Recycling Irrigation Water on Ornamental Nursery Operations: Could Consumer Premiums Compensate for Grower Adoption Costs?

Xiang Cao, Darrell Bosch¹, and James Pease

Department of Agricultural and Applied Economics, Virginia Tech, Hutcheson Hall, 250 Drillfield Drive, Blacksburg, VA 24060

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Abstract. The U.S. nursery and greenhouse industry is facing twin challenges of reduced water availability and increased pressure to mitigate pollution from horticultural production. Water-recycling technology (WRT) has been adopted by some nursery producers to improve crop water productivity and to enhance water supply security. This study estimated the economic feasibility of WRT adoption if producers received some portion of retail price premiums for eco-labeled products. Three annual bedding plants, *Geraniums* (*Pelargonium* spp.), *Petunias* (*Petunia* spp.), and *Chrysanthemums* (*Chrysanthemum* spp.) and three broadleaf evergreen plants, *Azaleas* (*Rhododendron* spp.), *Holly* (*Ilex* spp.), and *Boxwood* (*Buxus* spp.) were analyzed based on their sales in the study region of Virginia (VA), Maryland (MD), and Pennsylvania (PA). Of the eight case study nurseries and two synthesized nurseries examined, five showed increased net costs with recycling. However, in almost all cases for which at least a portion of a retail consumer premium was returned to growers, the premium was adequate to compensate for recycling investment costs.

Productivity of irrigation water use and contaminant runoff control are becoming increasingly important to nursery and greenhouse growers as well as to policymakers and the public. Increased attention to minimizing total applications of water to obtain a healthy plant (water use productivity) is prompted by water scarcity in U.S. regions such as the West as well as by environmental concerns about agricultural runoff. Concern for water quality in the Chesapeake Bay and its tributaries led the U.S. Environmental Protection Agency (USEPA, 2010) to issue a Total Maximum Daily Load plan for reducing nitrogen, phosphorus, and sediment runoff in the Chesapeake Bay watershed. Under increasing pressure to adopt solutions to address regulatory and drought concerns, some nurseries have adopted WRT, which involves capturing and recycling irrigation water to improve crop water productivity and

to enhance water supply security while reducing contaminants lost from nursery and greenhouse production sites. It is estimated that a 0.4 ha (1-acre) greenhouse producing ornamental crops requires ≈83,270 L (22,000 gallons) daily for irrigation, and container nursery operations may require up to 102,195 L (27,000 gallons) daily (Bailey et al., 1999; Robbins, 2010). With WRT, it is estimated that 40% to 50% of water applied could be conserved through recapture and reuse of both irrigation water and any storm water runoff (Wilson and von Broembsen, n.d.), thus increasing security of water supplies and reducing pollutant loads to nearby surface waters. Ferraro et al. (2017) provided detailed analysis of recycling requirements and costs for VA, MD, and PA nurseries.

Long-term access to secure irrigation water supply is of critical importance to nursery growers. WRT also can potentially provide social benefits by reducing discharge to streams and rivers of polluted water from horticultural operations. In some cases, the increased risk of water-borne plant pathogens spreading through recycled water has impeded WRT adoption and associated social benefits from reduced water pollution (Hong and Moorman, 2005; von Broembsen, 1998). In addition, the concern about production cost increases associated with WRT, and the uncertainty of revenue enhancement discourage many growers from implementing the new technology (Cultice et al., 2016).

Many retail customers of horticultural products are concerned about environmental

degradation and are now more aware of environmental aspects of production. Previous research has indicated that consumers are willing to pay premiums for plants produced and labeled as “environmentally friendly” or “eco-friendly” (Behe et al., 2014; Gardner et al., 2002; Michaud et al., 2012; Yue et al., 2010). Plants grown with WRT qualify for such a designation because WRT reduces discharge of polluted water. For example, consumers are willing to pay more for “eco-labelled” roses certifying eco-friendly cultivation practices (Michaud et al., 2012). Eco-labeling of environmentally friendly or “green” products has gained interest because environmental practices are highlighted (e.g., using recycled water). Consumers receive more information about the product, and new market opportunities and potential higher profits may be generated. In addition, contract farming has become more common in the U.S. horticulture industry (MacDonald, 2015). Contracting producers and wholesale purchasers such as landscapers or retailers such as “big-box” stores should share price premiums obtained from consumers with contracting producers as financial incentives to promote adoption of conservation practices such as WRT. Little research has been conducted as to how such price premiums might be transmitted through stages of the distribution system from consumers back to growers, or how such premiums relate to costs incurred by growers to produce such eco-labeled attributes. In this case, nursery growers find it hard to obtain useful economic information about the profit potential of WRT and its anticipated effect on their business’ long-term bottom line.

Will consumer premiums for plants grown with recycled water be sufficient to make WRT economically practical? This analysis evaluates the economic effects of labeling plants grown with WRT in selected nursery operations in the mid-Atlantic region of VA, MD, and PA. The goal is to estimate the economic feasibility of WRT production practices, which include capturing and recycling rainfall and irrigation runoff, combined with plant eco-labeling, and to determine how such a program would affect greenhouse/nursery production costs, gross revenues, and net revenues. Research results can help nursery growers and policymakers assess WRT adoption to improve crop water productivity and to reduce pollution of off-site surface waters.

Literature Review

Driven by increased awareness of the need for environmental protection, green products have become more popular among consumers in both food and non-food marketing systems. A so-called “green” product usually refers to a product produced with methods that improve environmental quality or reduce environmental pollution compared with an equivalent product produced with conventional practices (Durif et al., 2010). For example, plants grown with WRT could be considered “green” because recycling water may reduce discharge of polluted water

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¹Corresponding author. E-mail: bosch@vt.edu.

to rivers and streams. Schlegelmilch et al. (1996) illustrated that consumer environmental consciousness has positive effects on their purchasing decisions for green products. Laroche et al. (2001) investigated the profile of consumers willing to pay more for green products generally including their demographics, attitudes toward environmentally friendly programs, daily behavior, and personal values. They found this segment of consumers was more likely to be female, married, and with at least one child living at home.

Horticultural products provide both private and public benefits for consumers. Private product benefits are limited to the buyer, whereas public benefits are available to the buyer as well as others. For example, if a horticultural product is produced in a manner that reduces or eliminates pollutants, the product presents a public benefit. Consumers cannot readily evaluate some public benefits such as reduced pollution unless these attributes are communicated via product labeling. Research has found that consumers prefer and are willing to pay a price premium for horticultural products that promise environmental benefits (Behe et al., 2013, 2014; Gardner et al., 2002; Hartter, 2012; Khachatryan et al., 2014; Michaud et al., 2012; Yue et al., 2010, 2016). Gardner et al. (2002) used the contingent valuation method to estimate that consumers were willing to pay a retail premium of as much as \$13.35 for a flowering dogwood tree labeled as “resistant to powdery mildew.” Using hypothetical conjoint analysis and non-hypothetical experimental auctions, Yue et al. (2010) found that consumers were willing to pay premiums for plants grown in biodegradable vs. plastic containers. Michaud et al. (2012) found that consumers were willing to pay an average premium of €1.91 (\$2.56) per stem for roses with an eco-label and an average premium of €2.51 (\$3.36) per stem for roses claiming a carbon footprint reduction. Hartter (2012) conducted a choice experiment to estimate the premiums that consumers would be willing to pay for ornamental plants produced with WRT and labeled as “water conservation.” The author found that, on average, retail consumers were willing to pay 9% to 36% more than the average retail price for Geranium, Petunia, Chrysanthemum, Azalea, Holly, and Boxwood. Behe et al. (2013) profiled nine consumer segments in terms of their preferences for local and sustainably grown plant products.

More recently, a subsequent article by Behe et al. (2014) used eye-tracking technology to categorize three plant consumer groups as plant-oriented, production method-oriented, and price-oriented. The authors found that regardless of their groups, all consumers preferred ornamental plants labeled “grown using water-saving practices” over other production labels such as “grown using energy-saving practices,” “grown using sustainable practices,” and “grown using conventional practices.” The results also indicated that 11% of the respondents were production method-oriented among which water-saving label increased their Likert

willingness to pay (WTP) scale by $\approx 6.5\%$. Khachatryan et al. (2014) performed a mixed-logit model to estimate consumers’ premiums for environmental attributes of horticulture plants, finding that individuals were willing to pay a premium for energy-saving production practices (\$0.13), non-plastic containers such as compostable (\$0.23), plantable (\$0.12), and recyclable (\$0.16), and locally grown plants (\$0.22). Yue et al. (2016) investigated the U.S. consumers’ WTP for sustainable attributes in plants via experimental auctions. The results showed that consumers were willing to pay a price premium for energy and water savings in plant production of \$0.15 and \$0.12 per unit, respectively, and the WTP for products labeled “sustainable” was estimated at \$0.08 per unit. These previous studies indicate that consumers are willing to pay premiums for the underlying environmental attributes of a product that promises societal benefits.

However, product labels do not completely define a product, especially in terms of environmental attributes. Usually, certifications conveyed to consumers by product labeling confirm environmental attributes. Previous research has found that consumers prefer to pay more for certified vs. uncertified products and that they generally prefer third party certification to first party or “self-certification” (Aguilar and Vlosky, 2007; Curtis and Cowee, 2010; Hartter, 2012; Michaud et al., 2012). Hartter (2012) assumed three categories of third-party certification authorities for water conservation including governmental organizations, industry organizations, and nongovernmental organizations (NGO). Specifically, the U.S. Department of Agriculture represented the governmental organization; the American Nursery Association (a fictitious certifying authority) represented an industry-backed agency; and Water for Tomorrow and Plant Society of America represented a fictitious NGO for water conservation certification. The estimation results indicate that consumers have varying preferences and WTPs for plants certified by different authorities.

On the producer side of markets, studies of WRT adoption by horticultural growers are limited. Cultice (2013) conducted a mail survey of mid-Atlantic irrigated nursery producers to determine irrigation practices and used a conditional logit model to estimate the impacts of disease probability, drought probability, and water-recycling cost on producers’ WTP to adopt water-recycling techniques and practices. Of 260 irrigated nurseries, 55% reported that they did not capture any irrigation runoff, and only 14% captured all irrigation runoff (Cultice et al., 2016). Only six irrigated nurseries (2.3%) sourced all their irrigation water from captured runoff. Recycling cost was the most important deterrent factor to grower adoption of water recycling (Cultice et al., 2016). Dennis et al. (2010) surveyed greenhouse and nursery crop growers nationally regarding their sustainable practices including water recycling and other water conservation measures. The

authors found that 26% of their respondents had already adopted water-recycling practices, with only 4% considering future implementation of WRT. DeVincentis et al. (2015) conducted cost and benefit partial budgeting analysis of various disinfection techniques for recycled irrigation water in southern New Jersey. Disinfection methods included ultraviolet-lights, chlorinators, flooders, and drippers. The study calculated the net present value (NPV) of each disinfection technique based on site visits to five nurseries. The results indicated there was a positive correlation between system costs and the complexity of the water disinfection method. All the case nurseries had positive NPVs, indicating profitable investments. Most recently, Ferraro et al. (2017) used partial budgets to estimate and compare the annual costs of recapturing and recycling irrigation water vs. extraction costs from wells or municipal water supply sources. They found that six of eight case nurseries (all of whom had already adopted some WRT practices) had lower production costs from capturing and recycling on 75% of their production areas compared with using well or municipal water.

Materials and Methods

In this study, budgets from Ferraro et al. (2017) provide the basis for assessing producer costs of capturing and recycling. Calibrated consumer premium results are taken from Hartter (2012) as the prices that consumers would be willing to pay for plants grown with WRT. These premiums allow us to compare non-water-recycling practices (e.g., grower net returns sourcing irrigation water from municipal or private well sources) vs. returns from WRT. With adoption of WRT, changes in production costs including water-supply cost, labeling cost, and certification cost are compared with benefits from price premiums for plants labeled as “irrigation water recycled,” and varying proportions are assumed to be returned to growers as compensation for the WRT investment. Hinson et al. (2012) studied market channels of ornamental plant industry and concluded that mass merchandisers have sufficient market power to affect grower prices and profitability. Retailers (e.g., “big-box” stores) could use their market power to mandate grower WRT practices while retaining some of or the entire premium for themselves. We reflect this uncertainty by varying the proportion of the premium returned to the grower (R) as was done by White et al. (2014) in a study of consumer premiums for sustainable beef-production practices.

We conducted the study with eight case nurseries varying in terms of size, location, and water supply method. The eight case nurseries include three in VA (VA-1, VA-2, and VA-3), three in MD (MD-1, MD-2, and MD-3) and two in PA (PA-1 and PA-2). All eight operations are adopters of WRT as they capture rainfall and irrigation runoff in collection basins and then recycle the water to supplement water supply in addition to using municipal city water or well water. Nurseries

VA-2, VA-3, MD-2, MD-3, and PA-2 obtain 100% of their irrigation water from recycling, and VA-1, MD-1, and PA-1 obtain 34%, 50%, and 20%, respectively, from recycling. In addition, two simulated nurseries (SynSmall and SynLarge) representing mean characteristics and practices in terms of water source, grower size, and water usage are constructed based on survey responses of irrigated mid-Atlantic ornamental nurseries by Cultice et al. (2016). SynSmall represents small nurseries with gross revenues of \$500,000 or less, whereas SynLarge represents large nurseries with gross revenues greater than \$500,000. Most surveyed nurseries did not capture irrigation runoff or rainfall from any portion of their production area (Cultice, 2013), therefore, the most common alternative to WRT (well water) is assumed as the main irrigation water source for the simulated nurseries. Furthermore, we assumed the two simulated nurseries to be located in MD, where regulations for well drilling are the most restrictive and expensive. This provides the most favorable case for adoption of WRT (Maryland Department of the Environment, 2015). Table 1 indicates the general characteristics of case study nurseries with regard to size, location, and current water supply method.

According to the 2014 Census of Horticultural Specialties (Table 2), Geraniums (*Pelargonium* spp.), Petunias (*Petunia* spp.), and Chrysanthemums (*Chrysanthemum* spp.) rank among the top 5 annual plants sold in VA, MD, and PA. Azaleas (*Rhododendron* spp.), Holly (*Ilex* spp.), and Boxwood (*Buxus* spp.) are among the top 5 broadleaf evergreen plants sold in the three states. Because of their popularity and to be consistent with premiums estimated by Hartter (2012), this analysis uses these six plants for investigating impacts of WRT adoption and consumer premiums on sales.

This study estimates enterprise-level costs and returns from WRT for each of the six plants assuming that the 10 case nurseries produce only these plants. Similar to Hartter (2012), we assume that Geraniums are sold in 10.2 cm (4-inch) or 0.47 L (0.125 gallon) pots, that Petunias are sold in 6-packs, and that Chrysanthemums are sold in 3.8 L (1-gallon) pots. Azaleas and Boxwoods are sold in 3.8 L pots with plant heights ranging from 30.5 to 38.1 cm (12–15 inches), and

Hollies are sold in 7.6 L (2 gallon) pots with plant heights ranging from 38.1 to 45.7 cm (15–18 inches).

Because of varying container sizes, the normal production per hectare (without disease losses) differs by plant species. About 49,421–54,363 containers 3.8 L (1-gallon) in size will cover 1 ha of production area (Halcomb and Fare, 2009). For Geraniums planted in 10.2 cm (4-inch) pots, potential production is about 415,136 pots per hectare. For Petunias planted in a 6-pack, potential production per hectare is 69,189 six-packs. For Chrysanthemum, Azalea, and Boxwood planted in 3.8 L pots, 1 ha can produce ≈51,892 pots. For Holly planted in 7.6 L pots, 1 ha can produce nearly 25,946 pots. In the mid-Atlantic region, commercial nurseries generally produce only one cycle of these plants per year.

The possibility of increased plant death rates with WRT must be considered. Hong and Moorman (2005) found that risk is increased as water-borne pathogens such as *Pythium* and *Phytophthora* will re-inoculate with recycled irrigation water and runoff collected from nursery production areas. To mitigate such risks, growers typically treat recycled irrigation water with sterilizers such as liquid or gas chlorination systems. In the survey conducted by Cultice (2013), the average proportion of nursery revenue loss in sales from all types of plant disease (i.e., plant death rate) for both non-water recyclers and water recyclers was reported. On average, plant death rates for non-adopters and adopters of WRT were estimated at 2% and 3%, respectively. Based on the mean survey responses, this analysis assumes that plant death rate will increase to 3% because of diseases caused by water-borne pathogens after adoption of WRT compared with 2% for non-adoption of WRT. Thus, for the case nurseries and the two hypothetical nurseries, the reduced production per hectare resulting from converting to recycling for each of the six plants is assumed the same, which can be expressed as

$$\Delta Y_i = Y_i(-1\%) \quad [1]$$

where Y_i is normal production cost per hectare of the six plants without disease losses as stated previously and –1% indicates the reduction in yield resulting from a switch to WRT. Because the yield losses lead to

growers' sales losses, the opportunity cost of yield loss resulting from adoption of WRT for plant type i can be expressed as

$$OP_i = -\Delta Y_i P_i^w \quad [2]$$

where P_i^w is the wholesale price accepted by growers of plant i .

The change in production cost resulting from water recycling for plant i , ΔPC_i , is

$$\Delta PC_i = \Delta WSC_i + \Delta LC_i + \Delta CC_i \quad [3]$$

where ΔWSC_i is water supply cost change, ΔLC_i is labeling cost change, and ΔCC_i is certification cost change. Water supply cost change results from the change in cost of delivering irrigation water to the crop as a result of switching to WRT. Labeling cost change accounts for a change in cost of labeling individual pots resulting from yield changes. Certification cost change accounts for the cost of hiring a third-party contractor to certify that advertised plants receive water from WRT practices. These costs are described in the following paragraphs.

Ferraro et al. (2017) used partial budgets to evaluate water supply cost changes from adoption of recycling for the case nurseries. They analyzed differences in practices and associated costs for recycling in comparison with the next best option (well water or municipal water). Capital costs for both conventional water supply (well or municipal source) and WRT were amortized on an annual basis; thus ΔWSC_i refers to annual water-supply cost change. Partial budget results in 2014 dollars from Ferraro et al. (2017) are presented in Table 3. ΔWSC_i is the difference between WRT cost and the cost of the next best alternative; thus, a negative ΔWSC_i refers to a cost advantage with WRT and vice versa. WRT costs vary among nurseries depending on physical layout, distance to water source, and other factors. Nurseries VA-1, VA-2, VA-3, MD-1, MD-2, and PA-1 have cost advantages with WRT of –\$1624/ha, –\$29,910/ha, –\$6339/ha, –\$813/ha, –\$2851/ha, and –\$343/ha, respectively. As discussed in Ferraro et al. (2017), the major factors determining cost advantage per hectare from WRT are the availability and cost of the alternative well or municipal water source and the costs of WRT investment. For example, VA-2 saves more costs with WRT than VA-1 because of much higher costs of obtaining municipal water. WRT costs are also highly variable among nurseries because of differences in the cost of digging recapture ponds, opportunity cost (forgone income) of land used for ponds, and regrading cost.

Nurseries MD-3 and PA-2 incur increased costs with WRT, estimated at \$7516/ha and \$2199/ha, respectively (Table 3). For the two simulated nurseries SynSmall and SynLarge, that are assumed to use well water as the main irrigation water supply, WRT increased water supply costs by an estimated \$3810/ha and \$7651/ha, respectively.

Certification is necessary to assure consumers of the attribute associated with paying a premium. However, there are no industry-wide

Table 1. Size and water source of the eight case study nursery operations and two simulated nurseries.

Nursery	Hectares	Current water supply method
VA-1	1.0	34% recycling, 66% well
VA-2	40.5	100% recycling
VA-3	80.9	100% recycling
MD-1	6.7	50% recycling, 50% well
MD-2	42.5	100% recycling
MD-3	22.3	100% recycling
PA-1	2.0	20% recycling, 80% well
PA-2	10.9	100% recycling
SynSmall	5.5	100% well water
SynLarge	36.0	100% well water

Data source: Ferraro et al. (2017).

MD = Maryland; PA = Pennsylvania; VA = Virginia.

Table 2. Sales and percent of total U.S. sales of six horticultural plants by state in 2014.

	Geranium			Petunia			Chrysanthemum		
	VA	MD	PA	VA	MD	PA	VA	MD	PA
Wholesale (\$1,000)	6,773	1,112	5,585	6,253	1,594	1,077	7,204	N/A	2,485
	6.0%	1.0%	4.9%	9.8%	2.5%	1.7%	15.2%	N/A	5.3%
Retail (\$1,000)	854	326	3,185	260	200	857	47	N/A	207
	1.7%	0.6%	6.2%	1.6%	1.2%	5.4%	1.3%	N/A	5.7%
Total (\$1,000)	7,627	1,438	8,770	6,513	1,794	1,934	7,251	25	2,692
	4.6%	0.9%	5.3%	8.2%	2.2%	2.4%	14.2%	0.05%	5.3%
	Azalea			Holly			Boxwood		
	VA	MD	PA	VA	MD	PA	VA	MD	PA
Wholesale (\$1,000)	3,323	1,615	359	8,528	12,651	759	5,611	8,852	1,775
	3.8%	1.8%	0.4%	7.3%	10.8%	0.6%	4.8%	7.5%	1.5%
Retail (\$1,000)	36	75	105	91	256	248	36	14	429
	0.8%	1.6%	2.3%	1.6%	4.4%	4.2%	0.4%	0.2%	5.2%
Total (\$1,000)	3,359	1,690	464	8,619	12,907	1,007	5,647	8,866	2,204
	3.6%	1.8%	0.5%	7.0%	10.5%	0.8%	4.5%	7.0%	1.7%

Note: The percentage number placed under each sale volume represents each state's share of U.S. Retail/Wholesale/Total sales for each type of the six plants. Data source: U.S. Department of Agriculture, National Agricultural Statistics Service (2014). MD = Maryland; PA = Pennsylvania; VA = Virginia.

Table 3. Net water supply cost changes for eight nursery operations (VA-1 to PA-2) and two simulated nurseries (SynSmall and SynLarge) with alternative water sources.

Nursery	Alternative	More profitable option	WRT cost (\$/ha)	Alternative cost (\$/ha)	Water supply cost change with WRT (\$/ha)
VA-1	Municipal water	WRT	4,400	6,024	-1,624
VA-2	Municipal water	WRT	4,817	34,728	-29,910
VA-3	Municipal water	WRT	5,874	12,213	-6,339
MD-1	Well water	WRT	650	1,463	-813
MD-2	Municipal water	WRT	3,770	6,621	-2,851
MD-3	Well water	Well water	7,923	406	7,516
PA-1	Well water	WRT	26,967	27,310	-343
PA-2	Municipal water	Municipal water	4,242	2,044	2,199
SynSmall	Well water	Well water	5,956	2,146	3,810
SynLarge	Well water	Well water	9,035	1,384	7,651

Data source: Ferraro et al. (2017).

MD = Maryland; PA = Pennsylvania; VA = Virginia; WRT = Water-recycling technology.

certification systems to define production with recycled irrigation water. It is assumed that producers who wish to increase net returns with recycling would contract a qualified and respected third party to certify that their operation practices and nursery products accord with specific standards of WRT. Such standards would specify minimum requirements as to how water is recycled to ensure that the environmental benefits of recycling are achieved. After certification, producers are authorized to label plants as "produced with recycled water," whereby consumers can acquire environmental information that may influence their preferences and WTP for horticultural products.

Labeling cost and certification costs also relate to the documentation of cost changes in water-supply practices resulting from recycling. Based on the information provided by the owners and managers of the case nurseries during on-site interviews, the unit labeling cost is about \$0.10/pot. Thus, a labeling cost change is

$$\Delta LC_i = 0.1 \Delta Y_i \quad [4]$$

where ΔLC_i is the labeling cost change, and ΔY_i is the net negative change of normal production per hectare for recyclers specified in Eq. [1]. The labeling cost associated with WRT in Eq. [4] is negative because of the yield loss from increased plant death rate.

The example cost data for certification is developed from the "Sustainability Standard for Nursery and Greenhouse Operations"

operated by Food Alliance, a nonprofit organization that has certified over 330 farms, ranches, and food processors in Canada, Mexico, and 23 U.S. states for good environmental stewardship. Although the organization does not have an independent certification program focusing on water recycling for the nursery industry, the sustainability standard does contain specific criteria for water conservation and recycled water quality in nursery operations. The Food Alliance publishes detailed certification costs on its website that are used in this analysis. The certification costs consist of an inspection fee and a license fee. The inspection fee includes a nonrefundable \$350 document processing charge and a \$400 deposit toward the actual cost of inspection. According to Food Alliance, in most cases, the average inspection fee is between \$900 and \$1500. Because Food Alliance certification is valid for 3 years, the average annual inspection fee ranges from \$300 to \$500 per year. In addition, nursery operations pay a variable annual license fee based on a percentage of gross annual sales (\$100 flat fee less than \$100,000, 0.10% from \$100,000 to \$1,000,000, and 0.05% greater than \$1,000,000), with a licensing fee cap of \$5000. For example, gross revenue for nursery MD-2 reported in the survey is \$7,000,000; thus, the annual license fee would be \$3500. After adding the maximum average

annual inspection fee of \$500, the average annual certification cost would be $\approx \$94/\text{ha}$ ($[\$94/\text{ha}[\$3500 + \$500]/42.5 \text{ ha}]$). Errors in estimating certification costs are unlikely to affect final results because in three-fourths of the cases (Tables 4–7), the certification cost is 3% or less of the total production cost change.

For this analysis, it is assumed that in a typical wholesale nursery production contract, retailers offer price premiums to encourage contract growers to produce plants with WRT. Following Cultice (2013), $\approx 52\%$ of growers are wholesalers. Thus, a conservative assumption in this analysis is that the case nurseries are wholesalers who sell all plants directly to retailers, who in turn sell to consumers and return a portion of the premium to growers. If growers were retailers, they would retain all of the premium. Equation [5] clarifies how price premiums tied to WRT plants could be returned proportionally to growers and increase gross revenue.

$$\begin{aligned} \Delta GR_i &= GR_i^{\text{WRT}} - GR_i^{\text{Non-WRT}} \\ &= Y_i(100\% - 3\%)P_i^{\text{W}} - Y_i(100\% - 2\%)P_i^{\text{W}} \\ &= 0.97Y_i \cdot (P_i^{\text{W}} + \text{WTP} \cdot R) - 0.98Y_i P_i^{\text{W}} \\ &= \Delta Y_i \cdot P_i^{\text{W}} + 0.97 \cdot Y_i \cdot \text{WTP} \cdot R \end{aligned} \quad [5]$$

where $P_i^{\text{W}} = P_i^{\text{W}} + \text{WTP} \cdot R$ is the new wholesale price after adding a proportional premium (denoted as WTP), in which R is a conveyance rate indicating the fraction of

Table 4. Labeling cost change (ΔLC_i), certification cost change (ΔCC_i), and production cost change (ΔPC_i) with water recycling technology for Geranium.

Plant type	Nursery	Labeling cost change (\$/ha)	Certification cost change (\$/ha)	Water-supply cost change (\$/ha)	Production cost change (\$/ha)
Geranium (10.2 cm pot)	VA-1	-415	593	-1,624	-1,446
	VA-2	-415	136	-29,910	-30,189
	VA-3	-415	67	-6,339	-6,687
	MD-1	-415	300	-813	-929
	MD-2	-415	94	-2,851	-3,172
	MD-3	-415	56	7,516	7,157
	PA-1	-415	988	-343	230
	PA-2	-415	62	2,199	1,845
	SynSmall	-415	110	3,810	3,504
	SynLarge	-415	42	7,651	7,278

MD = Maryland; PA = Pennsylvania; VA = Virginia.

Table 5. Labeling cost changes (ΔLC_i), certification cost changes (ΔCC_i), and production cost changes (ΔPC_i) with water recycling technology for Petunia.

Plant type	Nursery	Labeling cost change (\$/ha)	Certification cost change (\$/ha)	Water-supply cost change (\$/ha)	Production cost change (\$/ha)
Petunia (6 packs)	VA-1	-69	593	-1,624	-1,100
	VA-2	-69	136	-29,910	-29,843
	VA-3	-69	67	-6,339	-6,341
	MD-1	-69	300	-813	-583
	MD-2	-69	94	-2,851	-2,826
	MD-3	-69	56	7,516	7,503
	PA-1	-69	988	-343	576
	PA-2	-69	62	2,199	2,191
	SynSmall	-69	110	3,810	3,850
	SynLarge	-69	42	7,651	7,624

MD = Maryland; PA = Pennsylvania; VA = Virginia.

Table 6. Labeling cost changes (ΔLC_i), certification cost changes (ΔCC_i), and production cost changes (ΔPC_i) with water recycling technology for Chrysanthemum, Azalea, and Boxwood.

Plant type	Nursery	Labeling cost change (\$/ha)	Certification cost change (\$/ha)	Water-supply cost change (\$/ha)	Production cost change (\$/ha)
Chrysanthemum; Azalea; Boxwood (3.8 L pot)	VA-1	-52	593	-1,624	-1,083
	VA-2	-52	136	-29,910	-29,826
	VA-3	-52	67	-6,339	-6,324
	MD-1	-52	300	-813	-566
	MD-2	-52	94	-2,851	-2,809
	MD-3	-52	56	7,516	7,521
	PA-1	-52	988	-343	594
	PA-2	-52	62	2,199	2,208
	SynSmall	-52	110	3,810	3,868
	SynLarge	-52	42	7,651	7,641

MD = Maryland; PA = Pennsylvania; VA = Virginia.

Table 7. Labeling cost change (ΔLC_i), certification cost change (ΔCC_i), and production cost change (ΔPC_i) with water recycling technology for Holly.

Plant type	Nursery	Labeling cost change (\$/ha)	Certification cost change (\$/ha)	Water-supply cost change (\$/ha)	Production cost change (\$/ha)
Holly (7.6 L pot)	VA-1	-26	593	-1,624	-1,057
	VA-2	-26	136	-29,910	-29,800
	VA-3	-26	67	-6,339	-6,298
	MD-1	-26	300	-813	-540
	MD-2	-26	94	-2,851	-2,783
	MD-3	-26	56	7,516	7,546
	PA-1	-26	988	-343	619
	PA-2	-26	62	2,199	2,234
	SynSmall	-26	110	3,810	3,894
	SynLarge	-26	42	7,651	7,667

MD = Maryland; PA = Pennsylvania; VA = Virginia.

the consumer premium being returned to the water-recycling nursery. After readjusting, $\Delta Y_i \cdot P_i^{wR}$ refers to the gross revenue loss from WRT because of yield loss, whereas $0.97 \cdot Y_i \cdot WTP_{i,R}$ is the increased gross revenue resulting from consumer premiums for plants grown with WRT.

Premium estimates obtained from growers by Hartter (2012) are based on survey

responses to a hypothetical choice experiment. However, hypothetical responses may suffer from "hypothetical bias," i.e., overstating consumer WTP compared with revealed choices of consumers with actual purchases in non-hypothetical situations (Blumenschein et al., 2008; Cummings et al., 1995; Harrison, 2006; Harrison and Rutström, 2008; List and Gallet, 2001; Silva

et al., 2007; Yue et al., 2010). For example, List and Gallet (2001) summarized 29 experimental studies and concluded that respondents on average overestimated their preferences by a factor of 3 in hypothetical settings compared with actual purchases. Silva et al. (2007) found that on average, the non-hypothetical estimates of WTP estimates for different groups of novel

products were from 8% to 29% lower than the hypothetical WTP estimates in two elicitation mechanisms including experimental auction and conjoint analysis. Blumenschein et al. (2008) concluded that the average WTP for a pharmacist-provided diabetes program in a real purchasing group was 50% lower than that obtained in hypothetical surveys. Yue et al. (2010) found that the mean WTP for plant containers made from rice hulls (straw) obtained from an experimental auction was 29% (39%) lower than that obtained from a hypothetical conjoint analysis. Although Hartter (2012) applied a “cheap talk” method as suggested by Cummings and Taylor (1999) to reduce hypothetical bias and the potential for artificially high WTP estimates, premium estimates are calibrated (divided by 3) as suggested by List and Gallet (2001).

The horticultural plant price data P_i^w (wholesale) and P_i^r (retail) is obtained from the Census of Horticultural Specialties (USDA/NASS, 2014). The calibrated (divided by 3) mean values of estimated premiums by Hartter (2012) are shown with 2014 census prices in Tables 8 and 9 after adjustment to 2014 dollars using the consumer price index of indoor plants and flowers (U.S. Bureau of Labor Statistics, 2015).

Finally, the net revenue change from recycling (ΔNR_i) is the difference between gross revenue change and production cost change:

$$\Delta NR_i = \Delta GR_i - \Delta PC_i \quad [6]$$

where ΔGR_i is the gross revenue change calculated with Eq. [5] and ΔPC_i is the production cost change calculated with Eq. [3].

The sensitivity of gross and net revenue changes to the conveyance rate (R) is evaluated with the premium estimate fixed at its mean value. Three possible R values are selected: 0%, P_i^w/P_i^r , and 100%. Zero percent is a pessimistic value at which the grower receives nothing from the consumer premiums; P_i^w/P_i^r is the census price ratio of wholesale price and retail price of each plant in Tables 8 and 9; and 100% is an optimistic value at which the grower receives the complete premium. Where price ratios P_i^w/P_i^r exceed 100%, such as Azalea in PA, Holly in MD, and Boxwood in VA and MD, 100% is used. In addition, break-even analyses to balance production cost and gross revenue change associated with WRT (i.e., $\Delta NR_i = 0$) are conducted in terms of conveyance rate R , premium estimate and plant death rate.

Results

Production cost changes. Labeling cost changes, certification cost changes and production cost changes resulting from WRT are presented in Tables 4–7. For each of the six plants, nurseries VA-1, VA-2, VA-3, MD-1, and MD-2 have lower production costs with WRT compared with well water or municipal water as the reduced labeling cost and water

supply cost more than offset the certification cost in each case. For nurseries MD-3, PA-1, and PA-2 and for the two simulated nurseries SynSmall and SynLarge, the production costs of WRT are higher than using well water or municipal water. Production costs increase for MD-3, PA-2, SynSmall, and SynLarge because of large water supply cost increases ranging from \$2199 to \$7651 per hectare. WRT reduces water supply costs for PA-1; however, production costs increase modestly because of the certification cost (\$988/ha/year). The high certification cost for PA-1 is mainly because of its reported high per hectare gross revenue ($\approx \$241,915/\text{ha}$), much higher than other nurseries.

Gross revenue changes with WRT. Table 10 shows the estimated changes in gross revenues by plant species with alternative conveyance rates. Y_i and ΔY_i are held constant for all nurseries, therefore, changes of gross revenues resulting from different wholesale prices garnered by each nursery operation are based on its geographic location. SynSmall and SynLarge are assumed located in MD, so their gross revenue changes match those of MD case nurseries. When no premiums go back to growers (conveyance rate $R = 0\%$), all nurseries have negative gross revenue changes for each of the six plants because of the assumed increased plant death rate with WRT. When the conveyance rate is 100% (growers obtain all the premium) and when $R = P_i^w/P_i^r$, all 10

nurseries have positive changes in gross revenue for five plants with Holly as an exception. For Holly, the nurseries in VA have decreased gross revenues at $-\$1098/\text{ha}$ when $R = P_i^w/P_i^r$; the nurseries in MD as well as the synthetic nurseries have negative gross revenue changes estimated at $-\$219/\text{ha}$ when $R = P_i^w/P_i^r$ or $R = 100\%$.

Net revenue changes with WRT. After deducting production cost changes from the gross revenue changes, the net revenue changes for alternative conveyance rates are shown in Tables 11 and 12. In the cases of Azalea in PA, Holly in MD, and Boxwood in VA and MD, the wholesale price (P_i^w) is greater than the retail price (P_i^r) reported in the Census as shown in Tables 8 and 9. In those cases, P_i^w is assumed equal to P_i^r resulting in the same gross revenue change as obtained for $R = 100\%$.

When the conveyance rate R is 0%, only nursery VA-2 has increased net revenue for all plants because of its large production cost saving from WRT that fully offsets the opportunity cost of yield loss. For nursery VA-1, only Petunia generates a positive net revenue change of \$291/ha. Nursery VA-3 has increased net revenues for all plants except Geranium ($-\$1034/\text{ha}$) and Boxwood ($-\$6561/\text{ha}$) as its production cost savings for these two plants fail to cover the opportunity cost of yield loss. MD-2 has relatively small positive net revenue changes for Petunia (\$1899/ha) and Chrysanthemum (\$157/ha).

Table 8. Calibrated premiums and wholesale and retail prices of three annual bedding plants by states, adjusted to 2014 dollars.

Plant type i	Premiums	Prices by state			
	Mean	State	P_i^w	P_i^r	P_i^w/P_i^r
Geranium (\$/10.2 cm pot)	0.52	VA	1.86	2.69	0.69
		MD	2.06	3.46	0.59
		PA	1.79	2.93	0.61
Petunia (\$/6-pack)	0.33	VA	1.17	3.12	0.38
		MD	1.34	2.67	0.50
		PA	1.20	2.76	0.44
Chrysanthemum (\$/3.8 L pot)	0.46	VA	3.59	5.88	0.61
		MD	5.11	5.11	1.00
		PA	3.72	5.77	0.64

Note: Wholesale and retail prices for Chrysanthemum in MD are not available, so the wholesale and retail prices are both equal to total sale value divided by total number sold.

Data sources: Hartter (2012) and U.S. Department of Agriculture, National Agricultural Statistics Service (2014).

MD = Maryland; PA = Pennsylvania; VA = Virginia.

Table 9. Calibrated premiums and wholesale and retail prices of broadleaf evergreen plants by states, adjusted to 2014 dollars.

Plant type i	Premiums	Prices by state			
	Mean	State	P_i^w	P_i^r	P_i^w/P_i^r
Azalea (\$/13.8 L pot)	0.43	VA	8.95	12.44	0.72
		MD	10.99	20.13	0.55
		PA	18.91	13.04	1.45
Holly (\$/3.8 L pot)	0.34	VA	13.50	47.57	0.28
		MD	33.50	21.83	1.53
		PA	23.48	31.55	0.74
Boxwood (\$/3.8 L pot)	0.60	VA	24.83	24.42	1.02
		MD	25.65	16.00	1.60
		PA	16.65	23.20	0.72

Data sources: Hartter (2012) and U.S. Department of Agriculture, National Agricultural Statistics Service (2014).

MD = Maryland; PA = Pennsylvania; VA = Virginia.

Table 10. Gross revenue sensitivity (ΔGR_i) to conveyance rates (R).

Nursery type	Gross revenue changes under alternative R values (\$/ha)					
	$R = 0\%$	$R = P_i^w/P_i^r$	$R = 100\%$	$R = 0\%$	$R = P_i^w/P_i^r$	$R = 100\%$
	Annual bedding plants			Broadleaf evergreen plants		
	Geranium			Azalea		
VA (1, 2, 3)	-7,722	136,136	200,331	-4,644	11,048	17,168
MD (1, 2, 3)	-8,552	115,318	199,501	-5,703	6,205	16,109
PA (1, 2)	-7,431	119,673	200,622	-9,813	11,999	11,999
Syn (Small, Large)	-8,552	115,318	199,501	-5,703	6,205	16,109
	Petunia			Holly		
VA (1, 2, 3)	-810	7,580	21,562	-3,503	-1,098	4,970
MD (1, 2, 3)	-927	10,300	21,444	-8,692	-219	-219
PA (1, 2)	-830	8,896	21,541	-6,092	214	2,381
Syn (Small, Large)	-927	10,300	21,444	-8,692	-219	-219
	Chrysanthemum			Boxwood		
VA (1, 2, 3)	-1,863	12,274	21,291	-12,885	17,484	17,484
MD (1, 2, 3)	-2,652	20,503	20,503	-13,310	17,059	17,059
PA (1, 2)	-1,930	12,997	21,224	-8,640	13,155	21,729
Syn (Small, Large)	-2,652	20,503	20,503	-13,310	17,059	17,059

Note: The two simulated nurseries are assumed located in MD, thus the results for Syn (Small, Large) and MD (1, 2, 3) are always equal in this table.
MD = Maryland; PA = Pennsylvania; VA = Virginia.

Table 11. Net revenue sensitivity (ΔNR_i) to conveyance rates (R) for three annual bedding plants.

Nursery	Net revenue changes under different R values (\$/ha)								
	$R = 0\%$	$R = P_i^w/P_i^r$	$R = 100\%$	$R = 0\%$	$R = P_i^w/P_i^r$	$R = 100\%$	$R = 0\%$	$R = P_i^w/P_i^r$	$R = 100\%$
	Geranium			Petunia			Chrysanthemum		
VA-1	-6,275	137,582	201,777	291	8,680	22,662	-780	13,357	22,374
VA-2	22,468	166,326	230,520	29,034	37,423	51,405	27,963	42,100	51,117
VA-3	-1,034	142,824	207,018	5,532	13,921	27,903	4,461	18,598	27,615
MD-1	-7,623	116,247	200,430	-344	10,883	22,027	-2,086	21,068	21,068
MD-2	-5,380	118,490	202,673	1,899	13,127	24,270	157	23,312	23,312
MD-3	-15,709	108,160	192,343	-8,430	2,797	13,941	-10,172	12,982	12,982
PA-1	-7,661	119,443	200,391	-1,407	8,320	20,965	-2,524	12,404	20,630
PA-2	-9,276	117,828	198,776	-3,021	6,705	19,350	-4,139	10,789	19,015
SynSmall	-12,056	111,813	195,996	-4,778	6,450	17,594	-6,519	16,635	16,635
SynLarge	-15,830	108,040	192,223	-8,551	2,676	13,820	-10,293	12,861	12,861

MD = Maryland; PA = Pennsylvania; VA = Virginia.

Table 12. Net revenue sensitivity (ΔNR_i) to conveyance rates (R) for three broadleaf evergreen plants.

Nursery	Net revenue changes under different R values (\$/ha)								
	$R = 0\%$	$R = P_i^w/P_i^r$	$R = 100\%$	$R = 0\%$	$R = P_i^w/P_i^r$	$R = 100\%$	$R = 0\%$	$R = P_i^w/P_i^r$	$R = 100\%$
	Azalea			Holly			Boxwood		
VA-1	-3,562	12,131	18,250	-2,446	-41	6,027	-11,802	18,567	18,567
VA-2	25,182	40,875	46,994	26,298	28,702	34,771	16,941	47,310	47,310
VA-3	1,680	17,372	23,492	2,795	5,200	11,269	-6,561	23,808	23,808
MD-1	-5,137	6,771	16,675	-8,152	321	321	-12,745	17,624	17,624
MD-2	-2,894	9,014	18,918	-5,909	2,564	2,564	-10,501	19,868	19,868
MD-3	-13,223	-1,315	8,588	-16,238	-7,765	-7,765	-20,831	9,538	9,538
PA-1	-10,406	11,406	11,406	-6,712	-406	1,761	-9,234	12,561	21,135
PA-2	-12,021	9,791	9,791	-8,327	-2,021	147	-10,849	10,946	19,520
SynSmall	-9,571	2,338	12,241	-12,586	-4,112	-4,112	-17,178	13,191	13,191
SynLarge	-13,344	-1,436	8,468	-16,359	-7,886	-7,886	-20,951	9,417	9,417

MD = Maryland; PA = Pennsylvania; VA = Virginia.

The remaining nurseries (MD-1, MD-3, PA-1, PA-2, SynSmall, and SynLarge) have negative net revenue changes for all six plants when R is 0%.

When $R = P_i^w/P_i^r$, MD-3 and SynLarge have decreased net revenue for Azalea, estimated at -\$1315/ha and -\$1436/ha, respectively. VA-1, MD-3, PA-1, PA-2, SynSmall, and SynLarge have negative changes for Holly, estimated at -\$41/ha, -\$7765/ha, -\$406/ha, -\$2021/ha, -\$4112/ha, and -\$7886/ha, respectively.

Except for three cases (Holly on MD-3, SynSmall, and SynLarge), all 10 nurseries gain more net revenues for all plants from WRT when the conveyance rate $R = 100\%$ than

well water or municipal water. Net revenues increase because the returned premiums generate larger gross revenues to offset the opportunity costs of yield losses as well as the increased production costs with WRT.

Break-even conveyance rate R . For those nurseries that suffer from decreased net revenues associated with WRT for different plants as shown in Tables 11 and 12, the corresponding break-even conveyance rates to balance gross revenue and production cost changes ($\Delta NR_i = 0$) are shown in Table 13. For example, for nursery VA-1, a small break-even conveyance rate $R = 3.0\%$ will balance the -\$6275/ha net revenue change associated with WRT for Geranium; whereas

for nursery PA-2, a large break-even $R = 98.3\%$ offsets the -\$8327/ha net revenue change related to WRT for Holly. With only three exceptions (Holly on nursery MD-3, SynSmall, and SynLarge), break-even conveyance rates are less than 100% as shown in Table 13, indicating that growers could cover WRT costs with a sufficient share of consumer premiums.

Break-even premium results. Table 14 shows the break-even premiums corresponding to the break-even R shown in Table 13 that should be returned to growers to balance net revenue. Overall, with only two exceptions (Holly in nursery MD-3 and SynLarge), the break-even premiums are \$0.50/pot or

less for all plants and all nurseries. Specifically, the break-even premiums for the three annual bedding plants are well below \$0.20/pot on average, and are more consistent with previous finding such as Yue et al. (2016), whereas the break-even premiums for the three broad leaf evergreen are slightly higher than previous findings.

Break-even death rate results. The death rate after adoption of WRT is assumed to be nondecreasing based on survey responses reported in Cultice (2013). However, pathogen mitigation practices (Hong and Moorman, 2005) might reduce plant disease incidence below the level obtained without WRT. Reducing plant disease incidence might provide another way to offset additional costs associated with WRT even without returned premiums. Table 15 shows the break-even death rates required to offset the added WRT production costs of nurseries MD-3, PA-1, PA-2, SynSmall, and SynLarge if no premiums are assumed to be

returned to producers ($R = 0\%$). These five nurseries are highlighted because they show an increase in production cost with recycling (Tables 4–7). The results illustrate that for most cases, reducing death rates below 2%, the assumed average rate for non-recycling nurseries, can offset the additional cost incurred from conversion to WRT even without returned premiums. However, there are six exceptions (e.g., Petunia for MD-3) where the death rate would need to be reduced by more than 2% to offset increased production cost with recycling. A greater than 2% reduction leads to a physically impossible negative death rate. For these exceptions, reducing plant disease incidence fails to completely offset the added WRT production costs.

Discussion

Public desire to improve water quality poses environmental challenges for the

horticulture industry as demonstrated by policies that require conservation measures. The nursery industry continues to face challenges of reduced product sales resulting from the downturn in the housing market in 2009, although it has partly recovered in recent years. At the same time, the industry faces increasing competition for scarce water supplies in some regions. This study concludes that consumer premiums for plants grown with recycled water could offer nursery growers a method to improve their net returns while addressing environmental challenges and improving irrigation crop water productivity.

Adoption of WRT offers some nurseries the opportunity to reduce water supply costs relative to well water or municipal water. In addition, consumer premiums that could be obtained from plants grown with WRT could outweigh increased production costs of WRT as well as possible economic losses

Table 13. Break-even conveyance rate R required to balance gross revenue and production cost changes ($\Delta NR = 0$).

Nursery	Break-even R					
	Geranium (%)	Petunia (%)	Chrysanthemum (%)	Azalea (%)	Holly (%)	Boxwood (%)
VA-1	3.0	N/A	3.4	16.3	28.9	38.9
VA-2	N/A	N/A	N/A	N/A	N/A	N/A
VA-3	0.5	N/A	N/A	N/A	N/A	21.6
MD-1	3.7	1.5	9.0	23.6	96.2	42.0
MD-2	2.6	N/A	N/A	13.3	69.7	34.6
MD-3	7.6	37.7	43.9	60.6	191.6	68.6
PA-1	3.7	6.3	10.9	47.7	79.2	30.4
PA-2	4.5	13.5	17.9	55.1	98.3	35.7
SynSmall	5.8	21.4	28.2	43.9	148.5	56.6
SynLarge	7.6	38.2	44.5	61.2	193.1	69.0

Note: N/A refers to the case where break-even analysis is not applicable because the net revenue change is already positive without any premium returned as show in Tables 11 and 12.

Break-even rates greater than 100% indicate that the estimated consumer premium is not adequate to cover production cost changes.

MD = Maryland; PA = Pennsylvania; VA = Virginia.

Table 14. Break-even premiums corresponding to the break-even R required to balance gross revenue and production cost changes ($\Delta NR = 0$).

Nursery	Break-even premium (\$/pot)					
	Geranium	Petunia	Chrysanthemum	Azalea	Holly	Boxwood
VA-1	0.02	N/A	0.02	0.07	0.10	0.23
VA-2	N/A	N/A	N/A	N/A	N/A	N/A
VA-3	0.003	N/A	N/A	N/A	N/A	0.13
MD-1	0.02	0.01	0.04	0.10	0.32	0.25
MD-2	0.01	N/A	N/A	0.06	0.23	0.21
MD-3	0.04	0.13	0.20	0.26	0.65	0.41
PA-1	0.02	0.02	0.05	0.21	0.27	0.18
PA-2	0.02	0.05	0.08	0.24	0.33	0.22
Syn-S	0.03	0.07	0.13	0.19	0.50	0.34
Syn-L	0.04	0.13	0.20	0.27	0.65	0.42

Note: N/A refers to the case where break-even analysis is not applicable because the net revenue change is already positive without any premium returned as show in Tables 11 and 12.

MD = Maryland; PA = Pennsylvania; Syn-S = SynSmall; Syn-L = SynLarge; VA = Virginia.

Table 15. Break-even death rate to offset added water recycling technology production costs of nurseries MD-3, PA-1, PA-2, SynSmall, and SynLarge when conveyance rate $R = 0\%$.

Nursery	Break-even death rate					
	Geranium (%)	Petunia (%)	Chrysanthemum (%)	Azalea (%)	Holly (%)	Boxwood (%)
MD-3	1.2	N/A	N/A	0.7	1.1	1.4
PA-1	2.0	1.3	1.7	1.9	1.9	1.9
PA-2	1.8	N/A	0.9	1.8	1.6	1.7
SynSmall	1.6	N/A	0.5	1.3	1.6	1.7
SynLarge	1.1	N/A	N/A	0.7	1.1	1.4

Note: For some plants, death rates would have to be negative for breakeven between recycling and not recycling without any premiums returned. Because negative death rates are impossible, such cases are labeled N/A.

MD = Maryland; PA = Pennsylvania; VA = Virginia.

associated with increased plant disease risk. Additional production costs of WRT could also be lowered by reducing plant death rate below levels that occur without WRT (Table 15). Therefore, treatment of recycled water with effective pathogen mitigation procedures should always be considered as suggested by Hong and Moorman (2005).

Nursery growers have diverse production operations and management practices, which depend on location, state and federal policies, market channel, and other considerations. For some nurseries, physical layout restricts the adoption of WRT. For example, limited land or shallow water tables will deter some nurseries from regrading or digging ponds for recycled water, making it impossible to implement WRT regardless of public or private incentives.

Although consumer premiums have potential to make WRT economically feasible for many growers, the logistical resources needed to establish a labeling program for WRT may be beyond the capability of a single horticultural firm. A centralized government or industry organization may be best suited to lead the implementation of certification and labeling of plants grown with WRT. In this case, the “green washing” for WRT practices imposed by sellers, i.e., the act of misleading consumers via promising more environmental benefits of the product than they actually deliver can be effectively mitigated through well-established industry standards and certification programs.

The results of this analysis are specific to only eight case nurseries and two simulated nurseries in mid-Atlantic states. These results should be replicated with a larger set of nurseries and in alternate climate zones. Further analysis could also focus on the upfront costs facing growers who wish to transition to WRT and the length of time required to pay back these costs with alternative recycling premiums. Investments in water-saving technology (e.g., precision watering) provide an alternate way of reducing water use and should be evaluated as well. Researchers should consider the potential for scale economies when evaluating such investments. The premiums estimated by Hartter (2012) were based on hypothetical questions instead of actual marketing experiments. Better estimation of consumer premiums should be possible through experiments involving actual consumer purchases (Chang et al., 2009; Hudson et al., 2012). Additional research should focus on how consumer premiums would be allocated at each distribution stage under different market channels, locations, and plant types. Such research could shed additional light on how consumer premiums for horticultural plants produced with WRT can assist the industry to address environmental challenges.

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