological diversity, and reduce competitiveness in hybrid poplar. *Plant Phys* 2012; **160**: 1130–1144.
- 113 Studer A, Zhao Q, Ross-Ibarra J, Doebley J. Identification of a functional transposon insertion in the maize domestication gene tb1. *Nat Genet* 2011; **43**: 1160–1163.
- 114 Aguilar-Martínez JA, Poza-Carrión C, Cubas P. Arabidopsis BRANCHED1 acts as an integrator of branching signals within axillary buds. *Plant Cell* 2007; **19**: 458–472.
- 115 Martín-Trillo M, Grandío EG, Serra F *et al*. Role of tomato BRANCHED1-like genes in the control of shoot branching. *Plant J* 2011; **67**: 701–714.
- 116 Shulaev V, Korban SS, Sosinski B *et al*. Multiple models for Rosaceae genomics. *Plant physiology* 2008; **147**: 985–1003.
- 117 IAEA Mutant Variety Database. Peach variety ‘Plovdiv 6’. Available at <http://mvgs.iaea.org/Search.aspx?ID=247> (accessed 18 December 2014).
- 118 Pooler MR, Scorza R. Irradiation and heat affect peach pollen germination and fertility. *HortScience* 1997; **32**: 290–291.
- 119 Martin T, Hu M, Labbe H, McHugh S, Svircev A, Miki B. PpAG1, a homolog of AGAMOUS, expressed in developing peach flowers and fruit. *Can J Bot* 2006; **84**: 767–776.
- 120 An L, Li T. Cloning, expression, and production of polyclonal antibodies of peach PpLFY. *Acta Hort Sin* 2008; **35**: 1573–1580.
- 121 Zhang L, Xu Y, Ma R. Molecular cloning, identification, and chromosomal localization of two MADS box genes in peach (*Prunus persica*). *J Genet Genomics* 2008; **35**: 365–372.
- 122 Tadiello, A, Pavanello A, Zanin D *et al*. A PLENA-like gene of peach is involved in carpel formation and subsequent transformation into a fleshy fruit. *J Expt Bot* 2009; **60**: 651–661.
- 123 Tani E, Polidoros AN, Fletmetakis E *et al*. Characterization and expression analysis of AGAMOUS-like, SEEDSTICK-like, and SEPALLATA-like MADS-box genes in peach (*Prunus persica*) fruit. *Plant Physiol Biochem* 2009; **47**: 690–700.
- 124 Yamane H, Ooka T, Jotatsu H, Sasaki R, Tao R. Expression analysis of PpDAM5 and PpDAM6 during flower bud development in peach (*Prunus persica*). *Sci Hort* 2011; **129**: 844–848.
- 125 Chen Y, Jiang P, Thammanagowda S, Liang H, Wilde HD. Characterization of peach TFL1 and comparison with FT/TFL1 gene families of the Rosaceae. *J Am Soc Hort Sci* 2013; **138**: 12–17.
- 126 Connors CH. Some notes on the inheritance of unit characters in the peach. *Proc Am Soc Hort Sci* 1920; **16**: 24–36.
- 127 Bailey JS, French, AP. The inheritance of blossom type and blossom size in the peach. *Proc Am Soc Hort Sci* 1942; **40**: 248–250.
- 128 Pozzi C, Vecchietti A. Peach structural genomics. In: Folta KM, Gardiner SE, (ed.) *Genetics and Genomics of Rosaceae*. New York: Springer, 2009: 235–257.
- 129 Van Tuyl JM, Lim, K-B. Interspecific hybridisation and polyploidisation as tools in ornamental plant breeding. *Acta Hort* 2003; **612**: 13–22.
- 130 Ranney TG, Frantz PR. ×*Gordlinia grandiflora* (Theaceae): An intergeneric hybrid between *Franklinia alatamaha* and *Gordonia lasianthus*. *HortScience* 2006; **41**: 1386–1388.
- 131 Jones JR, Ranney TG, Eaker TA. A novel method for inducing polyploidy in *Rhododendron* seedlings. *J Am Rhododendron Soc* 2008; **62**: 130–135.
- 132 Zhang Z, Dai H, Xiao M, Liu X. *In vitro* induction of tetraploids in *Phlox subulata* L. *Euphytica* 2008; **159**: 59–65.
- 133 Jones TA. When local isn’t best. *Evol Appl* 2013; **6**: 1109–1118.
- 134 Potter KM, Hargrove WW. Determining suitable locations for seed transfer under climate change: a global quantitative method. *New Forests* 2012; **43**: 581–599.
- 135 Moncada KM, Ehlke NJ, Muehlbauer GJ *et al*. Genetic variation in three native plant species across the state of Minnesota. *Crop Sci* 2007; **47**: 2379–2389.
- 136 Krauss SL, Sinclair EA, Bussell JD, Hobbs, RJ. An ecological genetic delineation of local seed source provenance for ecological restoration. *Ecol Evol* 2013; **3**: 2138–2149.

- 137 Williams AV, Nevill PG, Krauss SL. Next generation restoration genetics: applications and opportunities. *Trends Plant Sci* 2014; **19**: 529–537.
- 138 Kendle AD, Rose JE. The aliens have landed! What are the justifications for 'native only' policies in landscape plantings? *Landscape Urban Plan* 2000; **47**: 19–31.
- 139 Davis MA, Chew MK, Hobbs RJ *et al*. Don't judge species on their origins. *Nature* 2011; **474**: 153–154.
- 140 Simberloff D. Non-natives: 141 scientists object. *Nature* 2011; **475**: 36.
- 141 Qian H, Ricklefs RE. The role of exotic species in homogenizing the North American flora. *Ecol Lett* 2006; **9**: 1293–1298.
- 142 McKinney ML. Urbanization as a major cause of biotic homogenization. *Biol Conserv* 2006; **127**: 247–260.
- 143 Shochat E, Lerman SB, Anderies JM, Warren PS, Faeth SH, Nilon CH. Invasion, competition, and biodiversity loss in urban ecosystems. *BioScience* 2010; **60**: 199–208.
- 144 McKinney ML. Urbanization, biodiversity, and conservation. *BioScience* 2002; **52**: 883–890.
- 145 Lerman SB, Warren PS, Gan H, Shochat E. Linking foraging decisions to residential yard bird composition. *PLoS One* 2012; **7**: e43497.
- 146 Ellis EC, Antill EC, Kreft H. All is not loss: plant biodiversity in the Anthropocene. *PLoS One* 2012; **7**: e30535.
- 147 Matteson KC, Langellotto GA. Small scale additions of native plants fail to increase beneficial insect richness in urban gardens. *Insect Conserv Divers* 2011; **4**: 89–98.
- 148 Goddard MA, Dougill AJ, Benton TG. Scaling up from gardens: biodiversity conservation in urban environments. *Trends Ecol Evol* 2010; **25**: 90–98.
- 149 Tallamy DW. Available at <http://ir.nrec.org/content/outside-presentation-dr-doug-tallamy-author-bringing-home-nature> (accessed 12 November 2014).
- 150 Brummer EC, Barber WT, Collier SM *et al*. Plant breeding for harmony between agriculture and the environment. *Front Ecol Environ* 2011; **9**: 561–568.



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