Excessive Use of Water and Fertilizer by Homeowners: Why It Happens, How It Affects the Environment, and How the Nursery Industry and Extension Outreach Can Help

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Abstract

Despite global concerns regarding climate change, one thing remains constant: homeowners want gardens and landscapes that serve them functionally and aesthetically. The strong affinity homeowners have for their land can lead to excessive use of water and fertilizer. This literature review explores the relationships between homeowners and their residential landscapes and the efforts that can be made to address misuse and overuse of resources. Governmental organizations should work together with community groups, nursery and landscape associations, and university Extension faculty to understand homeowner desires and behaviors before instituting policies regarding resource use that are unpopular, resented, and ignored. Networking between the nursery industry and university Extension faculty and Master Gardener volunteers can provide educational opportunities for homeowners to understand and implement more sustainable landscape practices as well as showcasing ornamental landscape plants that can help meet both personal aesthetics and resource conservation goals.

Index words: irrigation management, nutrient management, urban landscapes.

Significance to the Horticulture Industry

This comprehensive literature review represents an analysis of homeowner beliefs and practices associated with the use of water and fertilizer in residential landscapes. The information derived from this analysis can help the landscape and nursery industries in providing science-based information to help their clients achieve their landscape goals while conserving resources and protecting the urban environment.

Introduction

Plants respond positively to increasing amounts of water and nutrients until those levels become excessive. Nurseries take advantage of this positive response to produce larger, lusher plants for sale. Unfortunately, when gardeners or landscapers purchase and install these plants, they may not be perceived to perform as well as they did in the nursery. This can lead to increased use of fertilizers and water, both of which may have unintended impacts on the surrounding environment. Nationwide, soil tests consistently show excessive levels of nutrients such as phosphorus in home gardens and landscapes due to fertilizer overuse. At the same time, climate change and increasing demands on water supplies exacerbate homeowner irrigation behaviors. Policy-making bodies from homeowner's associations to county and state governments increasingly restrict homeowner uses of water and fertilizers on gardens and landscapes to conserve and protect natural resources. When not fully understood by homeowners, these policies escalate tensions and increase mistrust of otherwise sound guidelines for managing landscapes in environmentally sustainable ways.

The results of this literature review helped identify opportunities for the green industry to become actively involved in helping educate homeowners to make informed selections of landscape plants. Furthermore, to assist homeowners in learning better practices, a brief set of science-based, practical guidelines for sustainably managing home gardens and landscapes are presented. These can be used by educators in academia and the horticulture industry to educate their clients about the sustainable use of water and fertilizer in their landscapes and gardens, thereby reducing unnecessary resource use and the amount of unintentional contamination of adjacent land and water ecosystems.

Methods

This review summarizes the current, pertinent scientific literature on the residential use of water and fertilizers and identifies general perceptions and behaviors of homeowners that could be modified to better conform to resource scarcity. Pertinent literature was identified in a search of the scientific databases using a combination of the following terms[2]:

- Irrigation OR "water use" OR fertilizer
- Resident* OR "home owner"
- Garden* OR landscape*

The search was limited to publications from 2000 onward and only included those for which complete manuscripts were available. Many of these articles also discussed the importance of personal aesthetics and peer approval in making landscape choices. These decision drivers are important to understand and are key to

Received for publication November 14, 2022; in revised form February 12, 2023.

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[2]The * used in the search denotes a truncation operator; any word that begins with the letters preceding the * will be included.

addressing homeowner behaviors through educational efforts.

I did not attempt to review the vast body of literature on resource management methods for residential landscapes (such as rain gardens and rain barrels, home composting facilities, etc.). Those resources can be found elsewhere and would be useful supplemental material for educational efforts.

Aesthetics, appearances, and acceptance

The importance of the typical homeowner's opinion of landscape aesthetics and/or conformance to social norms or to codes, covenants, and restrictions of local communities cannot be overestimated. In a recent study, aesthetics was ranked above water conservation, environmental concerns, and biodiversity as factors related to landscape goals (Morera et al. 2020). Concerns about the aesthetic appeal of one's landscape can result in increased use of both fertilizers and water; the latter is especially true in arid environments (Spinti et al. 2004).

The "*Desert Oasis*" *homeowner.* The arid southwest of the US has long been a destination point for snowbirds and retirees. Many of these part- or full-time residents enjoy the "desert oasis" aspect of the arid southwest, where nearly anything can be grown if enough water is provided. Thus, lawns and annual flowering plants are a common landscape component in southwestern cities. This landscape aesthetic is increasingly at odds with local agencies and governments, which commonly restrict residential use of water for irrigation and promote water-conserving landscapes as lawn replacements.

Homeowner acceptance of these less traditional, resource-conserving landscapes is variable. Long-time residents in desert communities, such as those in Santa Fe and Phoenix, are less likely to convert to water-conserving (xeric) landscape choices (Larson et al. 2017, St. Hilaire et al. 2010) and the same is true for residents of older neighborhoods in these communities. The desire of long-time residents to retain "desert oasis" landscapes with lush lawns and plantings (mesic landscapes) is both aesthetic and historic. An actual shortage of water was the only reason that many of them would consider landscape changes; environmental concerns, government regulations, and higher water bills were of less importance to these residents (St. Hilaire et al. 2010). In fact, many homeowners in such communities have less grass than they would prefer (Wheeler et al. 2020). Homeowners with these deeply-held aesthetic drivers, surrounded by like-minded neighbors, are resistant to changing their attitudes about landscaping choices.

Research on managing the dual demands of water conservation and landscape choice has focused on arid southwest communities; similar tensions exist wherever water availability is restricted (Morera et al. 2020). Short of strict water-use mandates, overcoming this resistance can be challenging to policy-making bodies.

The "*Desert Conscious*" *homeowner.* In contrast to the "desert oasis" homeowners, desert newcomers and residents living in newer neighborhoods are more willing to install xeric landscapes (Larson et al. 2017, St. Hilaire et al. 2010). Their personal aesthetics and desires to conform to social norms are no less strong, but they differ dramatically in their collective views on managing landscapes when water is a limiting factor. They are willing to forgo resource-demanding mesic landscapes for more climate-appropriate plantings.

The "*Aspirational*" *homeowner.* In parts of the country where water is not naturally limited by climate, homeowners may be unaware or unconcerned with the environmental costs of their individual yard care decisions (Nielson and Smith 2005). They are, however, concerned about how their neighbors view their landscapes. Living on a wealthy block, or living near others who value lush green lawns, predicts homeowner increases in both water and fertilizer use (Carrico et al. 2018). The homeowners using the greatest amount of fertilizer tend to be in lower wealth categories than others on their block, which suggests an aspirational use of yard care resources (Carrico et al. 2018). These residents may water, fertilize, and apply weed control at more frequent intervals than yard care experts recommend (Nielson and Smith 2005).

The "*Land Rich*" *homeowner.* There is a subset of homeowners whose behaviors do not align with previous groups. This group consists of homeowners with larger landscapes. Not only are their behaviors strikingly different, but they are not concerned with what their neighbors think (Visscher et al. 2014). Land rich behaviors are more in line with sustainable landscaping. In general, these "land rich" homeowners:

- Mow less of their land (Visscher et al. 2014).
- Are willing to reduce the amount of lawn on their property (Conrad et al. 2019, Grant et al. 2020).
- Retain more leaf litter on their land (Visscher et al. 2014).
- Are less likely to apply fertilizer and irrigate (Visscher et al. 2014).
- Are more likely to install drought-tolerant landscaping (Grant et al. 2020).
- Plant more trees and have large trees (Visscher et al. 2014).

Aesthetic appeal and the sustainable landscape. A sustainable landscape addresses ecological, and sociological concerns. While there are many ecological and environmental advantages to creating sustainable landscapes, none of these are as important to homeowners as aesthetics. Fortunately, sustainable landscapes can be aesthetically appealing if they are so designed (Khachatryan et al. 2020). A study in Switzerland surveyed homeowner responses to a gradient of garden designs which ranged from "conventional orthodox" (frequent lawn mowing and weeding, intensive use of pesticides and fertilizers) to "ecological unorthodox" (infrequent lawn mowing and weeding, no use of pesticides and fertilizers) (Lindemann-Matthies et al. 2013). The responses to the ecological gardens were decisively positive: these aesthet-

ically pleasing gardens were characterized as "natural" and "species-rich," while more conventional gardens were described as "boring" and "species-poor."

The key to achieving an aesthetically appealing, ecologically diverse landscape is highly dependent on design principles: homeowners do not want to see chaos but do want the assemblages of plants to make sense. Lack of an appealing design discourages homeowners from pursing low-input landscapes, even when the separate components of the landscape are preferred (Hayden et al. 2015). When designed and installed correctly, species-diverse landscapes are aesthetically appealing, create plant communities that provide significant environmental services, and provide food and habitat for beneficial wildlife (Chalker-Scott 2018, 2015a, Cubino et al. 2020).

Pathways for compromise. Fortunately, there are alternatives to "all or nothing" approaches to water-conserving landscapes. The goal should be to create opportunities for homeowners to make better decisions in a way that allows them to feel aesthetically fulfilled and accepted by their neighbors. Urban irrigation can often be substantially reduced without compromising aesthetics (Warner et al. 2016):

- Trees and other woody ornamental plants can be added to existing lawn-dominated landscapes, substantially reducing water use and providing other benefits such as shading and wildlife habitat (Bijoor 2021, Conrad et al. 2019, Grant et al. 2020).
- Mixed landscapes (those that contain both lawn and ornamental plants) are overwhelmingly preferred aesthetic choices by homeowners (Khachatryan et al. 2020).
- Low-input, mixed species landscapes have lower maintenance requirements and have economic appeal to homeowners (Khachatryan et al. 2020).
- Lawn species with high water requirements can be replaced with other grass species with lower water demand and high aesthetic value (Hayden et al. 2015).

Residential water use: perceptions and practices

Public perceptions about water conservation are now more ecologically and environmentally inclusive. Many residents in arid environments agree that traditional turfgrasses should be limited and that native, natural, and/or water-conserving landscapes should be installed (Carrico et al. 2018). Beyond residential landscapes, residents understand the value of wetlands and aquatic habitats and their need for protection and conservation (Mahler et al. 2019, Warner et al. 2020a, 2019a). Whether these beliefs and understandings translate to resident practices is questionable (Hurd 2006): increased water use is positively associated with landscape size[3], the presence of vegetable gardens, and underground sprinkler systems (Barnett et al. 2020). Extensive lawns appear to be the main driver of over-irrigation (Reyes-Paecke et al. 2019).

[3]The exception would be land-rich homeowners, who tend to have less intensive management behaviors as noted earlier.

While homeowners have a good understanding of the competing demands for potable water, especially in arid climates, this does not include comprehension of water quality issues (Hughes et al. 2012, Warner et al. 2018). In other words, homeowners are less cognizant of how their landscape maintenance and yard use can threaten the water quality of nearby aquatic ecosystems (Miller and Buys 2008, Neilson and Smith 2005, Volo et al. 2015). A surprising 85% of surveyed homeowners did not know that storm drains emptied directly into aquatic systems (Neilson and Smith 2005). Thus, potentially harmful activities such as overuse and misuse of fertilizers and pesticides directly contaminates nearby streams and ponds. Behaviors unrelated to landscape maintenance, like parking and washing vehicles on lawns (Miller and Buys 2008), can add oil and other toxic substances to aquatic ecosystems.

The lack of public understanding of the direct linkage between water quality and water stewardship in residential landscapes is at odds with policy makers at every level. Decision-making bodies who recognize the need to provide sufficient water and protect its quality have developed policies on water and fertilizer use in many parts of the country that may not resonate with homeowners. These policies include:

- Rebates
  - Removing turf and replacing it with drought tolerant landscaping (Bijoor 2021, Conrad et al. 2019, Grant et al. 2020).
  - Using weather-based irrigation controllers (Bijoor et al. 2021).
  - Purchasing high-efficiency sprinkler nozzles (Bijoor et al. 2021).
- Restrictions
  - Lawn size (Conrad et al. 2019).
  - Outdoor irrigation (Conrad et al. 2019).

In agreement with other authors, Barnett et al. (2020) suggest that educational or policy interventions which encourage residents to voluntarily reduce the amount of lawn or plants in their yards, remove their vegetable gardens, or replace their underground sprinkler systems may have limited utility for reducing residential water use. Financial incentives to install xeric landscapes, purchase water-saving technologies, or reduce water consumption are more likely to encourage homeowner acceptance (Hurd 2006).

Alternative water sources. Homeowners are increasingly willing to consider alternative water sources for irrigation purposes. Non-potable water can, within limits, be successfully used for irrigating garden and landscape plants (Botha and Jacobs 2019), particularly when potable water is unavailable due to competing demands. Alternative water sources include **air conditioner condensate**, **recycled/reclaimed water**, **greywater,** and **rainwater.**

- Air conditioner condensate is a high-quality alternative water source that can be collected and applied to landscape plantings.

- Recycled or reclaimed water is treated effluent from wastewater treatment facilities (Quesnel et al. 2019). While there can be an "ick" factor associated with using recycled water, it is safe to use for irrigation purposes.
- Greywater is water collected from sinks, washing machines, dishwashers, bathtubs, and showers. It does not include toilet water.
- Rainwater can be collected from rooftops and stored in barrels (Chalker-Scott 2017, Jennings et al. 2013). Where lawful, rainwater capture can reduce stormwater runoff, which can be damaging to soils and nearby aquatic systems.

Residents should be cautious when using lower-quality alternative water sources, such as greywater and rainwater. Greywater can contain dissolved salts as well as nutrients, with the former potentially damaging salt-sensitive species (Leinauer et al. 2010). Stored rainwater and low-quality groundwater can house pathogens, algae, and other contaminants; fruits and vegetables irrigated with these lower quality water sources should be rinsed well before consuming (Chalker-Scott 2017, do Espìrito Santo Silva et al. 2020).

Water management strategies in landscapes. There are existing and emerging technologies that can help residents manage irrigation water more effectively. In general, residents are more likely to adopt newer irrigation technologies, such as smart controllers, that are convenient and not management intensive (DeMouche et al. 2007, Fontanier et al. 2017, Khachatryan et al. 2019, Warner et al. 2020b). However, manufacturers of these devices would be wise to consider the wants and needs of homeowners (Zhang and Khachatryan 2019), which will differ depending on an individual's comfort with technology. The most promising development is the inclusion of real-time weather events like rainfall, which allows the smart controller to make irrigation adjustments in response.

Low-tech approaches to water conservation are also available and possibly more effective in increasing homeowner understanding of natural water cycles (Survis and Root 2017) as well as plant responses to environmental conditions. Following are some specific examples of low-tech approaches with substantial knowledge gain:

- Using soil moisture meters to reduce lawn irrigation. These meters were provided by local Extension personnel and highly effective in modifying homeowner behavior (Muntz et al. 2019).
- Consulting historical precipitation mapping as well as current precipitation measurements to inform irrigation use. Master Gardener programs have developed outreach activities to educate homeowners (DeMouche et al. 2007).
- Modifying irrigation time and frequency depending on the landscape type. Xeric landscapes can tolerate small, frequent irrigation events, which saves water compared to mesic landscapes with longer irrigations at a greater depth (Volo et al. 2015).
- Replacing landscape sprinklers with subsurface irrigation, which significantly reduces water loss from droplet evaporation, run-off, leaching, and wind drift (Leinauer et al. 2010). The easiest method of adding subsurface irrigation is the use of drip hoses. These can be installed underneath mulch.
- As reduced irrigation can give weeds and invasive species an advantage over landscape plants (Haeuser et al. 2019), the use of coarse arborist wood chips is highly recommended to suppress weeds while conserving water and benefiting desirable plants (Chalker-Scott 2015b, 2007).
- Using ratchet timers to limit irrigation to set intervals on hose end sprinklers.

Ultimately, the most effective way to deal with residential water conservation is to mandate conservation measures be put in place while residential subdivisions are being planned (Lowry et al. 2011). It is more feasible to require developers to install water-saving technologies in new homes, such as smart irrigation and greywater recycling systems, rather than imposing new regulations on existing home landscapes. Likewise, policies encouraging the substitution of trees, shrubs, and perennials for turfgrass in new residential developments are likely to be more successful than encouraging homeowners to convert existing landscapes to more water-efficient designs.

Residential fertilizer use

The quest for the perfect lawn (Carrico et al. 2018, Neilson and Smith 2005) and the widespread perception that other landscape plants also need "feeding" are the drivers of routine fertilizer overuse. While some homeowners are aware of environmental concerns and have reduced their use of fertilizers (Carrico et al. 2018), it is still an activity done in the absence of evidence of actual nutrient deficiencies in the soil. Without a soil test, it is impossible to know which, if any, nutrients are at deficient levels.

Disappointingly, most published research on the topic of home fertilizer use does not address whether fertilization is warranted vis-à-vis a soil analysis. Instead, the focus is on how often and at what rate fertilizer is added to lawns and other landscape plantings. Increased fertilizer use and subsequent high in situ nutrient levels seen by researchers has led to environmental concerns, including:

- Loss of nitrogen through denitrification (Raciti et al. 2011).
- Soil leaching of nitrogen, phosphorus, and potassium (Erickson et al. 2008, 2005, 2001).
- Nitrogen mobilization in front yards (Suchi et al. 2021).
- Significant contribution to nonpoint-source pollution of aquatic ecosystems (Neilson and Smith 2005).

Not unexpectedly, the response to the potential environmental damage caused by excessive use and runoff of landscape fertilizers has been to restrict or forbid the residential use of many high nitrogen and phosphorus fertilizers (Ghimire et al. 2019, Ryan et al. 2019, Souto et al. 2019). While restrictions can enhance homeowners' understanding of the environmental problems (Souto et al. 2019, Warner et al. 2019b) and successfully reduce the use

of residential fertilizers (Souto et al. 2019), they also lead to mistrust of government officials and landscape scientists (Ghimire et al. 2019, Ryan et al. 2019).

Soil testing for rational decision making. Researchers increasingly recognize the importance of soil testing before application of fertilizers (Mangiafico et al. 2011, Warner et al. 2018), but few homeowners routinely engage in this practice (Warner et al. 2019b). Without an idea of the current nutrient levels in a landscape soil, it is impossible to know what, if anything, is deficient. Without soil testing it is far too easy to add nutrients that aren't deficient and in doing so create excessive levels of nutrients, some of which have direct, negative effects on plant, soil, and aquatic life.

The benefits of a soil test, performed by a government or university lab[4] that is equipped to test and interpret residential soil samples, cannot be overstated. For a reasonable fee, homeowners can obtain a wealth of information on their soil health. Specifically, homeowners can discover:

- Levels of all essential macro- and micronutrients, except nitrogen[5].
- Soil organic matter content (highly variable but can be correlated with nutrient levels).
- Cation exchange capacity (greater than 5 meq per 100 g for nutrient retention).
- Presence of toxic metals of concern (such as lead, arsenic, chromium, etc.).
- Soluble salts (common in arid regions).
- Soil pH.

The most important attributes to look at before adding fertilizer of any sort are the essential nutrients. Any nutrients that are at or above optimal levels should NOT be added. Generally, P and K levels are high in residential landscapes, so "complete" fertilizers (NPK) cannot be used. Homeowners will need to find products that only contain nutrients that are at deficit levels. Often, this means that no fertilizers are needed. More science-based information on managing residential soil fertility has been recently published (Chalker-Scott and Downer 2020).

Lawns and the American landscape

Lawns are a popular landscape element in many if not most home landscapes. Traditional lawns are by far the most resource-intensive landscape element, as their maintenance can include extensive irrigation (Fontanier et al. 2017, Harlan et al. 2009, Larson et al. 2017, Reyes-Paecke et al. 2019), frequent fertilization (Carrico et al. 2018, Souto et al. 2019), in addition to the use of petrochemicals and labor to attain uniformly green lushness. Homeowner associations (HOAs) often mandate that residents keep lawns lush and green (Morera et al. 2020) – a requirement that is generally at odds with local agency or government water restrictions. Yet homeowners readily adopt a landscape aesthetic that is collectively valued by a community (Carrico et al. 2018), regardless of the repercussions of doing so.

Kicking the lawn habit. Lawns are not "bad" in and of themselves; they are superior to impervious surfaces in terms of the ecosystem services they provide (Thompson and Kao-Kniffin 2019). Historically poor choices have been made to create unnatural landscapes (i.e., monocultural expanses of grass) requiring constant maintenance to maintain turfgrass quality while preventing other plants (i.e., weeds) from establishing. Such unnatural conditions lead to increased use of water, fertilizer, various pesticides, petroleum, and labor.

Strategies for reducing the footprint of traditional lawns abound and range from individual homeowner actions to strict mandates from policy-making organizations. Homeowner-driven choices would include these types of activities:

- Discontinue the use of potable water for irrigation and replace with recycled/reclaimed water (Leinauer et al. 2010).
- Replace mesic turfgrass species with those requiring less water (Ghimire et al. 2019, Hurd et al. 2006, Leinauer et al. 2010, Wang et al. 2014).
- Replace part or all of lawns with low resource-demanding landscape choices, especially woody plants (Erickson et al. 2008, Hurd et al. 2006).
- Reducing irrigation water loss with the use of smart sensors (Leinauer et al. 2010) or subscribing to notifications of recent rainfall to offset the need to irrigate (Survis and Root 2017).
- Reducing irrigation frequency based on deficit irrigation practices (Fontanier et al. 2017).
- Reducing soil nutrient levels by reducing fertilizer rates and frequency, or by eliminating fertilizer application in favor of mulching mowers (Wang et al. 2014).

Requirements from policy-making organizations, including HOAs and governmental agencies, would include these types of restrictions and subsidies:

- Restrictions on lawn sizes (Conrad et al. 2019).
- Restrictions on fertilizer use during environmentally sensitive periods (Ryan et al. 2019, Thompson and Kao-Kniffin 2019).
- Restrictions on phosphorus fertilizers (Thompson and Kao-Kniffin 2019).
- Restrictions on pesticide applications, especially where children are in contact with turf (Thompson and Kao-Kniffin 2019).
- Restrictions on outdoor irrigation, including increased cost for higher use (Conrad et al. 2019).
- Requirements to use drought-tolerant turfgrass (Conrad et al. 2019, Grant et al. 2020).
- Subsidies or rebates for reducing or replacing lawns (Bijoor 2021, Conrad et al. 2019).
- Subsidies or rebates for upgrading irrigation equipment to high-efficiency systems (Bijoor 2021).

Not surprisingly, residents with existing lawns are most resistant to any mandated activity, with the exception of

[4]While there are private soil testing labs as well, university and government labs serve to provide information without a commercial interest.

[5]Nitrogen levels are highly variable over a short period of time and are not useful metrics.

replacing mesic turfgrass species with drought-tolerant varieties (Conrad et al. 2019). Subsidies and rebates have mixed success depending on the location. Familiarizing homeowners with the aesthetic appeal and ecological value of a well-designed sustainable landscape might convince a subset of them to consider replacing at least some of their turfgrass.

Given the reluctance of many homeowners to remove their existing lawns regardless of the consequences (Wheeler et al. 2020), it is less contentious (and probably more successful) to focus on new residential neighborhoods and implement changes at the development and design stage (Lowry et al. 2011). The green industry can play an active role in these discussions, as they are the best suited for suggesting alternative landscape plantings that will tolerate local conditions.

Plant selection

Thoughtful plant selection reduces the amount of supplemental irrigation in residential landscapes. It is well documented that grasses are generally the least water efficient plants (Wang et al. 2021), given their relatively large surface area and lack of significant storage tissues. Despite some nostalgia for the "desert oasis" landscape, many residents in arid environments now agree that traditional turfgrasses should be limited and replaced by water-conserving landscapes (Carrico et al. 2018).

In contrast to turfgrasses, woody plants native to arid climates tend to have small, thickened leaves with thick, waxy cuticles; they may also have dense pubescence. These adaptations reduce transpiration and decrease leaf temperature and as such are well adapted for use in desert landscapes. Many shrubs and trees have ornamental value, and offer an aesthetically pleasing substitute for at least some lawn area in arid climates. In fact, mixed-species landscapes with water conserving properties are found to be the most visually pleasing to residents living in water-restricted areas (Khachatryan et al. 2020). Desert plants have become extremely popular landscape choices in some southwestern communities, with most homeowners approving of plant palettes which include native desert species (St. Hilaire et al. 2010). It should be noted, however, that the presence of low water-use plants is not associated with lower levels of irrigation (Barnett et al. 2020): xeric plants will use additional water for increased vegetative growth, which is a visual reward for homeowners.

Contrary to popular belief, native species are not the only choices for sustainable and biodiverse landscapes (Chalker-Scott 2015a, 2018). With few exceptions, the native status of landscape plants has no impact on ecological biodiversity. Researchers have identified vertical structure, landscape function, and a diverse plant palette as the most important characteristics for enhancing wildlife biodiversity (Chalker-Scott 2015a). Native species can be part of this scenario, but can and should be supplemented with carefully chosen, non-invasive, introduced ornamentals that tolerate site conditions and add to species diversity. The ability of native plants to live in residential landscapes is determined by the environment – not by their genetics.

The green industry can contribute to water-conserving plant selection at the retail level, especially in regions that experience drought (Knuth et al. 2020). University Extension and research faculty can help provide retail nurseries with research-based information to use in creating signage and take-home flyers for customers. Easily seen signage can encourage customers to purchase plants with demonstrated value in:

- Reducing irrigation needs.
- Providing shade and natural cooling.
- Requiring less maintenance than lawns and annual plantings (Khachatryan et al. 2020).
- Providing resources for pollinators and other desirable wildlife.
- Adding texture and color to the landscape.

The residential yard: business in the front, party in the back

A widely held perception about residential yards is that front yards are more intensively managed as the "public face" of the home, while back yards are reserved for family activities and space for children and pets to play.

- More nitrate is found in front yards than back yards, from increased fertilizer use or atmospheric deposition from vehicles (Suchy et al. 2021). However, other researchers have not found differences in fertilizer applications in front and back yards (Locke et al. 2018).
- More ammonium is found in back yards than front yards, likely as a result of pet use (Suchy et al. 2021).
- Front yards may be more compacted than back yards, given their adjacency to impervious surfaces such as driveways and sidewalks (Suchy et al. 2021). This affects their hydrology in terms of absorbing and retaining water.
- Front yard and back yard soils and lawns did not differ in multi-city analyses. However, front yards contained fewer plant species than back yards; this could include the presence of vegetable gardens or increased weed presence in back yards (Locke et al. 2018).
- Arid climate residents are more likely to use desert plants in their front yards than back yards (Spinti et al. 2004, St. Hilaire et al. 2010). This probably reflects the perceived need for lawn for recreational space in back yards.
- Older homes, as well as those of long-term desert residents, are more likely to have traditional lawns in the front yard. This is particularly true of communities where the "desert oasis" aesthetic is still prevalent (Larson et al. 2017), while other desert regions have actively embraced use of native, drought-tolerant landscape plants (Spinti et al. 2004, St. Hilaire et al. 2010).
- HOA or local government regulations can require lawns in front yards compared to back yards which remain more private (Wheeler et al. 2020).

Research suggests that efforts to address water conservation and fertilizer overuse should focus on front yards. Front yards are visible to the neighborhood and the desire

to conform to community values is strong. Residents are more likely to resist perceived interference in their choices for back yard landscapes and gardens, which are regarded as private family space.

Green industry educational opportunities

Water restrictions will increase as potable water sources become more limited, and government mandates will reflect the needs of competing interests. The green industry would be wise to become actively involved in helping homeowners find solutions to improving outdoor water conservation that promote, not exclude, use of ornamental plants.

Leading by example. To become a trusted source of information regarding the need to conserve and protect water resources, the green industry needs to demonstrate its willingness to engage in the environmentally conscious behaviors it wishes consumers to adopt. For instance, there are simple but rational methods for assessing the potential for nutrient runoff; this is important to maintain the economic viability of the nursery and greenhouse industry. By taking part in online courses such as that offered by the University of Maryland, nursery personnel can learn how to create and implement site-specific water and nutrient management plans (Lea-Cox et al. 2004). These credentials will go a long way in reassuring customers that nurseries are truly interested in conservation goals – not just in making a sale.

Becoming mediators in the clash between homeowners and policy makers. Tensions run high as policy-making groups increasingly restrict landscape use of water and fertilizer. The green industry is in the unique position of understanding the need for water conservation efforts and able to provide desirable alternatives to mesic landscape features – especially lawns. Their potential role in civic engagement could be crucial in meeting the landscape needs of homeowners while following local policies (Harlan et al. 2009, Lamm et al. 2018, Ryan et al. 2019).

Providing current, accurate information on landscape design and plant selection. The overriding desire for aesthetically pleasing landscapes is the prime motivator for plant selection decisions. These decisions can clash with policymakers (Lamm et al. 2018), but there is a middle road to be found in making informed plant choices and following sustainable design concepts. This will require a close working relationship with university faculty who specialize in landscape horticulture. Specialists, especially those in Extension, will be able to provide easily understood information that is both science-based and practical. With the presence of Extension faculty at different land-grant institutions, it is possible to collaborate with specialists and thus strengthen the industry-academic collaboration.

These collaborations enable nurseries access to high-quality information they can share in signage, flyers, webpages, and other venues. These resources will reassure homeowners that there are aesthetically pleasing alternatives to lawns that can help reduce the use of natural resources, while allowing nurseries to continue selling landscape plants despite water restrictions (Knuth et al. 2020). Such information can include:

- Lists of plants, both native and nonnative, that are low-input yet attractive landscape additions.
- Tags on pots of plants that are drought tolerant and thus water-conserving (Lamm et al. 2018).
- Actual reductions in water use that would be expected if guidelines were followed (Morera et al. 2020).
- Suggestions, rather than commands, to conserve water by using appropriate plants (Knuth et al. 2020).
- Photographs or displays of environmentally sustainable landscapes that are aesthetically pleasing and realistic for the typical homeowner.

Creating collaborative educational efforts. Once a solid, trusting relationship can be established between the nursery industry and university Extension faculty with relevant expertise, the ability to develop and offer meaningful educational activities to homeowners is possible. As in many states, such collaborations already exist between Master Gardener programs and individual nurseries; these volunteers can effectively be used to collect data, educate the community (DeMouche et al. 2007), and serve as "opinion leaders" who could influence neighbors by demonstrating appropriate practices (Lamm et al. 2018).

Collaborations can go beyond traditional Master Gardener outreach efforts, and homeowners are very receptive to these approaches (Warner et al. 2019b). With the assistance of Extension partners, nurseries could offer a variety of seminars and workshops on topics such as:

- Interpreting soil test results and determining follow-up actions.
- Choosing environmentally friendly fertilizers (Hughes et al. 2012).
- Designing ecologically diverse, wildlife-friendly landscapes.
- Selecting appropriate ornamental plants for specific landscape needs.
- Incorporating scale-appropriate water features and reducing water needs elsewhere.

Identifying audience variety and targeting messages. Given the variety of attitudes about water conservation among homeowners (Chaudhary et al. 2019, Mahler 2019, Warner et al. 2016), it is important to tailor educational outreach efforts to target audiences. To group audiences by common interests, simple surveys could be developed, again with the help of Extension faculty who are practiced in this activity. Such a survey could be conducted passively with flyers at a nursery, or at the end of an introductory workshop or seminar.

Homeowners who realize the benefits of sustainable landscapes and the importance conservation efforts hardly need more encouragement (Chaudhary et al. 2019); instead, they could serve as peer-mentors to help educate neighbors who are not yet convinced of the merits of either. Engaging these latter homeowners might involve introduc-

ing them to attractive plant choices that require less water and thus save money. Easy and straightforward actions with tangible results are the best way to encourage unconcerned water users to at least become interested in the topic of water conservation.

Embracing the team approach. For various reasons, green industry professionals and university experts are rarely engaged in cooperative educational efforts. It is imperative that the nursery industry take the lead on breaking down the silos that isolate academics and practitioners because sales of ornamental plants could be reduced if water restrictions prevent consumers from irrigating plants outdoors. Industry groups, such as state nursery and landscape associations, and governmental agencies, such as state departments of agriculture, should provide seed grants for these cooperative relationships to form. There is a dearth of practical, science-based information for homeowners to follow and a collaborative effort between academia and industry would find a vast and interested audience.

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