Horticultural Producers' Willingness to Adopt Water Recycling Technology in the Mid-Atlantic Region

Alyssa K. Cultice

Thesis submitted to the faculty of the Virginia Polytechnic Institute and State University in partial fulfillment of the requirements for the degree of

Master of Science
In
Agricultural and Applied Economics

Darrell J. Bosch, Co-Chair
James W. Pease, Co-Chair
Kevin J. Boyle

July 12, 2013
Blacksburg, Virginia

Keywords: Choice experiment, conditional logit, green industry, horticulture, nursery, survey, technology adoption

Horticultural Producers' Willingness to Adopt Water Recycling Technology in the Mid-Atlantic Region

Alyssa K. Cultice

ABSTRACT

Water-recycling technologies have been developed to reduce water consumption and surface runoff in horticultural operations. However, WRT may increase risk of disease from water-borne pathogens such as *Pythium* and *Phytophthora*. More information is needed about producers' management practices and attitudes regarding irrigation runoff containment and recycling. A mail survey was administered in February 2013 to horticultural nursery growers in Virginia, Maryland, and Pennsylvania. Collected were respondents' demographic characteristics plus irrigation and disease management practices. The survey incorporated a choice experiment quantifying willingness to adopt water recycling given hypothetical disease outbreak, water shortage probabilities, and percentage cost increases via a conditional logit model. Two hundred and sixty respondents provide valuable insight into horticultural production in the Mid-Atlantic region. We were unable to calculate the implicit price of water or disease for adoption because the sample of 91 respondents for the choice experiment yielded a flat distribution of operations ranging in $100 to $7 million in nursery cost. However, findings did support the hypothesis that producers will be more likely to adopt selected WRT when cost decreases, probability of disease decreases. Only 33% chose to adopt. Cost is the biggest factor as the majority of producers are not equipped to handle water recycling or capture and would go out of business due to the expense. Disease is also significant factor inhibiting growers from adopting. Until mandatory environmental regulations in place to force producers to contain runoff, or until incentivized cost sharing programs are implemented, wide spread adoption of water recycling technologies is unlikely to occur.

Horticultural Producers' Willingness to Adopt Water Recycling Technology in the Mid-Atlantic Region

Alyssa K. Cultice

ACKNOWLEDGEMENTS

My thesis research is sponsored through the Specialty Crop Research Initiative (SCRI) of USDA-National Institute of Food and Agriculture (NIFA). Award #2010-51181-21140.

I would like to express my gratitude to my committee members Darrell Bosch, Jim Pease, and Kevin Boyle for their invaluable support and guidance. I am honored to have a thesis advisory committee of talented and dedicated mentors.

Thank you to Chuan Hong, John-Lea Cox, Gary Moorman, Jim Owen, and all of the other SCRI professors and industry project members for their assistance with the technicalities of plant pathology and horticulture. I could not have asked for a better group of people to collaborate with.

The mail survey success is due to the hard work and administration of Susan Willis Walton and the VT Center for Survey Research.

Thank you to the growers who took time out of their day for a site visit or to answer my survey.

A special thank you to Marshall, and my peers in the VT AAEA Master's Class of 2013 for always being there.

My thesis is dedicated to my parents, Bill and Kris, and my brother Will, for your perpetual love and support. Thank you.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I: INTRODUCTION

Industry Background

The United States' horticulture industry is a broad sector consisting of businesses involved in all aspects of the production and marketing of ornamental, fruit, and vegetable plants. The horticultural industry represents a small but significant part of the United States agricultural economy, generating $17 billion in sales per year. Total horticultural sales in Virginia, Maryland and Pennsylvania totaled $707 million in 2009 (USDA Census of Horticultural Specialties, 2010).

According to the 2007 Census, there are 4,785 greenhouse, nursery, and floriculture operations in the Mid-Atlantic region[12] whose sales exceed $1,000 annually and for which horticultural crops make up at least 50% of the operation's value of production. These firms include 1,085 businesses in Virginia, 673 in Maryland, and 3,027 in Pennsylvania (Table 45, USDA Census of Agriculture, 2007). The 2009 Census of Horticultural Specialties covers horticultural firms selling more than $10,000 per year, and includes most of the horticultural operations that use irrigation.[3] Nursery operations that irrigate crops are of specific interest in this study. A total of 1,027 producers reported irrigating nursery crops in the Mid-Atlantic in the 2008 Farm and Ranch Irrigations Survey. According to the survey, Virginia has 306 irrigating

---

[1] For the purposes of this study, the Mid-Atlantic region refers to Virginia, Maryland, and Pennsylvania.
[2] A nursery is a field, garden, greenhouse, or other form of growing space for specialty crops grown in the group. A container operation uses pots to grow plants (Pots can also be potted in the ground, this is known as the "pot-in-pot" method. A greenhouse is a structure enclosed with nonporous covering for the purpose of protecting specialty crops. An operation can include different types of growing practices within their operation.
[3] Includes all operations that reported horticultural crop sales of $10,000 or more, or the presence of sod, nursery products, short rotation woody crops or Christmas trees on the 2007 Census of Agriculture. Horticultural crops include bedding plants, potted flowering plants, cut flowers, cut cultivated florist greens, trees, shrubs, ground covers, vines, fruit and nut trees, sod, dry bulbs, greenhouse produced vegetables, commercial vegetable transplants, vegetable and flower seeds, Christmas trees, short term woody crops, aquatic plants, unfinished or prefinished plants, propagation materials, and other nursery or greenhouse plants.

nursery crop producers; 133 who produce under protection, and 177 who produce in the open[4] (Tables 2 and 3, US Farm and Ranch Irrigation Survey, 2008). Maryland has 184 irrigating nursery crop producers, 72 who produce under protection, and 122 who produce crops in the open (Tables 2 and 3, US Farm and Ranch Irrigation Survey, 2008). Pennsylvania has 537 irrigating nursery crop producers, 240 who produce under protection, and 297 who produce in the open (Tables 2 and 3, US Farm and Ranch Irrigation Survey, 2008).

Due to social concerns for improved environmental quality, there is an increased concern with possible environmental impacts of horticultural firms. One way to reduce environmental impacts is through the implementation of water recycling. Irrigation water recycling refers to runoff water capture and re-use of the captured water for irrigation purposes. Irrigation recycling conserves water and may reduce costs. State and local environmental regulators encourage growers to contain and recycle irrigation runoff to reduce pollution and enhance water quality. This practice has potential risks for operations as recycling may increase the risk of disease infection from water-borne pathogens. More information is needed about producers' practices to control negative environmental impacts. Necessary information includes their disease and management practices, attitudes toward capture and recycling of irrigation runoff, and the barriers to adoption of these practices.

Water Supply

Increasing urbanization in some areas is causing authorities to increase regulation. The use of both the use of municipal water and agricultural use of water resources is increasingly monitored and regulated by governments (Hong and Moorman, 2005). Water scarcity creates pressure on Mid-Atlantic horticultural producers to use recycled water. Horticultural operations

[4] Some businesses produce both under protection and in the open.

require a large water supply to satisfy the demands of irrigation. There are two common industry standard recommendations for irrigation water application in nurseries: 1) a minimum of 1 acre-inch of water, approximately 27,000 gallons, per acre of nursery stock per day of irrigation, or 2) an annual use of 13 acre-feet of water per acre of container nursery stock (Robbins, 2010). For greenhouse operations, 1-2 quarts per square foot of growing area per day are needed. (Robbins, 2010). These water requirements only include water used for irrigation, not other mechanical processes and facility use. See Table 1 below for the breakdown of water usage and area irrigated in all three states.

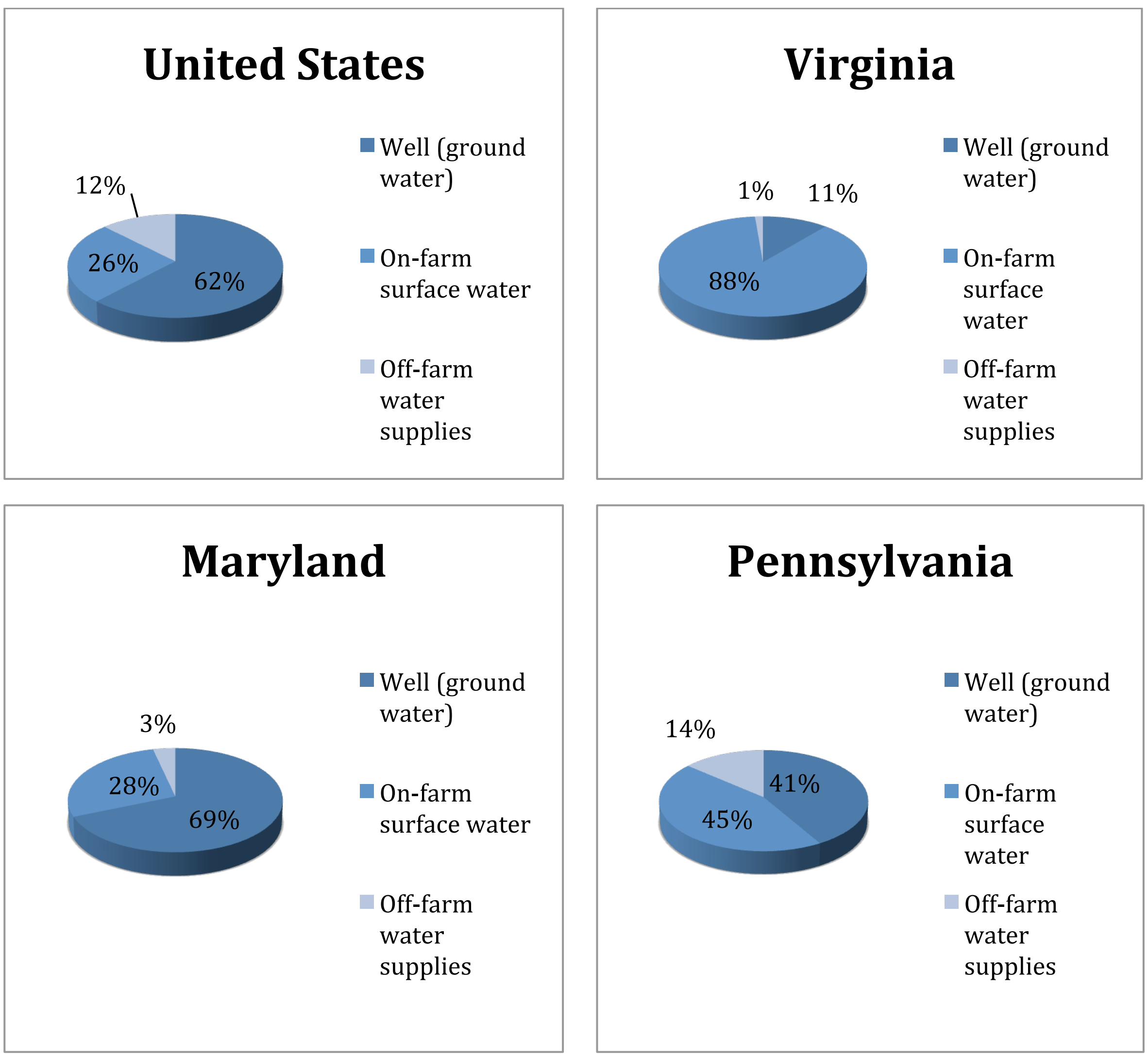
Table 1. Estimated Quantity of Water Applied to Crops Grown Under Protection on Irrigated Horticultural Operations by All Methods of Distribution and Water Source

State	Virginia	Maryland	Pennsylvania
Total number of operations	386	307	1,353
Total square feet irrigated	14,769,134 sq ft	10,791,959 sq ft	64,534,712 sq ft
Total gallons of water applied	371,391,000 gal	96,320,000 gal	558,752,000 gal
Average gallons of water applied per sq ft	25.14 gal/sq ft	8.92 gal/sq ft	8.65 gal/sq ft

Source: US Farm and Ranch Irrigation Survey, 2008 (Table 3)

These reported value equate to an average application of 25.14 gallons per square foot for Virginia operations, 8.92 gallons per square foot for Maryland operations, and 8.65 gallons per square foot in Pennsylvania. (US Farm and Ranch Irrigation Survey, 2008) The main sources of horticultural irrigation water are ground water from wells, on-farm surface water, and off-farm surface water. The following graphs in Figure 1 below were created with data from the 2008 US Farm and Ranch Irrigation Survey and show the breakdown of irrigation water sources in Virginia, Maryland, and Pennsylvania. Sources of irrigation water vary by state: Virginia and Maryland producers obtain the majority of their water (88% and 69% respectively) from on-farm surface water, such as rivers, streams, ponds, and lakes. Pennsylvania producers are more dependent on wells. They only obtain 45% of irrigation water from on-farm surface water sources, and 41% from wells. On average, producers in the entire United States get 12% of their water from off-farm sources, compared to only 1% in Virginia and 3% in Maryland. Pennsylvania producers use the most water from off-farm sources at 14%.

Figure 1. Estimated Quantity of Water Applied to Crops Grown Under Protection on Irrigated Horticultural Operations by Water Source



Source: US Farm and Ranch Irrigation Survey, 2008

Operations strive for irrigation efficiency by increasing the amount of water used by the plant's root zone while reducing runoff and evaporation. Three common efficiency measures employed are: drip irrigation, scheduled irrigation, and water recycling systems (Haman et al., 2005).

Pollution Concerns

Pollution control to protect water quality is an additional issue of significance for horticultural producers. Water runoff from nurseries can carry fertilizer nutrients, pesticides, herbicides and other chemicals to surface water bodies or into the sub-surface water table. This type of non-point source pollution is a growing concern in the mid-Atlantic region due to decreases in water quality in the Chesapeake Bay and its tributaries. Water pollution monitoring data show that the Bay has both poor water quality and low aquatic species populations as well as degraded habitats (US EPA, 2010).

On December 29, 2010 the U.S. Environmental Protection Agency established the Chesapeake Bay Total Maximum Daily Load (TMDL) limits for nitrogen, phosphorus and sediment under the Clean Water Act (US EPA, 2010). A TMDL is the calculation of the maximum amount of a particular pollution a water body can receive and still meet acceptable water quality standards (US EPA, 2010). The TMDL regulations are for states that are totally or partially within the Chesapeake Bay watershed: Delaware, Maryland, New York, Pennsylvania, Virginia, West Virginia and the District of Columbia. The allotted pollution load varies by the size and existing quality of each tributary basin and jurisdiction in the Chesapeake Bay watershed. For example, the goal for the Chesapeake Bay tributary basins in Virginia (James, York, Rappahannock, Potomac-Shenandoah and the Eastern Shore) is approximately 59 million pounds for nitrogen and roughly seven million pounds for phosphorus (Virginia Department of

Conservation and Recreation, 2013). The TMDL limit for the entire Chesapeake Bay watershed is 185.9 million pounds of nitrogen, 12.5 million pounds of phosphorus and 6.45 billion pounds of sediment per year. These limits equate to a 25 percent reduction in nitrogen, 24 percent reduction in phosphorus and 20 percent reduction in sediment (US EPA, 2010). The goal of the Chesapeake Bay TMDLs is to restore the Bay and its tributaries by 2025, and to complete at minimum 60% of planned actions by 2017 (US EPA, 2010).

States in the Chesapeake Bay watershed can utilize various regulatory and voluntary programs in the Watershed Implementation Plans (WIPs) to meet the proposed TMDL reductions (Virginia Department of Conservation and Recreation, 2013). Regulatory efforts include permits required under the Clean Water Act, and voluntary programs include tax and financial incentives such as Virginia's agricultural Best Management Practices (BMP) cost-share program. The EPA is taking a "backstop" approach to enforcement of TMDL reductions. Instead of taking immediate steps to ensure regulatory compliance to reach the target TMDL loads, the EPA is encouraging state and county level efforts to adopt voluntary programs to meet the reduction goals in Phase I and II Watershed Implementation Plans in addition to maintaining regulatory compliance of required point source permits. EPA will take a more active role in enforcement of requirements if the TMDL load reduction requirements are not met (Virginia Department of Conservation and Recreation, 2013). Although the EPA does not regulate voluntary state programs, it will be crucial for states to show the EPA that they are making progress to achieve the goals of the Watershed Implementation Plans. If the EPA determines that the States are not meeting allocations, they will utilize their "backstop" power and use the State's allocated federal funds to handle water quality issues at a national level in a more stringent way (Virginia Department of Conservation and Recreation, 2013).

In Pennsylvania the TMDL regulations have significantly increased enforcement and compliance of state requirements for agriculture. In Virginia and Maryland, EPA warns of the possible implementation of mandatory programs for agriculture if pollution reductions fall behind schedule (US EPA, 2010). Stricter regulations at the state level regarding agricultural operations could alter nursery grower management. Additionally future regulations could require horticultural operations to capture all water runoff.

Although compliance with such laws by farmers is often seen as a burden, the farmers have a significant stake in maintaining ecosystem services and conserving natural resources. Horticultural producers would be able to reduce nutrient and chemical pollution of the Bay and other water bodies by containing their water runoff and recirculating the water for irrigation.

Disease

Water recycling for irrigation purposes comes with increased risk of disease caused by water-borne disease pathogens. Of prime interest in this study are species of the genus *Pythium* and the genus Phytophthora because both are among the most destructive water-borne pathogens. *Pythium* primarily affects the roots of greenhouse plants and causes root rot (Moorman, 2010-B). *Phytophthora* primarily affects operations that grow plants in pots outdoors, and can cause root rot as well as stem rot or cankers (Moorman, 2010A). Both pathogens can affect plants at all stages of growth and are capable of killing a variety of ornamental crops. They are transmitted via mobile zoospores and other types of spores that are easily spread among plants through water or soil contamination (Wilson and von Broembsen, n.d.). Contaminated irrigation water is a primary (if not the sole) vehicle for *Phytophthora* infections (Hong and Moorman, 2005). The issues of plant pathogens like *Pythium* and *Phytophthora* have become a particular area of focus in the effort to implement best water conservation practices (Hong and Moorman, 2005).

Regardless of entry point of the pathogens, once crops are infected, these pathogens can spread and recirculated water can repeatedly expose plants (Hong and Moorman 2005). Even though no recent data exists, it is estimated that water borne plant pathogens such as *Pythium* and *Phytophthora* can cause crop losses of up to 12% in the United States (Pimentel, 1997).

Methods used to prevent or control disease include: sand filtration, ultraviolet light, chlorination, ozonation, heat, pressure, surfactants, sedimentation, antimicrobial compounds, suppressive potting mixes, adjusting flow rate, minimizing water contact time, fungicides, and biological control agents (Hong and Moorman, 2005, Wilson and von Broembsen, n.d.). WRT entail infrastructure investments to capture, treat, and recirculate water. Costs of such investments add to the costs of WRT and may dissuade growers from adopting WRT. Adoption of water recycling technologies is more expensive for nursery operations as opposed to greenhouse operations. Further understanding of water recycling disease management can reduce disease concerns for growers considering adopting water recycling technologies (Wilson and von Broembsen, n.d.).

Water Recycling Technologies

Local governments and concerned publics encourage horticultural growers to recycle the irrigation and rainfall runoff from their operations to increase conservation and reduce pollution of off-site water bodies. Recycling irrigation water can help growers conserve between 40-50% of their water and maximize use of fertilizer in recycled irrigation water (Wilson and von Broembsen, n.d.). Horticultural operations recycle irrigation water by collecting irrigation water via channels, ditches, and basins as it runs off from production areas and then pumping the water back to irrigation systems or to storage basins for future use. Channels, ditches, and basins are typically designed to capture both irrigation runoff and storm water runoff. Growers may choose to adopt water recycling practices to reduce pollution, reduce water costs, ensure a reliable water supply, control storm water on their property, and to increase management flexibility (Wilson and von Broembsen, n.d.). Today only a fraction of horticultural producers recycled irrigated water use on their operations (65 in Virginia, 18 in Maryland, and 64 Pennsylvania) (US Farm and Ranch Irrigation Survey, 2008). Below Table 2 displays horticultural operations in Virginia, Maryland, and Pennsylvania who participate in some water irrigation recycling in their operation.

Table 2. Recycled Water Use on Irrigated Horticultural Operations

	Total Operations	Under protection			In the open		
		Operations	Percentage (%)	Sq ft irrigated	Operations	Percentage (%)	Acres irrigated
VA	65	45	69%	9,983,495	53	81%	1,556
MD	18	16	88%	267,378	12	66%	1,282
PA	64	34	53%	20,629,052	36	56%	133

Source: US Farm and Ranch Irrigation Survey, 2008 (Figure 5)

Of those who do recycle, the majority of growers who recycle use the water for crops that are grown out in the open and under protection.

Water recycling is a potential solution to increase water conservation and water cost saving, but it comes with significant risks. These potential benefits are not without risk. Recycling comes with greater potential of disease due to water-borne pathogens. Buildup of salts, herbicides, pesticides, weeds, and seeds is also cause for concern when recycling water (Wilson and von Broembsen, n.d.). In addition, WRT entails infrastructure investment costs to capture, treat, and recirculate water. These costs and disease concerns may dissuade some growers from adopting WRT. The costs of water recycling and water treatment systems are highly variable. Variations may be due to the size of operation, type of operation, existing system, layout and topography of property, and volume of runoff and irrigation water. Adoption of water recycling technologies is more expensive for nursery operations than operations with greenhouses because nurseries require more water and have more land to control.

Problem Statement, Objectives, and Projected Benefits

Policymakers encourage growers to contain and recycle irrigation runoff to reduce pollution and enhance water quality. The initial fixed cost for WRT is high. Potential plant diseases, inadequate land, and poor information quality regarding the processes of adoption may dissuade owners from adopting. The initial cost for water recycling technologies (WRT) is high. Growers, other industry stakeholders, and regulators need more information regarding producers' irrigation and disease management practices, their attitudes toward containment, and recycling of irrigation runoff and the barriers to adoption of these practices.

This research is conducted as part of a United States Department of Agriculture (USDA) Specialty Crops Research Initiative (SCRI) funded project "Integrated Management Of Zoosporic Pathogens And Irrigation Water Quality For A Sustainable Green Industry" (Hong et al., 2010). This project includes primary investigators (PI's) that are horticulturalists, biologists, plant pathologists, economists, and extension agents from Virginia Tech, University of Maryland, Penn State, USDA, California University-Riverside, Rutgers University, and Christopher Newport University. Experiments that are being carried out by plant pathologists and horticulturalists includes plant growth studies, disease management, water management, and the development of guidelines and WRTs to assist managers in mitigating plant water-borne disease risks.

This thesis supports the Specialty Crops Research Initiative (SCRI) project goal of increasing adoption of water recycling systems in the green industry. The specific objectives of the research are:

1. Collect demographic information for horticultural production in the Mid-Atlantic region.
2. Identify barriers to adoption of water recycling technology (WRT)
3. Evaluate the effects of (1) disease probability, (2) water shortage probability, and (3) WRT implementation cost on producers' willingness to adopt water recycling.

The project results target horticultural growers, diagnosticians and field responders, extension specialists and agents, crop health care professionals, microbiologists, mycologists, bacteriologists, horticulturalists and irrigation specialists, conservation biologists, and policy-makers (Hong, 2010). The results of the survey will provide the basis for analysis of barriers to adoption by producers of WRT.

The project results will provide relevant and beneficial information regarding horticultural producers. This information potentially will be used by grant funding agencies, researchers, regulators, and policymakers to inform future research and policies to encourage adoption of WRT in the green industry. The project will also be an important input in future policy discussions of potential water and surface runoff restrictions or regulations affecting the green industry. It is absolutely necessary for regulators to understand factors that influence the investment decisions of farmers in order to predict their preferences and future behavior. This study will fill the literature void of studies of the economic costs of WRT and significant barriers to adoption of WRT.

Hypotheses

It is assumed that horticultural producers are profit-maximizing firms; a profit-maximizing firm will choose its inputs and outputs with the ultimate goal of achieving maximum economic profits. This assumption posits that producers are rational and will make decisions in order to make the difference between their total revenues and total economic costs as large as possible. The owners will weigh the costs and benefits of installing water recycling technologies in their particular operation to determine the best management decisions. The proposed project has the following testable hypotheses: Producers will be more likely to adopt selected WRT when:

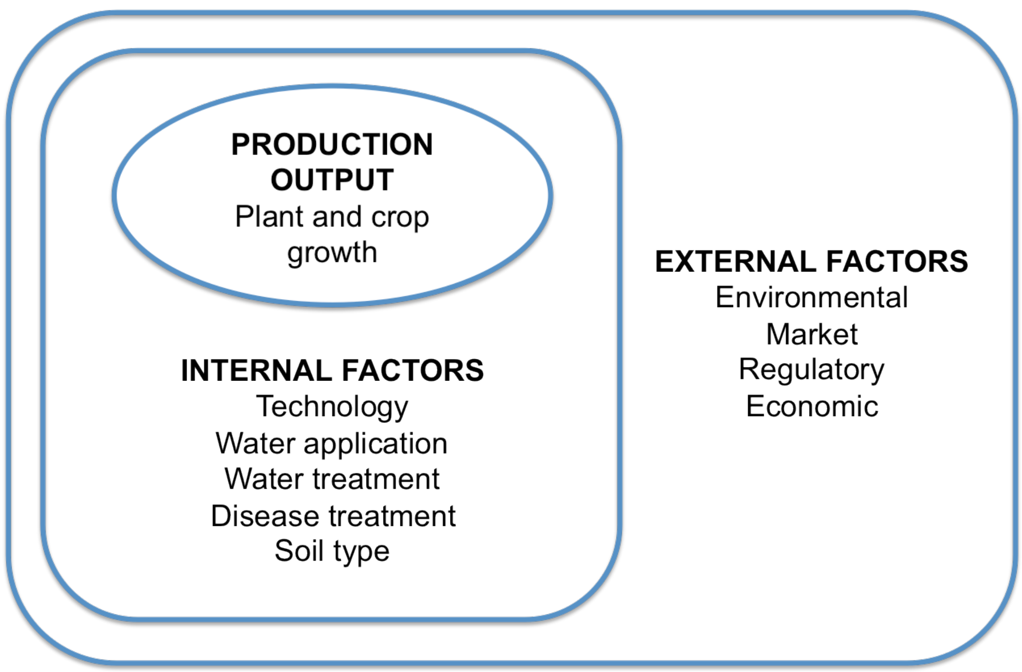
1. Cost of installing and operating WRT is lower
2. Likelihood of water-borne disease decreases
3. Likelihood of water shortage increases

CHAPTER II: CONCEPTUAL MODEL

Economic Theory

Horticultural production operation is a complex system that is responsive to external factors. As illustrated below in Figure 2, the grower must react to changing external factors to manage the operation within a closed control loop, where each decision influences all production processes (Lentz, 1998). Horticultural production can be characterized as a dynamic system because all decisions will influence future outcomes. Growers must consider long-term consequences when choosing to adopt new technologies in their operations.

Figure 2. Horticultural Production Practices



A horticultural operation's production inputs and outputs can be modeled as a production function. Aigner et. al (1977) presented the first linear production model with an error specification that is appropriate for the estimation of an industry production function. A stochastic frontier production function according to Aigner et al. (1977) can be presented as

$$y_i = f(x_i, \beta) + \varepsilon_i \qquad (1)$$

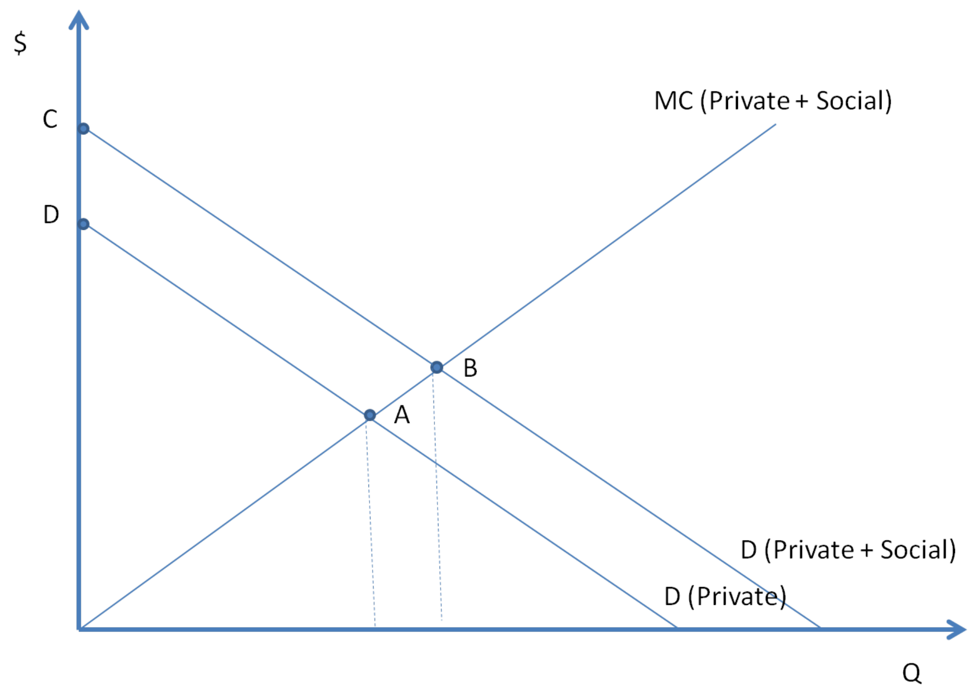
where y_i is the output obtained by the farm i, and x_i is the vector of used inputs, β is a vector of parameters to be estimated and ε_i is the error term that equals $v_i + u_i$. v_i is the symmetric error that captures the variations in production due to individual factors such as random errors in observation and measurement error. u_i is the error component that represents asymmetric term that captures technical inefficiency. Producers are assumed to strive for technical efficiency, which is the maximum potential output from physical production relationships from given inputs. An example horticultural producers' production function can be modeled as follows:

$$Production\ capability\ (y_i) = f(fixed\ costs, variable\ costs, land, water) + \varepsilon_i \qquad (2)$$

where the vectors include fixed costs (i.e. capital investment, machinery, labor costs), variable costs (i.e. supplies for water treatment and fungicides, soil, pots, fertilizer), land (i.e. rented facilities or the purchase of new land), and water (i.e. costs of obtaining water from municipal water sources or pumping costs for on site water resources). Producers will choose technology and other inputs including WRT to maximize their profit. WRT will be adopted only if its contribution to revenues exceeds its costs as perceived by the producer.

For this study, we are focusing on the demand side of supply and demand equilibrium of WRT. Horticultural producers are demanders of WRT, therefore this study will examine the demand for WRT and factors that shift demand. As seen below in Figure 3, we assume that the supply of WRT has an upward sloping supply curve, because as quantity increases, cost increases.

Figure 3. Supply and Demand for WRT Technology



We assume that horticultural producer's demand ("D") for WRT is downward sloping, because as price decreases, quantity increases. Because of the focus of the horticultural producer's willingness to adopt WRT and the associated costs in this study, only the social demand is added to the private demand and private supply graph in Figure 3. A single marginal cost curve shows both private and social marginal costs (supply or "MC"). The private demand curve is parallel to the social demand curve because the incremental social benefits are assumed to be constant at each quantity level.

Equilibrium at point A in Figure 3 represents the equilibrium between supply (including private and social costs) and demand. Equilibrium at point B in Figure 3 represents the equilibrium between supply including private plus social costs and private plus social demand. The trapezoidal region created by points A-B-C-D is the difference between the private and private plus social demand. Because we do not know the slopes of the supply or demand curves, we do not know the shape or size of the area. This area represents the costs that affect the environment that are not accounted for by private firms. Including the social costs into this study is important as illustrated by the private plus social demand curve. If horticultural producers could be induced to incorporate both private and social demand into their management decisions, the private demand curve could be shifted out and equilibrium will be closer to the social optimum of equilibrium at point B. We can define a change in welfare from the adoption of WRT at level B as the entire area in the trapezoid between private demand and social demand above the marginal cost (trapezoid created by points A-B-C-D). Yet growers in a very competitive industry might be endangering their ability to compete and survive by doing so. Other inducements (subsidies, technical support, etc.) are needed to accomplish such increased adoption. A higher level of WRT adoption will result in a larger welfare gain for society.

Private costs (or benefits) are defined as costs (or benefits) that an individual firm, a horticultural producer in this study, is able to quantify in monetary terms that directly affect his/her financial bottom line. Social costs (or benefits) are defined as costs (or benefits) resulting from firm activity, that are absorbed by individuals or groups that do not benefit directly from firm activities. Social benefits cannot be captured in a market. If these social benefits could be captured in a market, there would be no costs to society; individuals absorb all of the costs. Table 3, lists some of the costs (barriers) and benefits that would affect the decision-making process of an owner considering the installation of water recirculating technologies. These benefits and costs were identified during the horticultural producer site visits in this study.

Table 3. Private and Social Costs and Benefits to Water Recycling Adoption

	Benefits	Costs
Private	- Potential revenue enhancements from reduced product loss and increased prices paid by consumers - Decreased water consumption - Less dependence on other water sources - If applicable, less cost of water withdrawals - Elimination of contamination from other sources - Increased flexibility in the face of restrictions on water withdrawal - Increased water supply on site	- High capital investments for technology installation - Increased operating costs due to water treatment - Land taken away from production - Increased disease potential and revenue losses from plant loss - Increased weed potential (recycled water can pick up and transfer other types of plant seeds) - Increased crop losses from water-borne diseases may occur without proper disease management practices for WRT
Social	- Environmental integrity and quality through reduced water use, cleaner water - Reduced risk of spread of quarantine pathogens to surrounding areas - Improved public image of the green industry for being environmentally conscious	

Attribute Based Choice Models

We have developed and implemented an attribute-based choice model based on Holmes and Adamowicz and described in Champ et al (2003) to elicit a producer's probability of adoption and her/his willingness to pay for water recycling technology. Choice modeling is used to represent the decision-making process of an individual in order to estimate individual preferences in a specific or hypothetical situation and measure trade-off preferences between the attributes and the alternative(s). Responses are analyzed according to random utility theory (McFadden, 1974) and Lancaster's "New Approach to Consumer Theory" (Lancaster, 1966), which are the foundations of discrete choice modeling theory. According to Lancaster's Characteristics Theory of Value, consumers derive their utility from the different characteristics of the good, rather than from the good itself. The probability of choosing a specific alternative (good) is a function of the utility of the attributes linked to the good and the attributes of other choice options. Discrete choice models use random utility theory to estimate the probability that an alternative is chosen.

The utility received from alternative j by individual i can then be expressed as:

$$U_{ij} = V_{ij} + \varepsilon_{ij} \tag{3}$$

where an individual's (i) utility that can be observed and measured for object j is denoted U_{ij}. V_{ij} is a vector of attributes that object j exhibits and ε_{ij} is the random error component that contains unobserved factors that impact utility (U_{ij}) plus measurement error (Lancaster, 1966, Louviere et al., 2000). The random error component (ε_{ij}) takes into account that individuals have distinct preference strengths for different attributes (Train 2003).

An individual is assumed to make choices based on the attributes of the alternatives with some degree of randomness (McFadden 1974). The basic utility equation can then be expressed as:

$$U_{ijt} = \beta_i V_{ijt} + \varepsilon_{ijt} \tag{4}$$

where t is used to distinguish between multiple choice sets.

Adamowicz et al. (1998) outline how choice experiments relate to utility theory. Utility theory predicts that each individual will maximize his utility, and according to consumer choice, the consumer will choose object i if the utility he/she gets from object j is higher than the utility he or she could obtain from other choices (n).

$$V_{ij} + \varepsilon_{ij} > V_{in} + \varepsilon_{in} \forall j \neq i \tag{5}$$

The probability of choosing a particular object from a choice set containing competing alternatives j, for all alternatives in the choice set is the following:

$$P(i) = P\{V_{ij} + \varepsilon_{ij} > V_{in} + \varepsilon_{in}: \forall j \in C\} \tag{6}$$

Where C is the set of all possible alternatives. Equation 6 can be rearranged to show that in random utility modeling choices are based on the differences in utility across alternatives.

$$P(i|C) = P\left\{V_{ij} - V_{in}\right\} > + \{\varepsilon_{ij} - \varepsilon_{in}\}: \forall j \in C\} \tag{7}$$

Variables that stay for the same for an individual, such income, will drop out of the equation.

Logit models assume ε_j, the random error component, is logistically distributed (McFadden 1974). A conditional logit model was selected for this analysis to estimate producers' probability of adoption (WRT) and their willingness to pay for water recycling. As originally introduced in McFadden (1974), a conditional logit model allows the utility to be represented in terms of the characteristics of the alternatives, as opposed to the attributes of the decision maker. The conditional logit model regression then estimates how different attributes (V) influence the probability of an object being chosen. (Carmeron and Triveda, 2010)

In this choice experiment, V_i contains attributes of the scenario and there are three alternatives (A, B, and status quo). Assuming IID errors and independence between choice scenarios and individuals, the probability of choosing an alternative becomes

$$P\{i\} = \frac{e^{sV_j}}{\sum_{j \in C} e^{sV_n}} \tag{8}$$

where s is a scale parameter, usually assumed to be one (Adamowicz et al, 1998). The probability of choosing object j is equal to e raised to the utility of i divided by e raised to the utility of all choices n.

Irrigation and Water Recycling Technology Adoption

As initially described by Rogers (1962), adoption is a mental process specific to an individual that starts when the individual or operation learns about an innovation or technology, and ends at the final stage of adoption. Horticultural production operation is a complex system that is responsive to unlimited external factors. Horticultural growers must react to changing environmental factors to manage the operation within a closed control loop, where each decision influences all production processes (Lentz, 1998). Growers must think long-term when determining to adopt new technologies in their operations. Horticultural production can be characterized as a complex dynamic system that is affected by exogenous and endogenous factors. Factors include: weather, soil, insects, diseases, weeds, plant nutrition, input and output prices. The interaction between these factors creates uncertainty which is a key concern of long-term decision-making (Lentz, 1998). Management strategies for disease management, water conservation, and regulations will vary from firm to firm.

Multiple studies (e.g. Hall et al., 2009, Barreiro-Hurle et al., 2008, and Baynard and Jolly, 2007) have found that factors influencing producers' willingness to adopt conservation and sustainable production practices vary with industry practices. Practices include environmental regulation, customer-perceived value of the practice in question, individual producer attitudes toward the practice, and producer demographic characteristics. Past studies have found positive relationships between producers' attitudes, values, personal perceptions, and social capital levels and their implementation of various environmentally friendly technologies (Barreiro-Hurle et al., 2008; Baynard and Jolly, 2007; Burton et al., 1999; Hall et al., 2009; Jordan, 2005). Studies such as Hall et al. (2009) and Marra et al. (2003) have found that the most significant variables in the adoption of sustainable practices are producers' concern of implementation difficulty and the production risk associated with new technologies. There is a need for research which will highlight the roles of risk, uncertainty, and producers' demographics to better understand agricultural technology adoption (Marra et at., 2003; Dennis et al., 2010)

Knowledge of problems that horticultural producers may face is not sufficient for modeling, it is also necessary to understand the decision-making process, based on producers' values and objectives, which can be described from a theoretical point of view (Lentz, 1998). Management strategies to control for disease management, water conservation, and regulations will vary from firm to firm.

CHAPTER III: STUDY DESIGN

Site Visits and Preliminary Survey

Between January and August 2012, study investigators conducted ten site visits to nursery growers in Virginia, Maryland and Pennsylvania in order to formulate the survey questions. The purpose of the interviews was to learn about horticultural growers' experiences with water-borne diseases as well as water and cost management options. Nurseries visited in Virginia included a container nursery, two greenhouse/container nurseries, and three greenhouse/container/field nurseries. Maryland operations included two greenhouse/container nurseries and two aquatic greenhouse/container nurseries. Pennsylvania nurseries included a field nursery and a container nursery. An evolving survey of irrigation and disease management practices was administered at each site. Survey forms were sent to each grower in advance and completed during the visit, which lasted about two hours including a tour of operation facilities. Most of the growers recycle at least a portion of their irrigation and runoff water.

The preliminary survey entitled "Managing Water-borne Diseases in Horticultural Operations" was created to characterize current horticultural water and disease management practices. The survey is approximately 45 questions and contains detailed open-ended questions. The purposes of the survey were to learn about horticultural growers' experiences with water-borne diseases, including control costs and management options, plus learn about their water recycling systems and activities. Disease management options include water treatment, irrigation management (timing and amount), fungicide use, and species, timing, and location of plants. Growers were asked whether they recycle water, the perceived advantages and disadvantages of recycling, and what steps, if any, they have taken to increase residence time of recycled water before it is applied to plants. The survey also elicited general business characteristics of the operation. We followed up the survey questions with specific inquiries regarding the facility during site tour. The majority of growers visited during the site visits suggested that mail surveys would be the most effective vehicle for a large-scale follow up survey.

Our goal was to collect cost and production information from a variety of producers: different size operations, wholesale and retail, those with closed water recycling systems, those who contain their water but do not recycle, and those who do not contain their water. We wanted to ensure that the questions for the follow up mail survey were technically correct and used appropriate language. After each visit, edits were made to the survey based on growers' suggestions.[5]

Survey Development

The Tailored Design Method was utilized throughout survey development and administration (Dillman, 2009). Input and feedback were sought from horticulture experts in academia and industry throughout development of the survey form and research implementation. In addition to the feedback from producers, we hosted a focus group and consulted with the entire grant project team during our annual meeting, as well as in a final telephone meeting before the survey was finalized.

The annual project-wide SCRI "Integrated Management of Zoosporic Pathogens and Irrigation Water Quality for a Sustainable Green Industry" meeting took place on November 7-8, 2012 at the Virginia Tech Hampton Roads Agricultural and Research Center (Hong, 2012). Project investigators presented the draft survey. We received feedback from over 25 attending project investigators and industry advisors. Questions were taken during the presentation, and

[5] See Appendix A for detailed findings from the site visits.

individual questions that needed work were presented for group discussion. Surveys were distributed for detailed written feedback from participants.

We also hosted a Horticultural Nursery Producer Focus Group on December 6, 2012 at the Guilford County Extension Office in Greensboro, North Carolina. Attendees included three extension agents and two of the top local growers. During this meeting, attendees were informed about our project, took the survey "Ornamental Nursery Survey of Irrigation Practices and Disease Management," and provided feedback to clarify and increase the effectiveness of the survey. Greensboro was selected because it is outside of our survey area, but because it is located close to the Virginia/North Carolina state border it also has a similar climate and comparable geography to Virginia. It took attendees 15-20 minutes to complete the survey. Focus group attendees suggested improvements to the survey and new topics to explore for our research.

A final review was conducted on December 18, 2012. Project investigators spoke by telephone with project principal investigator, Chuanxue Hong, co-principal investigator, Gary Moorman, and Assistant Professor of Horticulture at Virginia Tech, Jim Owen. Input from meeting participants was used to ensure that the technical and horticultural production aspects of the survey made sense and would elicit usable responses and data.

Sample

According to the United States 2007 Census of Agriculture, there were 4,785 primarily[6] greenhouse, nursery, and floriculture production operations in the Mid-Atlantic region. Of those operations, 1,085 operations were in Virginia, 673 in Maryland, and 3,027 in Pennsylvania (Census of Agriculture 2007, Table 45). Because our research is concerned with adoption of

[6] Operations included in this total include farms that receive more than 50% of their total receipts from greenhouse, nursery, and floriculture products and are classified as NAICS (North American Industry Classification Standards) number 1114.

water recycling, we are primarily interested in those nurseries with irrigation. We focused on operations with at least some field and container nursery production, because unlike greenhouses, it is more complex to collect runoff and recycle from production outdoors.[7] According to the Census, there were 947 such nursery operations in Pennsylvania, 281 in Maryland, and 392 in Virginia, a total of 1,620 operations (US Census of Agriculture, 2007). A total of 1,027 producers were reported as irrigating nursery crop producers in the Mid-Atlantic (Tables 2 and 3, US Farm and Ranch Irrigation Survey, 2008). Table 4 below illustrates the breakdown of these greenhouse, nursery, and floriculture operations by type of nursery product.

[7] The sample does not include Christmas tree growers, fruit and vegetable plant growers, or any completely contained growing operation.

Table 4. Number of Operations in Virginia, Maryland, and Pennsylvania Categorized by Nursery, Greenhouse, Floriculture, Sod, Mushrooms, Vegetable Seeds, and Propagative Materials Grown for Sale

Type of Nursery Product	VA	MD	PA
Aquatic Plants	14	10	53
Bulbs, Corms, Rhizomes, And Tubers - Dry	12	5	42
Cuttings, Seedlings, Liners, And Plugs	30	15	52
Floriculture Crops - Bedding/Garden Plants, Cut Flowers And Cut Florist Greens, Foliage Plants, Potted Flowering Plants, And Other Floriculture And Bedding Crops, Total	527	406	1548
Bedding/Garden Plants	409	317	1252
Cut Flowers And Cut Florist Greens	104	84	188
Foliage Plants, Indoor	15	19	83
Potted Flowering Plants	102	104	466
Other Floriculture And Bedding Crops	6	3	12
Flower Seeds	8	4	9
Greenhouse Fruits And Berries	6	8	15
Total Greenhouse Vegetables And Fresh Cut Herbs	76	72	323
Greenhouse Tomatoes	51	56	248
Other Greenhouse Vegetables And Fresh Cut Herbs	51	33	132
Mushrooms	19	4	95
Mushroom Spawn	0	0	3
Nursery Stock	392	281	947
Other Nursery Crops	17	5	27
Sod Harvested	27	30	13
Tobacco Plants Sold For Transplant	54	3	49
Vegetable Seeds	11	8	20
Vegetable Transplants	34	37	101
Total NAICS 1114: Greenhouse, nursery, and floriculture Production	1085	673	3027

Source: Census of Agriculture 2007, Table 35 and 45

See Table 5 below for a breakdown of irrigating operations.

Table 5. Irrigated Horticultural Operations by Selected Crops Irrigated

	MD	PA	VA	Total
All Irrigated Horticultural Crops	307	1,353	386	2,046
Floriculture and bedding crops				
Under Protection	231	896	240	1,367
In the Open	140	385	139	664
Total	371	1,281	379	2,031
Nursery Crops				
Under Protection	72	240	133	445
In the Open	122	297	173	592
Total	184	537	306	1,027
Propagative Materials				
Under Protection	38	133	74	245
In the Open	3	20	19	42
Total	41	153	93	287
Food Crops Grown Under Protection	63	232	48	343
Mushroom Crops	0	78	0	78
Sod	16	19	16	51
Christmas Trees and Other Short Rotation Woody Crops	12	76	11	99
Other Horticultural Crops				
Under Protection	0	19	5	24
In the Open	23	76	45	144
Total	23	95	50	168

Source: Farm and Ranch Irrigation Survey, 2008

Operation mailing addresses and phone numbers were collected through publicly available Internet sources. Operation contact information was collected from Virginia, Maryland, and Pennsylvania's state permitted nursery operations listed on states' websites.[8] Mailing lists from the Virginia Nursery Landscape Association (VNLA), the Maryland Nursery Landscape Association (MNLA), and the Maryland Greenhouse Growers Association (MGG) were obtained from their respective association offices. These lists were crosschecked with public nursery

[8]Virginia Department of Agriculture and Consumer Services (http://www.vdacs.virginia.gov/plant&pest/pdf/91nursery.pdf)
Maryland Department of Agriculture (http://mda.maryland.gov/pdf/md_nurs_alpha.pdf)

listing sites such as Nursery Trees and Garden Guides.[9] The final list had 3,339 nursery operations listed from the Mid-Atlantic region. The list that was compiled was conservative, operations that were questionable in terms of existence or meeting irrigation and nursery production criteria were left on the list to make sure they were not overlooked in the sample.

The Virginia Tech Center for Survey Research was contracted to finalize the sample, administer the survey, and collect the results. Telephone callers from the Virginia Tech Center for Survey Research made screening calls to eliminate growers that did not include nursery operations and/or irrigate their crops.[10] The responses were categorized into call dispositions based on their screening call: no answer, busy signal, answering machine, callback, disconnected/changed, hearing barrier, soft refusal, hard refusal, fax tone, temporarily disconnected, new number, wrong number, and complete. There were 1,141 operations that did not have a nursery production operation[11], and these were removed from the list during the screening calls. There were 397 operations in the "complete" category; operations that responded to calls, said they would take the survey, and gave updated mailing information. Operations that refused the survey were removed from the list. Operations that had no responses after 5 calls were included in the final mailing list in the event that they had closed for the winter, during the period when screening calls were made. The final list included 2,035 operations for mailing surveys, far surpassing the target Census number of 1,027.[12]

[9] Nursery Trees Directory
(http://www.nurserytrees.com/States/National%20Nursery%20&%20Garden%20Center%20DIRECTORY.htm)
Garden Guides Directory (http://www.GardenGuides.com)
[10] See Appendix B for the script used for telephone screening calls.
[11] Where a nursery is defined as an outdoor growing area used to produce ornamental plants with or without containers.
[12] See Appendix C for breakdown of screening call disposition by state.

Survey

There are two main sections of the survey: general questions, and the choice experiment questions. Surveys were printed as two-sided stapled booklets on legal size paper. The survey is 44 questions long and includes both open-ended and circle-type answers. The survey was designed to take about 15 minutes to complete. The survey was kept as short as possible to avoid respondent fatigue and to increase usable responses. The goal of the general questions is to determine the characteristics of the operation and the managers/decision makers of those operations. These questions are asked in every survey version. The general questions include six sub-sections. The titles and information requested in each section are as follows:

1. Nursery irrigation management – Irrigation types/practices, water source, acres/square feet irrigated, water use, and water scarcity.
2. Disease incidence and cost – Types of risks (disease, water shortage, frost, insect damage, hail damage, weed competition, wind/blow over damage), disease prevention, and revenue lost to disease.
3. Disease management – Concerns with *Pythium* and *Phytophthora*, disease prevention methods (timing and method of water application, use of fungicides, treating water prior to irrigation, growing of susceptible plant varieties, grouping of plants by water needs, adjusting potting mix, destroying potentially infected plants, modifying irrigation system, and sanitizing growing environment, water treatment methods prior to collection, and water treatment methods prior to application), cost of water treatment, and total costs for fungicides, labor, equipment, and other.
4. Water runoff capture and recycling – Water runoff control practices used by grower including use of collection ponds, preferences on runoff control, water recycling practices

used by grower, grower preferences for recycling, steps taken to increase water residence time, and irrigation water supply from collection ponds.

5. Recycling Scenarios (Choice Experiment) – Hypothetical situation to elicit management preferences for recycling if collection were required.
6. General Business Characteristics – Type of nursery sales (wholesale, retail, re-wholesale/resale, or other), types of production operations (greenhouse, container, field, hoop houses, other), operation size, overall production costs, nursery production costs, ornamental plant types grown, revenue by product, operation gross revenue, revenue from ornamental crops, respondent job title, respondent education level, respondent college/graduate degree focus, respondent work years in horticulture industry, and grower questions or concerns regarding disease or irrigation management.

Choice Experiment

We implemented an attribute based choice (ABC) model with a choice experiment section to elicit willingness to pay for recycling technology that affects the likelihood of water-borne disease and the likelihood of water shortages. Stated choice experiments are a stated preference method in which respondents are asked to choose a preferred option from a finite number of alternatives given in a hypothetical scenario (Collins et al 2007). The goal of the analyses is to determine the influences of the attributes on the observed choices by the respondents as represented by an indirect utility function. The choice experiment software Ngene by Choicemetrics was utilized to create the experimental design for this study. Ngene uses attributes, attribute levels, number of desired choice sets, and number of iterations to determine the optimal choice sets for the most efficient design subject to the user-specified limit on number of iterations of the program.

Our survey includes skip directions in order to ensure that only appropriate respondents answer questions regarding water runoff and recycling. Respondents whose operations already recycle 100% of their water are told to skip over the "Recycling Scenarios" (Choice Experiment) section. The basis of the hypothetical choice scenario is that horticultural producers are required to recapture water. It is assumed that their decisions to recycle will be based on three main factors: 1) Probability of water shortage, 2) Probability of disease, and 3) Cost of installation and maintenance of water recycling technologies (WRT). These attributes were formulated from nursery grower input during visits, focus groups and other conversations with experts. The attributes and selected levels for hypothetical scenarios are illustrated below in Table 6.

Table 6. Choice Experiment Attributes and Levels

Attribute	Levels
Disease: Probability of disease detection	10 % (Baseline), 12%, 14%, 16%, 20%
Water: Irrigation water shortage probability without recycling	10%, 13%, 15% (Baseline), 17%, 20%
Cost: Percent increase in nursery production costs for installing and operating recycling	5%, 10%, 15%, 20%, (No baseline)

Attribute baseline and potential levels were determined by expert opinion as a range of realistic percentage cost or probability increases that could result from the specific attribute. "Disease" refers to probability of detecting disease pathogens (*Phytophthora* and *Pythium*) within a year with a baseline of 10% and 5 levels varying by up to 20%. Disease probability of 20% is the maximum level of disease detection beyond which experts considered that an operation would have difficulty staying in business. The survey makes it clear that this is not the probability that outbreak will occur, but rather the probability of disease detection.

"Water" is the probability of the firm incurring a shortage of irrigation water due to low rainfall, which affects private or public well supplies as well as stream water and other surface water supplies for some producers. The National Weather Service monthly average cumulative precipitation for Virginia, Maryland, and Pennsylvania, from 1895-2000 was used to estimate precipitation probabilities. In 15% of the years between 1895-2000, cumulative monthly rainfall during the growing season (April through August) was 1.75 inches or less in the Mid-Atlantic Region. Since there is no unique definition of "water shortage" for all purposes due to operation needs and differences among geographical region, we estimate that if the average precipitation per month in April-August falls below 1.75 inches (the 15% level baseline), then there may be a "water supply" problem for some producers. We state that the 15% baseline probability is the current probability of a "water supply" problem for producers. The levels of 10%, 13%, 17%, and 20% refer to alternative probabilities of cumulative rainfall per month being less than 1.75 inches.

"Cost" refers to the percent increase in annual nursery production costs necessary to install and operate recycling infrastructure and practices, with four possible alternatives: 5%, 10%, 15%, and 20% (as a percent of annual nursery production costs). There is no baseline value for the cost attribute because any new technology implies a cost increase to the operation. "Cost" is used as a percent of annual nursery production costs so that respondents can determine the percentage increase based on the size of their individual operations.

Stated choice experiments are designed prior to data collection, so we are required to assume the likely parameter estimates that will result from the study. The parameter prior information is usually obtained from literature reviews, pilot studies, or based on intuition. Because this is the first study of its kind, there were no relevant priors available, which potentially limits the accuracy and efficiency of the model. It is assumed that the coefficient for cost is expected to have a negative sign, because producers would be less likely to choose to recycle as cost increases. The coefficient for disease is expected to have a negative sign, because producers would be less likely to choose to recycle as disease probability increases. The coefficient for water shortage is expected to have a positive sign, because producers would be more likely to choose to recycle if water shortage probability increases.

Huber and Zwerina (1966) related the statistical properties of the SC experiments to their econometric models and found that reducing the asymptotic variance-covariance matrix will result in an efficient design (optimal design). An efficient design yields a data estimate parameter with minimum standard error. The D-efficiency measure was chosen for this study to determine the most efficient design as Collins et al (2007) found that using D-efficiency as an indicator resulted in improved statistical efficiency compared to other traditional orthogonal design methods (Collins et al 2007). A full factorial model with all possible combinations was run initially to test the proposed model. To increase the number of observations and the precision in this study, 20 choice sets were chosen for our study, 2 questions for each of 10 forms. The multinomial logit model was selected to create the choice sets for this study because it is the basic logit model commonly used to generate statistically efficient designs (Collins et al 2007).

A dominant alternative exists when all the levels of one choice option are unambiguously more attractive compared to the second choice option, where one option "dominates" the other. The choice set with the best D-efficiency rating was selected because it did not have any dominant alternatives. Ensuring that there are no dominant alternatives is important to make sure that the choice questions reveal useful information. The choice sets used do not have an attribute level balanced design, meaning that each attribute level does not appear an equal number of times in the choice set columns. Attribute level balance will only occur in a full factorial model of all possible combinations, and is not needed in this case for a fractional/orthogonal design. There were no choice scenarios that had no change from the baseline for either disease or water shortage attribute alternatives because such choices would give no incentive for the respondent to incur cost to invest in the technology. A multinomial model was used for the choice experiment formulations because Ngene does not include conditional logit models.[13]

The ten variants of the survey forms (coded forms 1-10) created by Ngene (Choicemetrics, 2007) were randomly and equally distributed across each state and by the call disposition group to ensure that each state and call disposition group had equal form representation.[14][15] The stratification of call distribution is critical so the potential respondents most likely to return the survey (those who consented to the survey and provided an updated mailing address) received an equal number of each one of the survey forms.

Respondents were provided with the following information to introduce the hypothetical scenario: "New state and federal regulations designed to improve water quality might require nursery and greenhouse producers to capture all irrigation water and runoff from storms. Capture means impeding water runoff from your operation so that it does not flow directly to adjacent property or streams."

Then respondents were posed the question as to how water capture would affect their operations as seen in Figure 4. Following this question, the possibility of recycling was posed as follows: "In addition to capturing irrigation water runoff, operations may choose to recirculate

---

[13] See Appendix D for Ngene codes for the full factorial and multinomial logit model.
[14] See Appendix E for a complete listing of all of the choice sets for each of the ten survey forms.
[15] See Appendix F for a breakdown of the survey version distribution by state.

this captured water for irrigation purposes. Factors that could have an impact on the choice to recycle 100% of their water include disease risk, risk of irrigation water shortage, and costs of recycling."

The respondents are then given descriptions of attributes that might affect their decision-making as seen in Figure 4 on the following page.

Figure 4. Choice Experiment Section from Survey "Recycling Scenarios" page 1

Recycling Scenarios

New state and federal regulations designed to improve water quality might require nursery and greenhouse producers to capture all irrigation water and runoff from storms. Capture means impeding water runoff from your operation so that it does not flow directly to adjacent property or streams.

25) **If water capture was required by regulatory authorities what would your operation have to do to comply?** (Circle all that apply.)

1 Acquire adjacent land for constructing storage ponds
2 Reduce size of production area
3 Construct new ponds from existing production area to create buffer
4 Resize existing ponds
5 Modify existing greenhouse/production area to facilitate drainage to storage pond
6 Change irrigation practices
7 My operation already meets requirements
8 Other (please specify ________________)

Conditions Under Which You Would Choose to Recycle
In addition to capturing irrigation water runoff, operations may choose to recirculate this captured water for irrigation purposes. Factors that could have an impact on the choice to recycle 100% of their water include disease risk, risk of irrigation water shortage, and costs of recycling.

Risk of plant disease
Disease risk refers to the probability of plants developing Pythium/Phytophthora disease if irrigation recycling were implemented on your operation. This is the probability of plants showing disease symptoms in a typical year. Recycling stored water runoff for irrigation poses the potential problem of transferring diseases back to crops. An industry baseline for disease probability is assumed to be 10%. If a producer invests in water recycling, one of the components of the system would attempt to control for Pythium/Phytophthora.

Risk of irrigation water shortage
Risk of irrigation water shortage refers to a shortfall in water supply caused by depleted private or public well water or falling stream or pond levels. In recent years, producers around the country have experienced severe heat and drought conditions that have caused irrigation water shortfall. An industry baseline for irrigation water shortfall is assumed to be 15%. In 15% of the years between 1895-2000, cumulative rainfall was at or below 1.75" in your region during April-August posing a water supply problem for some producers.

Increased cost of installing and operating recycling
Many operations are not currently equipped to comply with a "capture" regulation or recycle irrigation water without incurring additional costs.

The respondents are then told about two recycling choice questions aimed at eliciting actions they might choose and are provided with an example of a recycling choice question (Figure 5). The example recycling scenario choice question describes two alternative situations where respondents have the option to implement water recycling with the risks defined by the given probabilities.

After the description of attributes affecting the recycling decision and the example question, each respondent is presented with two scenario questions providing hypothetical conditions for the recycling choice (Conditions A and B), where each scenario provides a random combination of disease, water shortage, and cost attribute levels. Respondents are reminded to: "Keep in mind the changes you would have to make in your operation to install a recycling system. You will then answer whether you would choose to install water recycling if Condition A or B were to occur, or if you would choose not to invest in recycling." Respondents are asked to choose whether they would 1) invest in recycling if Condition A occurred, 2) invest in recycling if Condition B occurred, or 3) Not invest in recycling if either A or B occurred. Two choice questions per survey form were used in order to increase the number of observations collected.

Figure 5. Choice Experiment Section from Survey "Recycling Scenarios" page 2

EXAMPLE

The two recycling scenario questions on the following page seek to learn about the recycling actions you might choose/prefer to implement if capture were required.

The table below is an example of a recycling scenario question. The table describes two alternative situations where you have the option to implement water recycling at your operations with the risks defined by the given probabilities.

	Recycling Condition A	**Recycling Condition B**
Probability of annual disease detection (**Current industry probability is 10%**)	20% with recycling	No change from current probability
Probability of annual water shortage **(Current industry probability without recycling is 15%)**	No change from current probability	No change from current probability
Percent increase in annual nursery production costs for installing and operating recycling technology	5% with recycling	10% with recycling

EXAMPLE

Keep in mind the changes you would have to make in your operation to install a recycling system. You will then answer whether you would choose to install water recycling if Condition A or B were to occur, or if you would choose not to invest in recycling.

Following the adoption question, questions were asked to learn why producers answered "yes" or "no" to implementing the WRT. One question states: "If you selected response number 3 (I would not invest if either Condition A or B occurred) in either of the proceeding questions, is it because your operation could not afford to implement 100% recycling?" The respondents are then asked how confident they were in their answers, and how important each one of the factor attributes (disease, water, production cost) is to their decision-making (Figure 6). These questions will give us insight into respondents' confidence in their answers and what factors weighed the most when making their decisions (Figure 6).

Figure 6. Choice Experiment Section from Survey "Recycling Scenarios" page 3

28) **If you selected response number 3 (I would not invest if either Condition A or B occurred) in either of the preceding questions, is it because your operation could not afford to implement 100% recycling?**
    1 Yes
    2 No
    3 Not sure

29) **How confident are you in your answers for questions #26 and #27, the recycling scenarios?** (Circle one number: 1 = very sure, 2 = sure, 3 = somewhat unsure, 4 = unsure)
    1 2 3 4

30) **How important is each of the factors to your decision to recycle?** (Circle one number: 1 = very important, 2 = somewhat important, 3 = somewhat unimportant, 4 = not important)

Probability of disease	1	2	3	4
Probability of water shortage	1	2	3	4
Increase in nursery production costs for installing and operating recycling	1	2	3	4

The survey was distributed on February 21, 2013.[16] The first reminder card was sent on February 28th, and the second reminder card the following week on March 7th.[17] The second round of surveys was sent out on March 12, 2013.

Model Specification

For the application in this study, the three characteristics (or attributes) of the adoption of water recycling technology (the good), are (1) probability of disease outbreak, (2) probability of water shortage, and (3) percentage cost increase for installation of WRT. In this study, the respondent's choice to adopt or not adopt water recycling technology of each specified attribute becomes the model dependent variable and each attribute coefficient's parameter weight is estimated from the pooled responses (Collins et al 2007).

The conditional logit model estimated specifies the systematic utility for each of the alternatives (j) as:

$$\begin{aligned} y = {} & \beta\text{cost}(cost) + \beta 1(water1) + \beta 2(water2) + \beta 4(water4) + \beta 5(water5) \\ & + \beta 7(\text{disease2}) + \beta 8(disease3) + \beta 9(disease4) + \beta 10(disease5) \\ & + \beta 11(disease6) + \varepsilon_{ij} \end{aligned} \tag{9}$$

where "cost" is a continous variable for the percentage change in total nursery costs (cost attribute) multiplied by the nursery cost for each operation. "Water1" through "Water5" are binary variables for each level of the water attribute, 10%, 13%, 17%, and 20% respectively, where the baseline level "Water3" (15%) is omitted. "Disease2" through "Disease6" are binary variables for each level of the disease attribute, 12%, 14%, 16%, 18%, and 20%, respectively, where the baseline level "Disease1" (10%) is omitted. The dependent variable, y, is a binary

[16] See Appendix G for full survey
[17] See Appendix H for reminder letter.

variable for choice that denotes whether the respondent chose to adopt water recycling technologies under the respective conditions, where 1 equals adopt and 0 equals opt out. The probability of a respondent choosing to adopt as a function of the cost of implementation and the cost of all other attributes can be denoted as:

$$P(choice) = f(\gamma * \text{attribute}, \beta * \text{cost}) \tag{10}$$

where γ is the estimated parameter for the attributes in the model (either water scarcity probability or disease probability and β represents the cost parameter. The implicit price for a firm's willingness to pay given a change in an attribute (increase water scarcity probability or disease detection probability) is then calculated by monetizing these other attributes by dividing by the cost increase level at which they chose to adopt:

$$Implicit\ price = \frac{\gamma}{\beta} \tag{11}$$

It is hypothesized that the coefficients for the "cost" variable will be negative, because as costs increase, the probability of adoption will decrease. The coefficients for the water variables that are below the baseline probability for water scarcity, "water1" and "water2" would be negative, as the probability of water scarcity decreases, the repondents would be less likely to adopt. The coefficients for the water variables that are above the baseline probability for water scarcity, "water4" and "water5" would be positive, as the probability of water scarcity increases, the respondents would be more likely to adopt. The coefficients for the disease binary variables "disease2" through "disease6" are hypothesized to be negative. As the probability of disease outbreak increases, the probability of adoption decreases. It is hypothesized that the absolute values of the coefficients will increase as the disease probabilities increase from 12% to 20%, because operations would be less likely to adopt as the probability of disease increases over 5 levels.

CHAPTER IV: RESULTS

Response Rate

Out of 2,035 surveys mailed, 265 were returned as undeliverable, and 436 surveys were returned completed. A total of 1,770 valid surveys were administered for a response rate of 25%. The number of 1,770 viable addresses where surveys were sent compares to the target agricultural census number of 1,027 mentioned previously. Seventy-seven of the surveys returned were from Virginia (18%), 64 surveys came from Maryland (15%), and 292 surveys came from Pennsylvania (67%).[18] Table 7 below shows the frequency of returned survey responses from each of the call disposition groups.

Table 7. Screening Call Disposition Response Frequencies

	Frequency	Percent (%)
No Answer	35	8
Busy Signal	5	1
Answering Machine	182	42
Callback	4	1
Disconnected/Changed	46	11
Soft Refusal	11	3
Automated Refusal Service	1	<1
Computer Fax Tone	3	1
Wrong Number	12	3
Complete	135	31.0
Tracking Label Damaged	2	1
Total	436	100

[18] State totals only sum to 433 because two surveys had their tracking numbers damaged in the mail so two of the survey states are unknown, and one respondent's operation was located in North Carolina, outside the survey area.

Interestingly, the largest response rate came from the "answering machine" group at 42%, second is the "complete" group at 31%. Surprisingly, only 115 (29%) of the respondents who completed the screening calls responded out of 397.

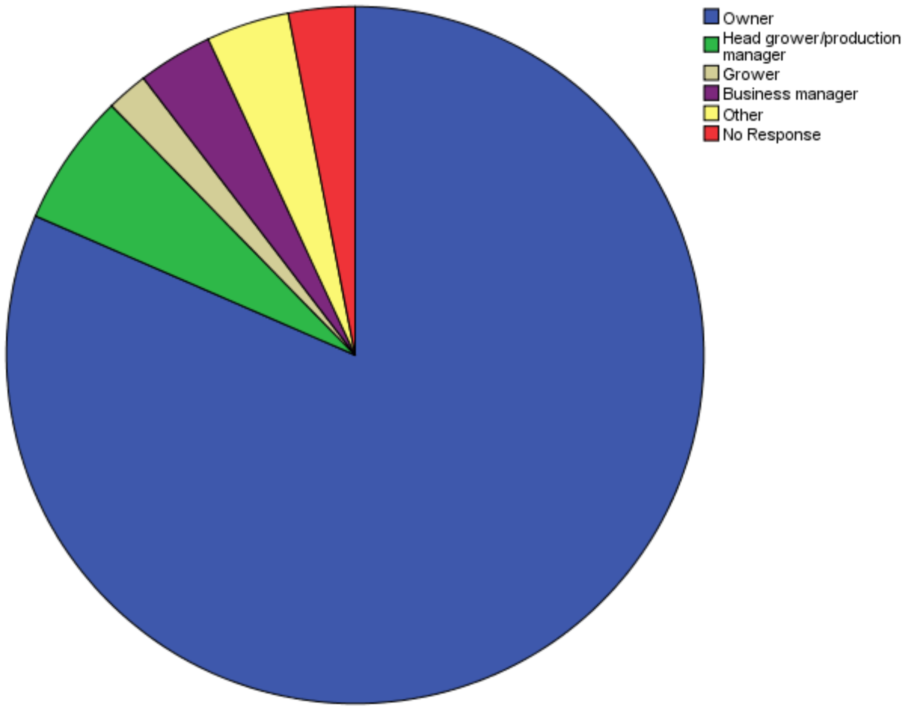
One hundred seventy-six of the returned surveys were from operations that did not irrigate (as answered in question #1) and returned the uncompleted survey as directed. Two hundred and sixty of these operations fit the criteria for this study as irrigated operations, completed and returned the survey. Of the completed surveys 63 surveys came from Virginia (24%), 38 from Maryland (15%), and 157 from Pennsylvania (61%).[19]

Respondent Demographics and Firm Characteristics

Almost all of the respondents who filled out the survey were the owner of the operation (82%). Other respondent job titles included head grower/production managers (6%), growers (2%), business managers (4%), and other (4%), and illustrated in Figure 7.[20]

[19] State totals for irrigating operations only sum to 258 because two surveys had their tracking numbers damaged in the mail, as mentioned before.
[20] 8 respondents (3%) did not answer this question.

Figure 7. Horticultural Survey Respondent Job Title



It is acknowledged that 20% of the respondents were not the owners of the operation and may have reported information in the survey other than the actual hypothetical management decisions or values of the owner. Education varied among respondents as seen in Table 8 below. the largest group was respondents who hold a 4-year degree (36%), followed by high school/GED degree (24%).

Table 8. Respondent Education Level

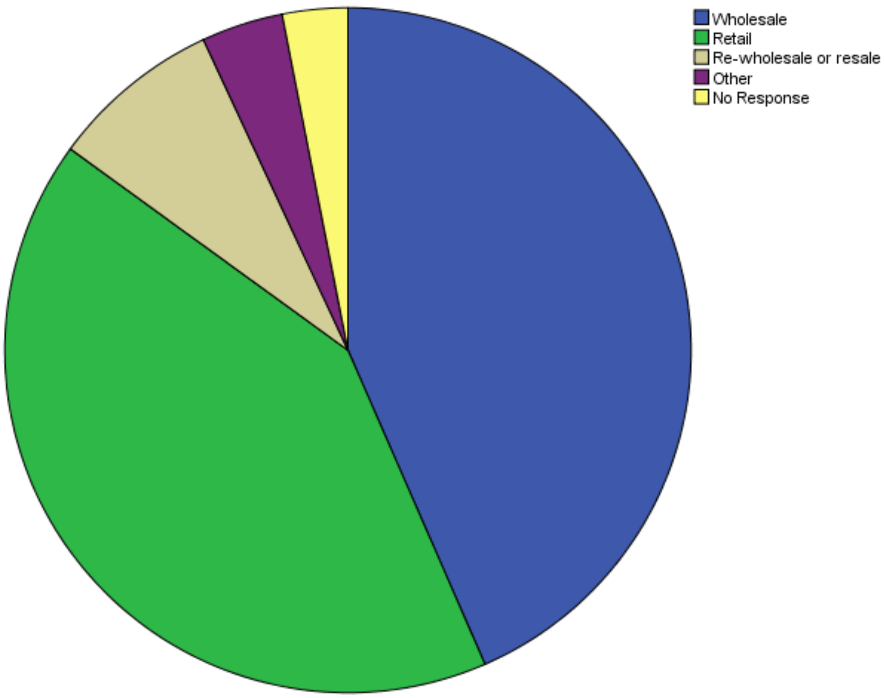
Education level	Frequency	Percentage (%)
Less than high school	22	9
High school/GED	62	24
2 year degree	27	10
4 year degree	94	36
Post-graduate	43	17
No Response	12	5
Total	260	100

Of the 137 respondents with a 4-year degree education level or higher, 55% (76 respondents) reported that they held a degree in plant pathology, horticulture, agronomy, or a related field. The average number of years that the respondent has worked in the horticulture industry was 27 years, with a standard deviation of 15 years. Twenty-five percent of the respondents have worked 15 years or less in the industry, and 50% of the respondents have worked between 16 and 37 years. Notably, 5% of respondents have worked at least 51 years in the industry, and the longest working respondent has worked in the industry for 75 years!

Firm Characteristics

The targeted nursery operations can be classified into four major sales categories: wholesale, retail, re-wholesale or retail, and other. As seen on the following page in Figure 8, 113 of the respondents' operations included wholesale sales (43%), and 108 reported retail sales (42%). Twenty-one operations include re-wholesale or resale sales (8%), and 10 operations reported having other types of sales (4%).

Figure 8. Horticultural Operations by Sales Type



Many operations reported that they participate in multiple types of production within their operation. Just over half of respondents participate in greenhouse and/or container production. Field nursery operations made up 40% of respondents. Table 9 below shows the breakdown of the different types of production operations.

Table 9. Horticultural Operations by Types of Production

Type	Frequency	Percentage (%)
Greenhouse	134	52%
Container (including Pot-in-Pot)	140	54%
Field nursery	105	40%
Hoop houses	97	38%
Other	13	5%

Note: Respondents can circle more than one response

One hundred and forty operations produce trees, 130 produce evergreen shrubs (average of 38% of sales revenue for those who produce), 129 produce deciduous shrubs (average of 28% of sales revenue), 118 produce annual bedding/garden plants (average of 19% of sales revenue), 92 produce potted flowering plants (average of 24% of sales revenue), 136 produce herbaceous perennial plants (average of 28% of sales revenue), and 35 sell other types of plants. Table 10 below shows gross revenue reported for all products and services in 2012.

Table 10. Horticultural Operation Gross Revenue For All Products and Services in 2012

Sales in dollars ($)	Frequency	Percent (%)
Less than $25,000	60	23
$25,001 to 100,000	54	21
$100,001 to 250,000	38	15
$250,001 to 500,000	26	10
$500,001 to 750,000	16	6
$750,001 to 1,000,000	9	4
$1,000,001 to 2,000,0000	11	4
$2,000,001 to $4,000,000	10	4
$4,000,001 to $6,000,000	5	2
$6,000,001 to $8,000,000	6	2
Greater than $10,000,000	3	1
No Response	22	9
Total	260	100

The median level of gross revenue is in the range of $100,001 to $250,000. The lower quartile ends within the $25,001 to $100,000 range, and the upper quartile begins within the $750,001 to $1,000,000 range.

Irrigation Practices

Out of the 433 respondents, 258 irrigate and filled out the survey, 175 of the respondents indicated that they did not irrigate in their operation and returned the survey as directed. Sources of irrigation water include: river/stream for 25 operations, pond fed by river or stream for 22 operations, pond fed by runoff for 46 operations, well water for 184 operations, public water source for 35 operations, and 21 operations said other. The majority of respondents who wrote in an answer for the "other" category reported that they use irrigation water from a spring or cistern. The clear majority gets irrigation water from wells (184 of 260), and the proportion of their total irrigation water coming from a well is very high (71%).

Overhead sprinklers are used by 167 operations for irrigation, 126 operations use drip irrigation, 6 operations use ebb and flow, 6 operations use hydroponic or nutrient film technology, and 64 listed "other". Fifty-six of the 64 respondents who listed another type of irrigation practice in the "other" category, reported using hand watering with a hose. Table 11 on the following page reports the reported typical gallons of water used per day to irrigate nursery crops. Forty-four percent of the respondents were in the lowest category, which matches up with the gross revenue information indicating that the majority of the respondents were smaller type operations.

Table 11. Horticultural Operations' Typical Gallons of Water Used Per Day to Irrigate Nursery Crops

Gallons of water per day	Frequency	Percentage (%)
0-100,000 gallons	190	73
100,001 to 200,000 gallons	14	5
200,001 to 300,000 gallons	2	1
300,001 to 400,000 gallons	3	1
400,001 to 500,000 gallons	5	2
500,001 to 1,000,000 gallons	5	2
1,000,001 to 2,000,000 gallons	2	1
2,000,001 to 5,000,0000 gallons	1	<1
5,000,001 to 10,000,000 gallons	1	<1
Don't know	26	10
No Response	11	4
Total	260	100

At this time, scarcity of water is not a concern for the majority of respondents. Sixty-nine percent of respondents have never run out or come close to running out of water for irrigation. Thirty percent of respondents have run out or come close to running out of irrigation water, so water scarcity is a concern for a portion of growers and they are aware of the implications of water shortage scarcity to their operation. Table 12 below shows the breakdown of water shortages.

Table 12. Number of Times in the Past Decade Operations Have Either Run Out or Come Close to Running Out of Water for Irrigation

Number of times	Frequency	Percent (%)
Never	180	69
One or two times	47	18
Three or four times	12	5
Five times or more	10	4
Don't know	3	1
No Response	8	3
Total	260	100

Disease

Operations have their own financial risk concerns depending on the type of operation and location. Table 13 below shows the rating of common financial risk factors for all operations. Disease is by far the most important financial risk concern for growers within the sample, with 77% growers reporting that disease is an important concern to their operation.

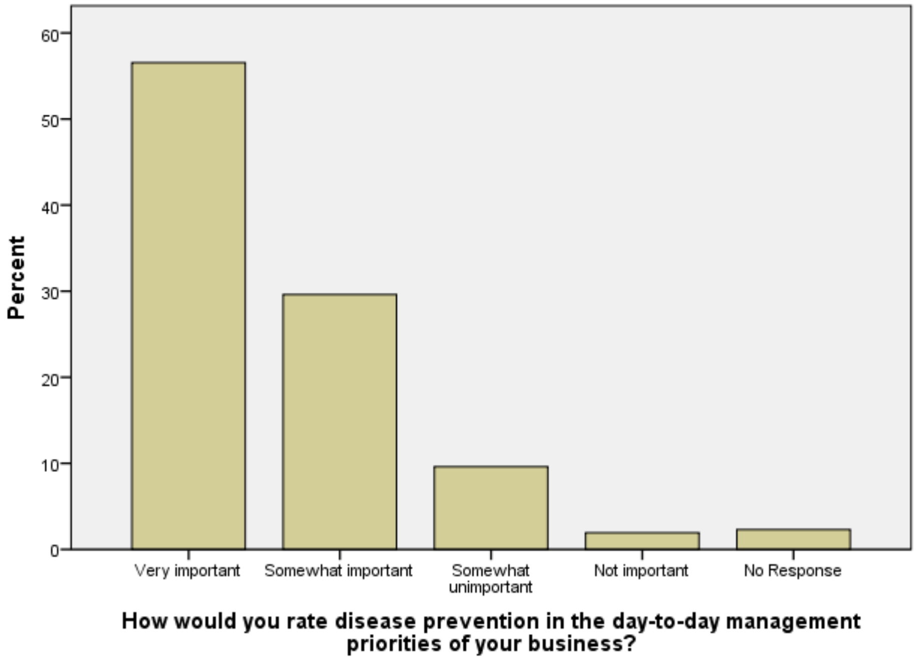
Table 13. Importance Rating of Financial Loss Risk Factors by Operation Percentage

Rating (%)	Disease	Drought	Frost/freeze	Insects	Hail	Weeds	Wind
Very important	48	36	29	39	15	23	16
Somewhat important	29	22	25	35	17	28	27
Somewhat unimportant	11	19	18	17	25	28	29
Not important	7	18	22	5	37	17	24
No opinion	2	1	1	<1	2	1	1
No Response	4	5	6	4	4	4	4
Total[21]	101	101	101	100	100	102	101

Disease prevention is an important part of the day-to-day management of horticultural businesses. As illustrated on the following page in Figure 9, 57% of respondents reported that disease management was very important, and 30% reported that it was somewhat important, for a combined 87% of respondents taking disease management seriously within their operations.

[21] Some totals do not add up to 100% due to rounding error.

Figure 9. Importance of Disease Management in Day-to-Day Management Operations



Only 37% of respondents lose less than 1% of their nursery sales revenue to disease in a given year, while 64% of respondents lose more than 1% of their nursery sales revenue to disease in a given year. Table 14 below illustrates the percentage revenue lost by respondents in a given year.

Table 14. Percentage of Nursery Sales Revenue Lost to Disease in a Given Year

Range	Frequency	Percentage (%)
Less than 1%	95	37
1-2%	70	27
3-5%	64	25
6-10%	20	8
11-20%	6	2
Greater than 20%	1	<1
No Response	4	2
Total	260	100

Nursery sales loss to plant disease is a significant issue for 3% of respondents, losing more than 11% of their nursery sales to plant disease in a given year. Table 15 below shows the maximum annual nursery sales revenue loss ever experienced by an operation as a result of disease. Notably, 9% of respondents have experienced greater than 10% annual nursery sales loss to disease.

Table 15. Maximum Annual Nursery Sales Revenue Loss Ever Experienced as a Result of Disease

	Frequency	Percentage (%)
Less than 1%	80	31
1-2%	54	21
3-5%	65	25
6-10%	33	13
11-20%	13	5
Greater than 20%	10	4
No Response	5	2
Total	260	100

Because water-borne plant diseases are so easily spread, the main concern for horticultural operations is the risk of widespread infection. Although these widespread infections do not occur frequently, operations often spend significant time and money to avoid large-scale contamination. Specifically, 32% of operations reported Phytophthora as a problem and 26% of operations see Pythium as a problem at their operations. From the site visits and discussions with industry professionals, operations don't always have the knowledge or capabilities to identify specific types of diseases. It is possible that some of the operations do not realize the disease issues that they may have are *Phytophthora* or *Pythium*. Table 16 on the following page shows the breakdown of operation problems with *Phytophthora* and *Pythium*.

Table 16. Operation Problems with *Phytophthora* and *Pythium*

	Phytophthora		*Pythium*	
	Frequency	Percentage (%)	Frequency	Percentage (%)
Significant problem	20	8	10	4
Problem	62	24	58	22
Insignificant problem	93	36	106	41
Not a problem	77	30	78	30
No Response	8	3	8	3
Total	260	100	260	100

Many types of methods are used to prevent damage from disease within horticultural operations. The most frequently used method is quickly destroying any potentially infected/diseased plants with 60% of respondents regularly using this technique (Table 17). The second most commonly used technique is grouping plants with similar water needs; this is used 48% of the time. The third most commonly used technique is reducing water application frequency; this is used 40% of the time. Seventy nine percent of respondents apply fungicides to plants to treat disease. Seventy four percent of respondents do not treat their water prior to irrigation, while 69% do not modify the irrigation system by adjusting channels and pipe locations. Modifying the irrigation system by increasing residence time is a major focus of science within the SCRI project and this is an opportunity for extension activities. On the following page, Table 17 shows the full breakdown of the various methods to prevent disease and the frequency with which they are used within respondent operations.

Table 17. Frequency of Methods Used to Prevent Disease by Percentage of Operations

Percentage (%)	Reduce water application frequency	Change timing of daily water application	Apply fungicides to plants	Treat water prior to irrigation	Stop growing susceptible plants
Regularly	40	30	33	10	27
Sometimes	33	40	46	10	43
Never	21	25	16	74	24
No Response	6	6	5	6	6
Total	100	100	100	100	100

	Group plants with similar water needs	Alter potting mix for susceptible plants	Destroy potentially infected/diseased plants	Modify the irrigation delivery system	Sanitize growing environment
Regularly	48	23	60	6	33
Sometimes	30	30	27	19	37
Never	18	39	7	69	24
No Response	5	8	6	7	6
Total	100	100	100	100	100

Some operations reported treating irrigation water prior to application: 26 operations use sand filters, 3 use ultra-violet light, 1 uses dye, and 30 use chemical disinfectants such as chlorine or bromine. Thirty-two reported using other methods including: copper ion, mesh/sediment filters/screens, phosphoric acid, oxygen, and hydrogen peroxide. Forty-five respondents reported an average yearly cost of $2,415 for the purchase of chlorine and other disinfectants, with a standard deviation of $5,547, and a maximum value of $30,000. Thirty respondents reported an average yearly cost of $1,696 for labor for water treatment, with a standard deviation of $2,828, and a maximum value of $10,000. Thirty-two respondents reported an average yearly cost of $1,315 for water treatment equipment, with a standard deviation of $2,547, and a maximum value of $10,000. Seventeen respondents reported an average yearly treatment cost for "other" expenses of $4,576, with a standard deviation of $16,876, and a maximum value of $70,000.

Seventy nine percent of operations reported using fungicides to control for disease within their operation, and 63% respondents reported the yearly cost for fungicides. The average yearly cost for fungicide is $2,360 with a standard deviation of $7,729, and a maximum value of $75,000. Only 43% of respondents reported their yearly cost for labor to apply fungicides, the average cost being $1,680, with a standard deviation of $3,551, and a maximum value of $20,000.

When asked about water runoff treatment methods used before water is collected for on-site use, 245 operations reported that they utilized critical area stabilization, 248 use erosion control blankets and netting, 198 use grass waterways or rip-rap, 223 use sediment basins, 249 use constructed wetlands, and 194 use vegetative zones/buffer strips/groundcover.

Water Capture and Recycling

Operations that collect and/or recycle water from production areas are set up to drain water to storage areas, such as tanks or holding ponds. The majority of operations (63%) are not currently set up to drain water from production areas to a pond or other storage area. However, 7% of operations currently drain 1-25% of water from production areas to a storage area, 4% drain 26-50%, 7% drain 51-75%, and 17% drain 76-100% of their water from their production areas to a storage area.

Over half (55%) of respondents reported that they do not capture any of their irrigation runoff, and 16% of respondents reported that they capture some but not all of their irrigation runoff. Only 9% of respondents (22 operations) reported capturing all of their irrigation water runoff, and 5% (14 operations) of respondents operations' have the ability to capture all irrigation water runoff and additional water runoff from a 2-3" storm. The 224 (86%) of 260 respondents who do not already collect 100% of their water runoff were asked if four reasons for not capturing water runoff applied to their operation: high cost, increased disease risk, limited land available, and physical layout of operation not suitable for runoff capture (See Table 18 below). The most popular reason for not capturing water runoff was physical layout of operation is not suitable for capturing water runoff affecting 48% of operations (strongly agree and agree).

Table 18. Horticultural Operation Reasons for Not Capturing Water Runoff on Site

Percentages (%)	High cost	Increased disease risk	Land availability	Physical layout
Strongly agree	11	10	17	36
Agree	10	12	9	12
Disagree	4	6	6	4
Strongly disagree	6	5	7	2
No opinion	18	17	13	9
No Response	51	50	48	37
Total	100	100	100	100

Interestingly, 18 respondents wrote that they do not capture water runoff because they have minimal to no water runoff in their operations. Some respondents gave various reasons for not having any water runoff on their operations, including: drainage floors in production areas, flat land, drip irrigation systems that water only as necessary, grass/wetlands that collect the water runoff, minimal watering, and small size production operations.

Of the 36 operations (14%) of 260 operations capturing all of their irrigation water runoff, 19 respondents recycled only a portion of the captured runoff water for later use. Of the 17 respondents who capture irrigation water runoff but don't recycle, reasons stated for not recycling include that land is limited (1 respondent), and physical layout of operation is not suited for recycling (5 respondents). A recommendation for *Pythium* and *Phytophthora* control as discussed previously is to prolong water residence time in storage prior to reuse. A few of the recycling operations have used techniques to increase the residence time, one respondent has adjusted pond location, two have adjusted runoff entrance to a pond relative to the pump inlet, two have adjust the size of the pond, two have altered the number of ponds, and one has altered the conveyance system from pond to production area.

Of the 19 recycling operations, three operations get 1-20% of their total irrigation water from their collection ponds, one operation gets 41-60%, three get 61-80%, six get 81-99%, and six get 100% of their irrigation water from their collection ponds. It is possible that most operations that recycle their irrigation water get the majority of their water from ponds on their operations. These six operations that already recycle 100% of their irrigation water were directed to skip over the choice experiment questions because they are already implementing recycling within their operation.

Summary Statistics for Choice Experiment Sample

The analyses of the choice experiment questions require three question to be completed: the choice experiment questions, total production costs, and total nursery costs.[22] One hundred and sixty-three respondents were removed from the sample because they did not answer at least one of these questions. Six of the respondents were directed to skip the choice experiment section because they indicated that they already practice 100% water recycling. The final sample for choice experiment analysis resulted in 91 usable respondents, or 546 observations. See

[22] Total production costs and nursery costs were both needed to ensure a realistic ratio between the two, i.e. nursery cost production should not exceed the total production costs.

response rates for both parts of this study, the demographic and firm characteristics report, and the choice experiment analysis displayed in Table 19 below.

Table 19. Sample Sizes for Demographic and Firm Statistics and Choice Experiment

Sample Type	Number of Valid Survey Responses
Demographic and Firm Statistic Analysis	260
Choice Experiment Analysis	91

Five hundred and forty six observations are created by the stacked data set that is required for conditional logit analysis, each respondent has 6 observations, one for each of the possible choices for each choice of the two choice questions: (1) condition A, (2) condition B, or (3) neither. The following statistics were calculated from the stacked data file with the final sample of 540 observations.

If water capture were required by regulatory authorities, the respondents who are directed to answer the choice experiment questions would need to implement changes to their operations to be able to comply with regulations. Table 20 on the following page shows how many operations would have to make the listed changes to comply with regulations.

Table 20. Changes Required for Operation to Capture All Irrigation Water and Water Runoff

Change	Frequency	Percentage (%)
Acquire adjacent land for constructing storage pond(s)	18	20
Reduce size of production area(s)	34	38
Construct new ponds from existing production area(s) to create a buffer	65	72
Resize existing pond(s)	14	16
Modify existing greenhouses/production areas to facilitate drainage to storage pond(s)	67	74
Change irrigation practices	51	57
Operation already meets requirements	36	40
Other	59	66

Notably, 25 of the 59 respondents who chose the "other" category for changes needed to comply with such regulations said that they would be forced to shut down production.

Almost half of respondents reported that their operation's gross annual revenue was \$100,000 or less. Only 15% of respondents (12 respondents) reported that their operation sold over one million dollars last year. See Table 21 on the following page for the breakdown of the respondent's gross annual revenue for only the 91 respondents included in this choice experiment analysis.

Table 21. Horticultural Producers' Gross Annual Revenue for 2012

Gross revenue (Dollars)	Frequency	Percentage (%)
Less than 25,000	20	22
25,001 to 100,000	21	23
100,001 to 250,000	12	13
250,001 to 500,000	11	12
500,001 to 750,000	9	10
750,001 to 1,000,000	3	3
1,000,001 to 2,000,0000	2	2
2,000,001 to 4,000,000	6	7
4,000,001 to 6,000,000	1	1
$6,000,001 to $8,000,000	2	2
Greater than $10,000,000	1	1
No response	3	3
Total	91	100

The survey responses included operations with total production costs ranging from $300 to $7,849,726. The mean, median, and standard deviation of total production costs were $420,054, $52,000, and $1,085,846, respectively. There is a $10 million difference between the largest and smallest operations. Significantly, there is a $368,000 difference between the mean and median total production costs. Table 22 on the following page shows the total production costs as reported by percentiles.

Table 22. Total Production Costs for 2012

Production cost range ($)	Frequency	Percentiles (%)
300 - 2,500	9	10
2,400 - 5,500	9	20
5,800 – 11,000	9	30
13,000 - 25,000	9	40
26,000 - 44,000	9	50
20,000 - 50,000	9	60
75,000 - 150,000	8	70
150,600 – 320,000	10	80
400,000 – 930,399	9	90
1,292,000 – 7,849,726	10	100
Total	91	100

The sample included a range of 7 million dollars in total nursery costs as seen below in Table 22. The distribution was flat, as the operations were spread relatively evenly. The survey responses included operations with nursery costs ranging from $100 to $7,215,899. The mean, median, and standard deviation of nursery production costs were $366,510, $20,000 and $1,006,727, respectively. Table 23 shows the nursery production costs as reported by percentiles.

Table 23. Total Annual Nursery Production Costs

Nursery Cost Range ($)	**Frequency**	**Percentiles (%)**
100 - 1,500	9	10
1,800 - 2,400	9	20
2,500 - 4,300	7	30
5,000 - 11,000	11	40
12,000 - 19,000	9	50
20,000 - 50,000	9	60
52,001 - 92,000	9	70
99,001 – 200,000	9	80
255,000 - 809,000	9	90
930,399 - 7,215,899	10	100
Total	91	100

The skewed distribution of respondents is indicated in water use as well as production costs and revenues. Slightly more than three-fourths of respondents use less than 100,000 gallons of irrigation water on a typical summer day, but a few use much larger quantities, such as the more than 1 million gallons reported by eight nurseries. Two-thirds of respondents stated that they wouldn't choose to adopt in the choice experiment scenario, regardless of the attribute levels. Thirty-three percent of respondents would choose to adopt. In this sample, neither the size nor the production costs of the operation affected whether or not the respondent said they would chose to adopt. The operations that reported they would recycle were of varying operations sizes and total cost ranges, spread out across the sample distribution.

Conditional Logit Model Results

Two sets of conditional logit models were created to consider the cost willingness variable in two forms. The first set of conditional logit models included a cost variable, "cost," which is the size of each firm's individual cost increase for adopting water recycling technologies. Cost is the operation's total nursery cost multiplied by the percentage cost increase the respondent is faced with in the choice experiment question. This "cost" variable would be used to calculate the respondent's implicit price for WRT (Equation 11). The second set of conditional logit models includes a cost variable, "percentcost," which is the percentage cost increase each respondent faced directly from the choice experiment questions. Both sets of models analyze the effect of the magnitude of the attributes (percentage cost increase, disease outbreak probability, and water shortage probability), on the firm's choice to invest in water recycling technology if required to contain all water runoff.

Two models were estimated (Models 1.1 and 1.2). Model 1.2 is a nested version of model 1.1. A nested model was estimated to determine whether the various levels of water and disease that were originally specified as binary variables would be better specified as single collapsed binary variables. The collapsed binary variables would indicate any increase in water shortage probability or any increase in disease detection probability. The model could be better specified as a nested model if the different levels of disease and water had similar magnitudes of effects on the probability of adoption. The nested models were created to test the hypotheses using likelihood ratio tests that the original models could be rejected as fitting significantly better than the smaller, simpler models with fewer variables. The variables "water3" and "disease1" are the baseline values for the attributes and are omitted from the model. Table 24 below shows estimated coefficients for Models 1.1 and 1.2.[23]

Table 24. Estimated Conditional Logit Models with Cost Increase Variable (Models 1.1 and 1.2)

	Model 1.1		**Model 1.2**	
Variable	**Coefficient**	**SD**	**Coefficient**	**SD**
Cost	-2.10e-06	1.66e-06	-2.42e-06	1.63e-06
Water1	-1.216**	0.584	-	-
Water2	-0.891	0.664	-	-
Water4	-0.526	0.351	-	-
Water5	-0.287	0.346	-	-
Disease2	-1.815***	0.463	-	-
Disease3	-1.736***	0.540	-	.
Disease4	-0.890*	0.490		
Disease5	-0.502	0.509	-	-
Disease6	0.273	0.648	-	-
Diseasedum	-	-	-1.353***	1.880
Watermore	-	-	-0.379*	0.214
Log likelihood	-147.124		-153.982	

Notes: SD = Standard deviation, * = p <0.10 level, **= p <0.05 level, *** p <0.01 level

[23] See Appendix I for all conditional logit model STATA codes.

The coefficient signs and magnitudes for "cost" were insignificant and did not make economic sense due to their small size. Because the variable "cost" was not significant, likelihood ratio tests were not performed and therefore implicit prices could not be calculated. With the second set of models, we used the percentage cost increase as indicated in the survey as the explanatory variable.[24] During preliminary modeling, robustness analysis was conducted by omitting 5 and then 10% of the lowest cost operations, highest cost operations, or both. The variations in firms included had minimal effects on the results, so the sample was unchanged from the original 91 respondents. Table 25 below shows estimated coefficients for Models 2.1 and 2.2.

Table 25. Estimated Conditional Logit Models with Percent Cost Increase Variable (Models 2.1 and 2.2)

	Model 2.1		Model 2.2	
Variable	**Coefficient**	**SD**	**Coefficient**	**SD**
Percentcost	-12.983***	3.282	-9.787***	1.964
Water1	-1.383	0.928	-	-
Water2	-1.062	0.868	-	-
Water4	-0.871	0.549	-	-
Water5	-0.754	0.490		
Disease2	-1.223**	0.549	-	-
Disease3	-1.119**	0.593	-	
Disease4	-1.249*	0.551	-	
Disease5	-1.098*	0.576	-	
Disease6	-1.134	0.761	-	-
Diseasedum	-	-	-0.649**	0.232
Watermore	-	-	-0.177	0.245
Log likelihood	-137.035		-153.982	

Notes: SD = Standard deviation, * = p <0.10 level, **= p <0.05 level, *** p <0.01 level

[24] Models 2.1 and 2.2 are specified the same as 1.1 and 1.2 except for the cost variables: percent cost increase for Models 2.1/2.2, and the specific nursery percent cost increase (percent cost increase multiplied by nursery cost) for Models 1.1/1.2.

For both Models 2.1 and 2.2 as seen in Table 24, the cost variable is negative and significant, supporting the hypothesis that as percent cost increases, the respondents are less likely to choose to adopt. The coefficients for the water binary variables below the baseline level for Model 2.1, "water1" and "water2," were both negative, which is consistent with our hypothesis of a direct relationship between water scarcity and willingness to adopt WRT. The negative coefficients for "water4" and "water5" are unexpected because this would indicate that when probabilities of water scarcity increase above the baseline, water recycling technology adoption would decrease. Since "water4" and "water5" were not significant, they were collapsed into a single binary variable, "watermore," to analyze any increase in any water shortage probability. However, "watermore" was still not significant when added to Model 2.2 in place of the binary variables.

The coefficients for "disease2" to "disease5" were significant and negative in both Models 2.1 and 2.2 as consistent with the hypothesis that when the probability of disease outbreak increases from the baseline, respondents are less likely to adopt. "Disease6" was not significant but it did have a negative sign. Because the binary variables for the levels of the disease were approximately the same given the small size (-1.223, -1.119, -1.249, -1.098, and -1.134), respondents are not responsive to the individual levels of disease probability detection. Since respondents are not responsive to the different levels of disease probability detection, binary variables were collapsed into a single binary variable, "diseasedum," which indicates whether or not any increase in disease probability detection occurred.

A likelihood ratio test was performed to compare Model 2.2 to Model 2.1 in order to determine whether the original models fit significantly better than the nested model. The likelihood ratio test between Models 2.2 and 2.1 tests the null hypothesis restrictions that the binary variables “disease2” through “disease6” are collapsed into one binary variable, that “water1,” “water2” are equal to zero, and that “water4” and “water5” are collapsed into one binary variable “watermore” (Model 2.2). The result of the likelihood ratio test is seen below in Table 25. Due to the insignificant test statistic, we can assume that the variables that were set equal to zero in the nested Model 2.2 produced no significant difference from the original specification of Model 2.1 in terms of explanatory power. This means we can conclude that Model 2.2 (using percent cost as a continuous variable, water shortage and disease as binary variables) is the best fit.

Table 26. Likelihood Ratio Tests for Condition Logit Models 2.1 and 2.2

Models	Probability > Chi^2	Degrees of Freedom	Conclusion
Model 2.2 and 2.1	0.529	7	Fail to reject null

Notes: Chi^2 is significant at the 10% level. Fail to reject null (that the non-nested model has more explanatory power), means that the nested model (2.2) is as statistically significant as the non-nested/original model (2.1). Degrees of freedom is the difference of the number of variables in the two models [10 (in Model 2.1) – 3 (in Model 2.2) = 7].

Discussion

We can justify Model 2.2 as the best model due to the rejection of the null hypotheses as a result of the likelihood ratio test. The findings support the hypothesis that producers will be less likely to adopt selected WRT when cost is higher (negative and significant) and probability of disease decreases (negative and significant). However, adoption is negatively affected by increased probability of water shortages (negative but insignificant) which is counter to our hypothesis.

It was not possible to successfully model the continuous scaled nursery production cost variable. Possibly the problems with this variable can be attributed to scaling problems due to a flat distribution. As seen in Table 22, there is more than a $7 million difference between the production costs of the smallest versus the largest firm (the median total production cost is $52,000 compared to the mean of $420,054, and the median total nursery costs is $20,000 compared to a mean value of $365,085).

The signs of the coefficients were as expected for both Models, 2.1 and 2.2, as seen in Table 24, except for the coefficients for two binary variables for increased probability of water shortage in Model 2.1. Water variables were insignificant in all models. The results for the effects of water shortage on the likelihood of recycling adoption are inconclusive. The result may be associated with the current source of irrigation water. Relatively few of the respondents had ever experienced a previous water shortage. Of all of the respondents, 180 operations (69%) have never experienced a water shortage, although 22 respondents (8%) had experienced a water shortage three or more times previously. The majority of respondents get irrigation water from a well (184 of 260), and the proportion of their total irrigation water coming from a well is also very high (71%). Possibly respondents with well water have fewer concerns with water availability.

A total of 87% respondents considered disease as a very important or somewhat important risk of financial loss. Thirty-seven respondents stated that they experience less than 1% of nursery sales loss annually from plant disease. On the other hand, 27 operations have lost more than 5% revenue from disease annually. Forty percent of operations reported a maximum loss of 5% or more revenue from disease loss in a year, and 10% reported losing 20% or more revenue. This shows that revenue loss from disease is a pressing issue for operations, as losing around 20% of revenue from disease would have a significantly detrimental effect on an operation's productivity.

Because the magnitudes of the coefficients for the probability of increased levels of disease detection ("disease2" through "disease6" in Model 2.1 have a similar impact (-1.223, -1.119, -1.249, -1.098, and -1.134 respectively), the increased level of disease detection appears not to matter to respondents. The collapsed binary variable ("diseasedum") for all levels of increased disease detection as seen in Models 2.2 was created for this reason. We can conclude that the specific level of probability of disease detection does not matter to respondents - they want to avoid disease altogether. Operation size scaling problems could also impact the disease variables as larger operations have more costs involved in managing disease. For example, 10 operations spend more than $10,000 each on fungicides annually, while half of the nurseries reported here spend less than $250.

We can attribute the problems with the cost to a flat distribution, i.e. respondents distributed over a wide range of nursery production costs with relatively few observations for each cost interval. It is possible that the coefficients for water have unexpected signs due to variation in our small sample. The large nursery operations could be overshadowing the effects of the smaller operations. The nested Model 2.2 is possibly not significantly different from Model 2.1 for the same reason, the large operations are overshadowing all relationships so even as variables are taken out, the coefficients' signs for all attributes remain the same. Additionally, only 33% of operations chose to adopt when presented with the choice experiment questions. This, in turn, makes estimation even more difficult with a sample size of 91 usable surveys for the choice experiment analysis.

The demographic and firm characteristics survey results provide valuable insight into irrigation and disease management practices for nursery operations in the Mid-Atlantic region. Although the survey did not uncover a significant relationship for the cost variable, the “percentcost” variable was significant and showed that cost is the biggest influence on their choice, as supported by the large negative coefficient on the “percentcost” variable. We conclude that at this time, cost of installing recycling technology poses a significant barrier to adoption for most horticultural producers. The majority of producers are not equipped to handle water recycling or capture in the immediate future, and costs for installing such technology would pose significant burdens and possibly threaten their ability to stay in business. The fear of increased disease outbreak, as supported by the significant negative coefficient on disease, supports that disease is another important barrier to adoption for many growers. Education and assistance from the government might be needed to overcome this barrier. Unless environmental regulations are in place that force horticultural producers to contain all of their runoff or cost saving programs are implemented, wide spread adoption of water recycling technologies is unlikely to occur in the Mid-Atlantic region. Results from this study will inform research programs as to types of innovations needed to enhance adoption of WRT, and will be useful for future policy discussions of potential water and surface runoff restrictions or regulations affecting the green industry.

CHAPTER V: CONCLUSIONS

Summary

Horticultural producers face difficult management choices due to water shortages, disease outbreaks, costly technologies, and nutrient management challenges. Water recycling is a potential option to conserve water, but is costly and comes with potential for increased risk of disease outbreak. A choice experiment survey was administered to horticultural producers in the Mid-Atlantic region, specifically, Virginia, Maryland, and Pennsylvania. A choice model approach was employed to estimate horticultural producers' willingness to adopt water-recycling technologies. The survey was developed through expert advice (academic and industry), site visits (Virginia (4), Maryland (4), Pennsylvania (2)) and a focus group with producers and extension agents outside of the sample area (Guilford County, NC) in order to provide data for an econometric analysis. Potential barriers to adoption of WRT for horticultural growers were analyzed with the goal of informing researchers, regulators, policymakers, and industry stakeholders on growers' willingness to adopt WRT. If producers are required to recapture water, their decision to recycle may be influenced by three main factors: 1) probability of water shortage, 2) probability of disease, and 3) cost of installation and maintenance of water recycling technologies (WRT). More information is needed about producers' irrigation and disease management practices and their attitudes toward containment and recycling of irrigation water runoff.

A total of 1,770 surveys were administered and 436 surveys were returned for a response rate of 25%. Seven-seven of the surveys returned were from Virginia (18%), 64 surveys from Maryland (15%), and 292 surveys from Pennsylvania 67%). Two hundred and sixty of these operations fit the criteria for this study as irrigated operations and completed and returned the survey. Of the completed surveys 63 surveys were from Virginia (24%), 38 from Maryland (15%), and 157 from Pennsylvania (61%).[25] However, only 91 respondents filled out the three questions necessary (choice experiment, total production cost, nursery production cost) for the choice experiment analysis.

A conditional logit model was run using STATA to quantify the impact of the levels of the attributes cost increase, water shortage probability, and disease outbreak probability on the respondents' choice whether or not to implement water recycling if water capture is hypothetically mandated by regulatory authorities. The demographic and firm characteristics survey results provide valuable insight into irrigation and disease management practices for nursery operations in the Mid-Atlantic region. The findings of the choice experiment support the hypothesis that producers will be less likely to adopt selected WRT when cost increases (negative and significant) and probability of disease increases (negative and significant). However adoption is not significantly related to the probability of water shortage (negative but insignificant). It is possible that the coefficients for water are insignificant due to small sample size and the large variation in cost among respondents and the fact that most respondents had not experienced water shortages in the past. The majority of producers are not equipped to handle water recycling or capture in the immediate future because they would have to spend significant amounts of money or go out of business. Cost is the biggest influence on their choice, as supported by the large negative coefficient on the "percentcost" variable. Even in the hypothetical choice experiment, only 33% would choose to adopt. The fear of increased disease outbreak, as supported by the significant negative coefficient on disease, supports that disease is another reason inhibiting growers from adopting. Education and financial assistance from the

[25] State totals for irrigating operations only sum to 258 because two surveys had their tracking numbers damaged in the mail.

outside or public sources might be needed for change to occur. Unless mandatory environmental regulations are in place that will force horticultural producers to contain all of their runoff or cost saving programs are implemented, wide spread adoption of water recycling technologies is unlikely to occur in the Mid-Atlantic region. Results from this study will inform research programs as to types of innovations needed to enhance adoption of WRT, and will be useful for future policy discussions of potential water and surface runoff restrictions or regulations affecting the green industry.

Limitations

The most important limitation of this study is the small number of usable responses for the choice experiment analysis. The returned sample of 260 respondents was promising, but only 91 respondents filled out the three key questions needed for analysis: choice experiment questions, production costs, and nursery costs. In addition, only one third of the respondents who answered the choice experiment questions chose to adopt. Future studies could utilize other survey methods such as phone or online interviews to obtain a better response rate for the choice experiment questions.

Another limitation was the timeframe during which the survey was administered. The survey screening calls and distribution occurred at the end of the off-season. The off-season time frame was chosen because producers might not be as busy. As such, screening calls were made during January of 2013 and 1,020 of the numbers went to answering machines that indicated that the operation would be closed until March. Therefore we were unable to screen those respondents to see if they fit the criteria or would respond to the survey. Although surveys were sent to operations that could not be reached by telephone, response rates might have improved had we been able to reach them first by telephone.

Finally, due to the small survey sample response, we were unable to analyze the differences in producer preferences by individual states. If future studies are able to obtain a better response rate, possibly by including other types of operations besides nurseries, differences in production and preferences might be analyzed by state. From the site visits, we found that there are differences among states in production management practices, such as irrigation methods and water sources. These practices vary due to their geographical location and climate.

Future Studies and Implications

There are several recommendations for future studies on the subject. First, future research should focus on obtaining enough respondents of varying sizes. Results of the current research indicate that nursery operations are too diverse in terms of operating costs and size to be grouped together for analysis. A larger sample size would also allow for a state-by-state analysis.

Second, future studies could also use a multinomial logit or conditional logit with interaction terms to include demographic characteristics in the analysis. Conditional logit models can utilize interaction terms to include the case specific demographic variables to the model so they don't drop out due to no within case variation. By adding interaction terms to the conditional logit model, it is possible to see how demographic variables such as education and income affect the decision to adopt WRT by interacting demographic variables with the choice-specific attributes. Interaction terms can detect preference variation due to individual characteristics. The 169 respondent surveys not used in the choice experiment analysis because they did not answer key questions might provide additional insight into producer operations.

Third, future surveys could also be improved. For example, one area for improvement is clarification of the choice experiment scenario. It is possible that the hypothetical nature of the choice experiment question confused some respondents. Here, increased emphasis could be placed on the choice experiment scenario to include more details in order to make it more realistic to respondents. Adding more attributes could be beneficial to split up the answers. In addition, future surveys could also be administered in the western United States where water shortage and water scarcity problems are more prevalent and stricter regulations restricting water use are already in place. Preferences between growers in the Eastern and Western United States and their operation characteristics could be compared.

Finally, in addition to the fixed cost of water recycling technologies, it would be useful to estimate the annualized cost of water recycling systems and water treatment equipment. The estimation of transaction costs (such as time, capital, and labor) could also be beneficial in determining a comprehensive estimate for potential adopters.

There are several beneficial implications for the results of this study. First, regulators and policymakers will be able to use the results of this study to understand and be aware of the impact of future regulations on producers given the current state of the industry. In addition, state agricultural and environmental agencies can target educational programs for industry segments where they can have the greatest impact. This study will also be useful for future policy discussions of potential water and surface runoff restrictions or regulations affecting the green industry.

Secondly, this study will also serve to inform new research programs. This will include research on types of innovations needed to enhance adoption of WRT such as improved recycling systems with better disease control, as well as education and extension resources to safely and correctly implement these technologies. The contributions from additional research and new technologies currently in progress from other researchers on this grant project will expand industry knowledge and options for adoption. As shown in this study, producers can benefit from future education efforts as they are unaware of all the technologies and the costs to adopt WRT, as well as potential benefits and savings possible from its adoption. An important continuation of this study will be the extension effort that combines the result of this work with Hartter et al. (2012), which determined the price premium that horticultural consumers are willing to pay for certified disease-free or water conservation plants. The combination of the above studies will be able to shed additional light on the nexus of public and consumer demand for water conservation, disease-free ornamental plants and producers' willingness to adopt WRT.

Finally, the information presented in this study will help horticultural producers move toward more environmentally friendly irrigation practices. This in turn will assist in promoting a more sustainable and economically viable horticultural industry.

REFERENCES

Adamowicz, W., P. Boxall, M. Williams, and J. Louviere. "Stated preference approaches for measuring passive use values: Choice experiments and contingent valuation." *American journal of agricultural economics*. Vol. 80. No. 1. (February 1998): 64-75.

Aigner, Dennis, C. A. L. Lovell, and Peter Schmidt. "Formulation and estimation of stochastic frontier production function models." *Journal of econometrics* 6, no. 1 (1977): 21-37.

Barreiro-Hurle, J., M. Espinosa-Goded, and P.Dupraz. "Does intensity of change matter? Factors affecting adoption in two agri-environmental schemes." Presented at 107th EAAE Seminar, Seville, Spain, 29 Jan. to 1 Feb. 2008. 12 June 2008. Retrieved from http://purl.umn.edu/6458

Baynard, B. and C.M. Jolly. "Environmental perceptions and behavioral change in hillside farmers: The case of haiti." *J. Caribbean Agro-Econ*. Soc. 7:122–138. (2007)

Burton, M., Rigby, D., & Young, T. "Analysis of the determinants of adoption of organic horticultural techniques in the UK." *Journal of agricultural economics*, *50*(1), 47-63. (1999).

Carmeron, C.A., Triveda, P.K. *Microeconomics using stata revised edition.* Statacorp LP College Station, Texas. 2010.

Champ, P. A., K. J. Boyle, and T. C. Brown. *A primer on nonmarket valuation*. Kluwer Academic Publishers, Dordrecht, The Netherlands. (2003).

Collins, A.T., Rose, J.M., Bliemer, M.C.J. "Ngene - the cutting edge in experimental design for stated choice experiments." The University of Sydney, Australia: Institute of Transport and Logistics Studies. (2007).

Dennis, J. H., Lopez, R. G., Behe, B. K., Hall, C. R., Yue, C., & Campbell, B. L. "Sustainable production practices adopted by greenhouse and nursery plant growers." *HortScience*, *45*(8), 1232-1237. (2010).

Dillman, D.A., Smyth,, J.D., Christian, M.L. *Internet, mail, and mixed-mode surveys: the tailored design method.* Hoboken, NJ: Wiley. (2008).

Hall, T. J., Dennis, J. H., Lopez, R. G., & Marshall, M. I. "Factors affecting growers' willingness to adopt sustainable floriculture practices." *HortScience*, *44*(5), 1346-1351. (2009).

Hartter, David L. "Understanding consumers' ornamental plant preferences for disease-free and water conservation labels." Master's Thesis, Virginia Polytechnic Institute and State University. (2012).

Hong, C. X., Bush, E. A., Richardson, P. A., & Stromberg, E. L. "The major deterrent to recycling irrigation water in nursery and greenhouse operations despite the lack of alternatives for limiting nonpoint source pollution" Paper presented at the Virginia Water Symposium, Charlottesville, VA. (2001).

Hong, C. X. "Irrigation Pathogens and Water Quality." Project Website. http://www.irrigation-pathogens.ppws.vt.edu/index.php (accessed July 1, 2012). (2010).

Hong, C. X., and Moorman, G. W. (2005). "Plant pathogens in irrigation water: Challenges and opportunities." *Critical Reviews in Plant Sciences*, 24(3), 189-208.

Jordan, J.L. "Farmer's choice of using sustainable agricultural practices: A social capital approach." Presented at the Southern Agricultural Economics Association Annual Mtg. Little Rock, AR, 6–8 Feb. 2005. Retrieved from http://purl.umn.edu/35505

Lancaster, K. J. "A new approach to consumer theory." *The Journal of political economy*, 74(2), 132. (1966).

Lentz, W. "Model applications in horticulture: A review." *Scientia horticulturae*, *74*(1), 151-174. (1998).

Louviere, J.L., D.A. Hensher, J.D. Swait. *Stated Choice Methods: Analysis and Applications* Cambridge University Press. (2000)

Louviere, J.L., T.N. Flynn, R.T. Carson. "Discrete choice experiments are not conjoint analysis" *Journal of Choice Modeling*, 3(3), pp 57-72. (2010)

Marra, M., Pannell, D. J., & Abadi Ghadim, A. "The economics of risk, uncertainty and learning in the adoption of new agricultural technologies: Where are we on the learning curve?" *Agricultural systems*, *75*(2), 215-234. (2003).

McFadden, D. "Conditional logit analysis of qualitative choice behavior." In P. Zarembka (Ed.), *Frontiers in Econometrics* (Vol. 1, pp. 105-142). (1974). Academic Press. Retrieved from http://elsa.berkeley.edu/pub/reprints/mcfadden/zarembka.pdf

Mid-Atlantic United States Environmental Protection Agency. "Frequently Asked Questions about the Bay TMDL." Washington, 2012. Retrieved from http://www.epa.gov/reg3wapd/tmdl/ChesapeakeBay/FrequentlyAskedQuestions.html

Moorman, G. *"Phytophthora Root Rot, Stem Rot and Cankers on Ornamentals" Plant Disease Fact Sheets.* Penn State Extension. The Pennsylvania State University. (2010a). Retrieved from http://extension.psu.edu/plant-disease-factsheets/all-fact-sheets/pythium

Moorman, G. "*Pythium*" *Plant Disease Fact Sheets*. Penn State Extension. (2010b). Retrieved from http://extension.psu.edu/plant-disease-factsheets/all-fact-sheets/pythium

Nzomoi, J. N., Byaruhanga, J. K., Maritim, H. K., & Omboto, P. I. "Determinants of technology adoption in the production of horticultural export produce in Kenya." *African Journal of business management*, *1*(5), 129-135. (2007).

Pimentel, David, et al. "Water resources: agriculture, the environment, and society." *BioScience*. *47*(2) 97-106. (1997)

Pimentel, D., Berger, B., Filiberto, D., Newton, M., Wolfe, B., Karabinakis, E., & Nandagopal, S. "Water resources: Agricultural and environmental Issues. *BioScience, 54*(10), 909-918. (2004).

Robbins, J.A. Irrigation water for greenhouses and nurseries. University of Arkansas: Division of Agriculture. Arksansas Cooperative Extension Service. FSA6061. (2010). Retrieved from http://www.uaex.edu/Other_Areas/publications/PDF/FSA-6061.pdf

Toze, S. "Reuse of effluent water - benefits and risks." *Agricultural water management*, *80*(1), 147-159. (2006).
Train, K. *Discrete choice methods with simulation*. Cambridge: Cambridge University Press. (2003).
Tsagarakis, K. P., & Georgantzis, N. "The role of information on farmers' willingness to use recycled water for irrigation. *Water science & technology: Water supply*, *3*(4), 105-113. (2003).
United States Environmental Protection Agency. Chesapeake Bay Total Maximum Daily Load (TMDL) Fact Sheet. Washington, 2010. Retrieved from http://www.epa.gov/reg3wapd/pdf/pdf_chesbay/BayTMDLFactSheet8_6.pdf
United States Environmetal Protection Agency. "Agriculture Polluted Runoff - US EPA." US EPA Water Home. http://water.epa.gov/polwaste/nps/agriculture.cfm#fact (accessed April 11, 2013).
United States Environmental Protection Agency. "US EPA Final Bay TMDL Executive Summary." Chesapeake Bay TMDL . http://www.epa.gov/reg3wapd/tmdl/ChesapeakeBay/tmdlexec.html (accessed April 12, 2013).
United States Department of Agriculture. National Agricultural Statistics Service. *Census of Horticultural Specialties*. Washington, 2010. Retrieved from http://www.agcensus.usda.gov/Publications/2007/Online_Highlights/Census_of_Horticuture_Specialties/HORTIC.pdf
United States Department of Agriculture. *Census of Agriculture.* Washington DC, 2007. Retrieved from http://www.agcensus.usda.gov/Publications/2007/Full_Report/Volume_1,_Chapter_2_US_State_Level/usv1.pdf
United States Department of Agriculture. *Farm and Ranch Irrigation Survey*. Washington DC, 2008. Retrieved from *http://www.agcensus.usda.gov/Publications/2007/Online_Highlights/Farm_and_Ranch_Irrigation_Survey/fris08.pdf*
Virginia Department of Conservation and Recreation. "Bay TMDL Phase II WIP FAQ.". http://www.dcr.virginia.gov/vabaytmdl/baytmdlvap2faq.shtml (accessed April 8, 2013).
Wilson, S. K., & von Broembsen, S. (n.d.) *Water Quality Series: Capturing and recycling irrigation runoff as a pollution prevention measure.* Oklahoma University: Division of Agricului Sciences and Natural Resources. Oklahoma Cooperative Extension Service. BAE-1518. Retrieved from http://osufacts.okstate.edu/docushare/dsweb/Get/Document-7408/BAE-1518web.pdf.

APPENDICIES

Appendix A: Site Visit Key Findings

A survey "Managing Water-borne Diseases in Horticultural Operations" was created to characterize current horticultural water and disease management practices. The purposes of the survey are to learn about horticultural growers' experiences with water-borne diseases, including control costs and management options, plus learn about their water recycling systems and activities. In order to gain insight into Horticultural producers' management, site visits are conducted where the survey is administered along with a tour of the facility. The goal of the survey and the in-depth site visits is to be able to better understand water and disease management practices the different operations that we visit. As of August 31, 2012 personal interview surveys have been conducted with four growers in Virginia, four growers in Maryland, and two growers in Pennsylvania.

General Business Characteristics

- Virginia operation types included:
  1) container nursery
  2) greenhouse/container nursery
  3) greenhouse/container/field nursery
  4) greenhouse/container nursery
- Maryland operation types included:
  5) greenhouse/container nursery
  6) greenhouse/container nursery
  7) aquatic greenhouse/container nursery
  8) aquatic greenhouse/container nursery
- Pennsylvania operation types included:
  9) field nursery
  10) container nursery

Disease incidence and cost

- All growers (besides the two strictly aquatic operations) listed disease management as one of their top 3 priorities.
- *Phytophthora* is a disease concern at 4 of the 10 operations.
- Pythium is a disease concern at 3 of the 10 operations.
- Other disease concerns include: Anthracnose, Botrytis, Entomosporium, Downy Mildew, Black spots, Crown rots, Fusarium and Septorium.
- The two aquatic operations do not have significant disease problems and spend very little money on disease control
- The maximum plant loss ever experienced at an operation from a result of disease was an average of 5%, minimum of 2% and max of 10%.

- In a typical year, around 2-5% of plants sales value is lost from disease.
- The most commonly listed crop production risks that are the most important sources of revenue loss in the operations were: disease, overwatering, and insects.
- The majority of operations had very general biosecurity procedures, mostly cleaning materials that come into contact with the crops and checking products that are brought into the operation.

Disease management

- Of the operations that utilized the techniques, the majority of growers said that treating water before applying, adapting water application or time of application, and applying fungicides, are all very useful to control for disease (5 on a 1-5 scale).
- The majority of the growers are unaware that changing the irrigation system to increase residence time could lower disease occurrence. Growers were interested in this idea indicating it is a good area to focus on for future extension work.
- Half of the growers are unable to adapt the types of plants grown and the timing of planting due to their buyers' and customers' demand schedule. If growers were able to adjust plant types grown and schedules, they avoided plants that are easily susceptible to disease.

Water treatment options

- 5 out of the 8 non-aquatic growers used chlorine to treat their water. Both liquid and gas forms of chlorine were used. Other methods of treatment include sand filter, aeration, lake dye, disk filter, silt ponds, copper ionization, and ozone.
- The main advantages to chlorine water treatment are its low cost and effectiveness of disease removal.
- The disadvantages of chlorine usage include safety hazards and phytoxicity in plants.
- The majority of the growers had automatic systems installed to regulate water treatment: high initial costs and low maintenance costs.
- Growers are wary of expensive retrofits needed for other water treatment and irrigation systems.

Irrigation management options

- Virginia irrigation systems included:
  1) overhead sprinkler, drip or micro sprinkler
  2) overhead sprinkler, drip or micro sprinkler
  3) overheard sprinkler, drip or micro sprinkler (spray stakes)
  4) overhead sprinkler
- Maryland irrigation systems included:
  5) overhead booms, drip, ebb and flow (flood)
  6) overhead sprinkler, drip or microsprinkler, ebb and flow
  7) overhead sprinkler, drip or microsprinkler, other: sub-irrigation (aquatic)
  8) other: sub-irrigation (aquatic)
- Pennsylvania operation types included:

9) drip tape, overhead sprinkler, drip or micro sprinkler
10) overhead sprinkler, drip or microspinkler

- Water sources included ponds, wells, and rivers.
- The majority of the growers irrigate continuously (water as needed in the winter).
- The most management intensive component of the irrigation systems for all non-aquatic growers is insuring that all plants were receiving the correct amount of water. Plants are grouped by water need and tolerance.

Fungicides

- All non-aquatic growers use fungicides to treat water-borne plant disease.
- All growers had variable percentage of fungicides used for control of water-borne diseases, ranging from 0%-80%.
- The majority of growers apply fungicides routinely and when disease is evident.
- Growers use Dosatrons or sprayers to apply fungicides, or a mix of both.
- The amount spent per year on fungicides for water-borne diseases ranges from $0-$25,000.

Irrigation water recycling

- All 8 non-aquatic growers capture all or part of their surface runoff.
- 7 of the 10 growers recirculate at least part of their water.
- Main barriers to water capture and recycling include cost, increased risk of disease, and lack of need due to existing abundant water supply.
- Advantages for recirculating water include water conservation and decreased cost from pumping less water.
- None of the operations have adjusted the location of pump inlet or increased size of ponds to increase residence time specifically for disease control

New information

- Three types of growers exist in terms of water runoff management. We need to ensure that the survey is usable regardless of what type of growers receives the survey.
    1. No water recapture or recycling
    2. Recapture water only
    3. Recapture water and recirculate
- Grower knowledge:
    - Growers have not made any changes to increase water residence time, whether through changing inlet location or pond size. Some growers already have "correct" inlet location and pond size.
    - Some growers seem to be unaware that increasing residence time in their collection pond can help control disease.
    - We need to be specific about defining terms such as "disease." Not all producers have in-depth knowledge about horticultural science.

Appendix B: Screening Call Phone Script

Ornamental Nursery Survey of Irrigation Practices and Disease Management
Recruitment 2013

CALL RECORD

Record Number	**Priority**	**Callback Date/Time**
Phone Number	**Interviewer ID**	**Interviewer Message**
FIPS	**Number of Attempts**	**Current Begin Date/Time**
Respondent Number	**Last Contact**	**Current End Date/Time**
Status	**Last Disposition**	

Final Call Disposition

Answering Machine	Complete	Hearing Barrier	Soft Refusal
Automated Refusal Service	Computer/Fax Tone	Incomplete	Temporarily Disconnected
Busy Signal	Disconnected/Changed	Language Barrier	
Callback	Hard Refusal	No Answer	

A. Hello, my name is _________ __________ and I'm calling from Virginia Tech. We are conducting research with ornamental plant growers in order to better understand related policy, plant disease and water quality issues.

Q1. Do you grow ornamental plants?

YES 1
NO [GO TO END 1] 2
DK 3
RF [GO TO END 1] 4

Q2. Do you irrigate the plants?

YES 1
NO [GO TO END 1] 2
DK 3
RF [GO TO END 1] 4

Q3. Are the plants grown in a greenhouse only such that they are never outdoors during any part of the process?

YES [GO TO END 1] 1
NO 2
DK 3
RF 4

Q4. We would like to send you a brief survey in the mail. May I have the name and address for the person we should send the survey to? The person completing the survey should be knowledgeable about financial and production decisions of the business.

YES 1
NO, DOESN'T WANT SURVEY [GO TO END 2] 2
DK/RF [GO TO END 2] 3

Q5. NAME ENTRY
STREET ADDRESS/NUMBER ENTRY
CITY ENTRY
STATE, ZIP ENTRY

END 1. I'm sorry, our research requires that we speak only with growers who irrigate ornamental plants outside or in containers. Thank you for your help with our study. Have a nice day/evening.

END 2. Those are all of my questions. Thank you for your help with our study. Have a nice day/evening.

INTERVIEWER IF ASKED: "This study is being conducted with support from the U.S. Department of Agriculture. If you have any questions about the purpose of the study, you may call the research director Dr. Darrell Bosch at 540-231-5265."

Appendix C: Sample Screening Call Disposition by State

Disposition	**State code**			**Total**
	PA	**MD**	**VA**	
No Answer (After Multiple Attempts)	117	24	27	168
Busy Signal (After Multiple Attempts)	11	6	8	25
Answering Machine (After Multiple Attempts)*	594	151	82	827
Callback (After Multiple Attempts)	25	6	4	35
Disconnected/Changed	230	97	99	426
Hearing Barrier	2	1	0	3
Soft Refusal -- Can Try Again	26	6	11	43
Computer/Fax Tone (After Multiple Attempts)	24	11	4	39
Temporarily Disconnected (After Multiple Attempts)	4	1	2	7
New Primary Number Callback (After Multiple Attempts)	1	0	0	1
Wrong Number	59	16	24	99
Complete (Updated Information for Mail Survey)	213	58	91	362
TOTAL	**1306**	**377**	**352**	**2035**

After a maximum of five phone call attempts were made to reach each operation, respondents were classified into groups from their dispositions. In addition to the respondents who said that their operation was applicable and they were willing to complete the survey, other potential disposition groups are chosen to be sent the survey. In order to maximize response rate, surveys were sent out to all potential respondents except those who had a hard refusal, automatic refusal, did not meet qualifications, were no longer in business, or didn’t want the survey. Screening calls were completed on 2/14/2013. A number of answering messages state operations were closed until March 2013

Appendix D: Ngene Codes

First, a full factorial model was run to initially to check compatibility and look at possible choice sets.

<u>Full Factorial</u>

```
Design
;alts = A, B, C
;rows = 144
;fact
;model:
U(A) = b1 + b2*disease[0.10:0.20:0.02] + b3*water[0.10:0.20:0.02] + b4*cost[0.05:0.20:0.05] /
U(B) =      b2*disease                 + b3*water                 + b4*cost $
```

Second, a multinomial logit model was selected because it does not require coefficient estimates as we do not have price data. Conditional logit models are not available in Ngene.

<u>Multinomial Logit (MNL)</u>

```
Design
;alts = A, B, C
;rows = 24
;eff = (mnl,d)
;alg = swap(stop=total(100000 iterations))
;model:
U(A) = b1[1] + b2[1] * disease[0.10:0.20:0.02] + b3[1] * water[0.10:0.20:0.02] + b4[-1] *
cost[0.05:0.20:0.05] /
U(B) =      b2 * disease                 + b3 * water                 + b4 * cost $
```

This code produced the choice set used in this research

Appendix E: Choice Scenario Sets

Choice 1	Disease	Water	Cost	Choice 11	Disease	Water	Cost
Condition A	18%	15%	5%	Condition A	14%	17%	10%
Condition B	12	15%	20%	Condition B	16%	13%	15%
Choice 2	Disease	Water	Cost	**Choice 12**	Disease	Water	Cost
Condition A	18%	10%	20%	Condition A	12%	20%	10%
Condition B	12%	20%	5%	Condition B	16%	10%	15%
Choice 3	Disease	Water	Cost	**Choice 13**	Disease	Water	Cost
Condition A	16%	17%	5%	Condition A	14%	15%	10%
Condition B	14%	13%	20%	Condition B	14%	15%	15%
Choice 4	Disease	Water	Cost	**Choice 14**	Disease	Water	Cost
Condition A	12%	15%	20%	Condition A	10%	17%	15%
Condition B	18%	17%	5%	Condition B	20%	13%	10%
Choice 5	Disease	Water	Cost	**Choice 15**	Disease	Water	Cost
Condition A	20%	13%	5%	Condition A	16%	10%	20%
Condition B	10%	15%	20%	Condition B	12%	20%	5%
Choice 6	Disease	Water	Cost	**Choice 16**	Disease	Water	Cost
Condition A	12%	20%	10%	Condition A	16%	15%	5%
Condition B	18%	10%	15%	Condition B	12%	15%	20%
Choice 7	Disease	Water	Cost	**Choice 17**	Disease	Water	Cost
Condition A	14%	13%	15%	Condition A	18%	10%	15%
Condition B	14%	17%	10%	Condition B	10%	20%	10%
Choice 8	Disease	Water	Cost	**Choice 18**	Disease	Water	Cost
Condition A	12%	13%	20%	Condition A	10%	20%	10%
Condition B	16%	17%	5%	Condition B	18%	10%	15%
Choice 9	Disease	Water	Cost	**Choice 19**	Disease	Water	Cost
Condition A	20%	10%	15%	Condition A	20%	13%	5%
Condition B	10%	20%	10%	Condition B	10%	17%	20%
Choice 10	Disease	Water	Cost	**Choice 20**	Disease	Water	Cost
Condition A	10%	20%	15%	Condition A	10%	17%	20%
Condition B	20%	10%	10%	Condition B	20%	13%	5%

Disease = Probability of annual disease detection (Current industry probability is 10%)
Water = Probability of annual water shortage (Current industry probability without recycling is 15%)
Cost = Percent increase in nursery production costs for installing and operating recycling

Appendix F. Survey Version Distribution

Survey Version	State code			Total
	PA	MD	VA	
01 (Choice sets 1 &11)[26]	131	38	35	204
02 (Choice sets 2 &12)	131	38	35	204
03 (Choice sets 3 &13)	131	38	35	204
04 (Choice sets 4 &14)	131	37	36	204
05 (Choice sets 5 &15)	131	37	36	204
06 (Choice sets 6 &16)	131	37	35	203
07 (Choice sets 7 &17)	130	38	35	203
08 (Choice sets 8 &18)	130	38	35	203
09 (Choice sets 9 &19)	130	38	35	203
10 (Choice sets 10 &2 1)	130	38	35	203
Total	1306	377	352	2035

This Table shows the version frequencies by state after the random assignment. The only difference between the survey versions is the two choice experiment questions (#27 and #28), where the attribute levels that the respondents faced differed.

Among the survey dispositions to be included in the mailing, potential respondents were sorted by state and call disposition and then randomly assigned the survey booklet group (1-10) in equal numbers across cases. This information is embedded in the tracking numbers that appear on each survey booklet and on the outgoing labels.

[26] See Appendix D for choice sets

Appendix G: Survey

Ornamental Nursery Survey of Irrigation Practices and Disease Management
Center for Survey Research
Attn: Darrell Bosch
Virginia Tech
Blacksburg, Virginia 24061

February 2013

Dear Horticultural Producer:

Researchers from Virginia Tech, University of Maryland, and Penn State are investigating disease and irrigation water management by horticultural producers. This study is funded by the USDA. You are one of a select group of producers chosen to represent the horticultural industry. Your answers to this survey will help us advise policymakers and the industry on ways to maintain industry competitiveness and environmental quality. Please help us by taking a few minutes to answer the questions on this survey.

One issue we are investigating is the potential costs and obstacles to irrigation water capture and recycling. Irrigation recycling is a sustainable practice that conserves water and may reduce costs. Policymakers encourage growers to contain and recycle irrigation runoff to reduce pollution and enhance water quality. However, recycling may also increase risk of disease due to water-borne pathogens. More information is needed about producers' irrigation and disease management practices and their attitudes toward containment and recirculation of irrigation runoff.

All information that is collected will be kept strictly confidential and anonymous. Your name or operation name will NOT appear anywhere on the survey. Your participation is voluntary. **The survey will take about 15 minutes to complete.** Please return the completed survey in the enclosed, postage-paid envelope or send it to the address above. If you have questions about the survey please contact us at (540) 231-5265 or by email (bosch@vt.edu). If you have questions about your rights as a research participant, please contact the Virginia Tech Institutional Review Board at (540) 231-4991.

Thank you in advance for your help!

Sincerely,

Darrell Bosch

Dr. Darrell Bosch

Nursery irrigation management

If your nursery has more than one production site, please include all operations when answering questions.

1) **Does your operation irrigate? If you have multiple operations, do any of them irrigate?** (Circle one number)

1 Yes → Continue to question #2
2 No → You do not need to answer any additional questions. Please return the survey.

2) **What share of your irrigation water comes from the following sources in a typical year?** Answers should sum to 100%.

River/stream	_____%
Pond fed by river or stream	_____%
Pond fed by runoff	_____%
Well	_____%
Public water supply	_____%
Other (please describe) ____________	_____%
Other (please describe) ____________	_____%
TOTAL	100%

3) **How many acres (square feet) do you irrigate with each of the systems listed below?** (Please select unit and use the appropriate column.)

overhead sprinkler	_____ sq. ft.	or	_____ acres
drip	_____ sq. ft.	or	_____ acres
ebb & flow	_____ sq. ft.	or	_____ acres
hydroponic, nutrient film	_____ sq. ft.	or	_____ acres
others (please describe) _____________	_____ sq. ft.	or	_____ acres
TOTAL	_____ sq. ft.	or	_____ acres

4) **On a typical summer day, what is your best estimate of the gallons of water you use to irrigate your nursery crops?** (Circle one number.)

1 0-100,000 gallons
2 100,001 to 200,000 gallons
3 200,001 to 300,000 gallons
4 300,001 to 400,000 gallons
5 400,001 to 500,000 gallons
6 500,001 to 1,000,000 gallons
7 1,000,001 to 2,000,000 gallons
8 2,000,001 to 5,000,0000 gallons
9 5,000,001 to 10,000,000 gallons
10 Greater than 10,000,000 gallons
12 Don't know

5) **How many times in the past 10 years has your operation either run out of or come close to running out of water for irrigation?** (Circle one number.)

1 Never
2 One or two times
3 Three or four times
4 Five times or more
5 Don't know

Disease incidence and cost

6) **How important is each of the following as a risk of financial loss to your business?** (Circle one number: 1 = very important, 2 = somewhat important, 3 = somewhat unimportant, 4 = not important)

Disease	1	2	3	4	No opinion
Drought (due to crop loss or high watering costs)	1	2	3	4	No opinion
Frost or freeze damage	1	2	3	4	No opinion
Insect damage	1	2	3	4	No opinion
Hail damage	1	2	3	4	No opinion
Weed competition	1	2	3	4	No opinion
Wind or blow over damage	1	2	3	4	No opinion
Other (please describe all)	1	2	3	4	No opinion

7) **How would you rate disease prevention in the day-to-day management priorities of your business?** Disease prevention includes actions to eliminate disease such as sanitation, scouting, and applying fungicides. (Circle one number.)

1 Very important
2 Somewhat important
3 Somewhat unimportant
4 Not important

8) **What proportion of nursery sales revenue does your business lose to all types of plant diseases in a <u>typical</u> year?** (Circle one number.)

1 Less than1%
2 1-2%
3 3-5%
4 6-10%
5 11-20%
6 Greater than 20%

9) **What is your maximum annual nursery sales revenue loss ever experienced as a result of disease?** (Circle one number.)

1 Less than 1%
2 1-2%
3 3-5%
4 6-10%
5 11-20%
6 Greater than 20%

Disease management

Phytophthora and **Pythium** are two water-borne diseases that can affect horticultural crops.

Typical symptoms of **Phytophthora** are foliage blight, root and crown rot, canker or dark streaks on stems, smaller than normal foliage, stunting of entire plant, wilting and death of plant.

10) **Is Phytophthora a disease problem at your operation?** (Circle one number: 1 = significant problem, 2 = problem, 3 = insignificant problem, 4 = not a problem)

1 2 3 4

Typical symptoms of **Pythium**: stunted plant growth, wilted plants during the day that recover at night, brown or dead root tips, brown tissue on the outer portion of the roots that are stunted, and yellowing plants that eventually die.

11) **Is Pythium a disease problem at your operation?** (Circle one number: 1 = significant problem, 2 = problem, 3 = insignificant problem, 4 = not a problem)

1 2 3 4

12) **How often do you use the following methods in your operation to prevent disease damage in your operation?** (1 = regularly, 2 = sometimes, 3 = never)

Reduce water application frequency	1	2	3
Change timing of daily water application	1	2	3
Apply fungicides to plants	1	2	3
Treat water prior to irrigation	1	2	3
Stop growing susceptible plant varieties	1	2	3
Group plants with similar water needs	1	2	3
Alter potting mix for susceptible plants	1	2	3
Destroy potentially infected/diseased plants	1	2	3
Modify the irrigation delivery system including storage, channels, and pipes	1	2	3
Sanitize growing environment	1	2	3
Other (Please specify ________________________)	1	2	3

13) **Do you use any of the following to treat water runoff before it is collected for on site use?** (Circle all that apply.)

1 Critical area stabilization
2 Erosion control blankets and netting/mulch
3 Grass waterways or rip-rap
4 Sediment basins
5 Constructed wetlands
6 Vegetative zones/buffer strips/groundcover

14) **Do you use any of the following to treat irrigation water prior to application?** (Circle all that apply.)

1 Sand filter
2 Ultra-violet light
3 Dye
4 Chlorine and other disinfectant (Bromine, etc.)
5 Other (please describe__________________)

15) **Approximately how much do you spend per year for each of the following to treat your irrigation water?**

$_______________ purchase of chlorine and other disinfectants

$_______________ labor for water treatment

$_______________ equipment for water treatment

$ _______________ other treatment costs (please specify___________________________)

16) **Do you use any fungicides to control disease?**

1 Yes
2 No → Skip to question #18
3 Don't know → Skip to question #18

17) **Approximately how much do you spend per year for each of the following to control disease?**

$_______________ purchase of fungicides

$_______________ labor to apply fungicides

$_______________ equipment to apply fungicides

$ _______________ other costs of fungicide application (please specify_______________)

Water runoff capture and recycling

18) Water runoff capture refers to containing water runoff from your operation using collection ponds or other methods so runoff does not flow directly off-site.

What proportion of your production area drains to a pond or other storage area?

1 None
2 1-25%
3 26-50%
4 51-75%
5 76-100%

19) **How much water do your collection ponds hold?**

1 Don't capture irrigation runoff
2 Some but not all irrigation runoff
3 All irrigation runoff → Skip to question #21
4 All irrigation runoff and runoff from a 2-3" storm → Skip to question #21

20) **If you don't capture runoff, why not?** Circle one number for each reason.
(1 = strongly agree, 2 = agree, 3 = disagree, 4 = strongly disagree)

High costs	1	2	3	4	No opinion
Increased disease risk	1	2	3	4	No opinion
Limited land available	1	2	3	4	No opinion
Physical layout not suitable for runoff capture	1	2	3	4	No opinion
If you have other important reasons for not capturing, please specify: ______________________	1	2	3	4	No opinion

→ Skip to question #25

Irrigation water recycling refers to runoff water capture and the re-use of the captured water for irrigation purposes.

21) **Do you recycle a portion of the captured runoff for later irrigation?** (Circle one number.)

1 Yes → Skip to question #23
2 No

22) If you don't recycle, why not? Circle one number for each reason.
(1 = strongly agree, 2 = agree, 3 = disagree, 4 = strongly disagree)

High costs	1	2	3	4	No opinion
Increased disease risk	1	2	3	4	No opinion
Limited land available	1	2	3	4	No opinion
Physical layout not suitable for recycling	1	2	3	4	No opinion
If you have other important reasons for not recycling, please specify: ______________________	1	2	3	4	No opinion

→ Skip to question #25

23) A recommendation for Pythium and Phytophthora control is to prolong water residence time in storage prior to reuse. **Have you used any of the following methods in order to increase water residence time?** (Circle all that apply.)

1 Adjusted collection pond location
2 Adjusted runoff entrance to pond relative to pump inlet
3 Adjusted size of pond
4 Altered number of collection ponds
5 Altered conveyance system from pond to production area
6 Others (please specify) ________________________
7 None of the above
8 Don't know

24) What % of total irrigation water supply comes from your collection ponds? (Circle one number.)
1 1-20%
2 21-40%
3 41-60%
4 61-80%
5 81-99%
6 100% → Skip to question #30 "General Business Characteristics"

Recycling Scenarios

New state and federal regulations designed to improve water quality might require nursery and greenhouse producers to capture all irrigation water and runoff from storms. Capture means impeding water runoff from your operation so that it does not flow directly to adjacent property or streams.

25) **If water capture was required by regulatory authorities what would your operation have to do to comply?** (Circle all that apply.)

1 Acquire adjacent land for constructing storage ponds
2 Reduce size of production area
3 Construct new ponds from existing production area to create buffer
4 Resize existing ponds
5 Modify existing greenhouse/production area to facilitate drainage to storage pond
6 Change irrigation practices
7 My operation already meets requirements
8 Other (please specify ________________)

Conditions Under Which You Would Choose to Recycle

In addition to capturing irrigation water runoff, operations may choose to recirculate this captured water for irrigation purposes. Factors that could have an impact on the choice to recycle 100% of their water include disease risk, risk of irrigation water shortage, and costs of recycling.

Risk of plant disease

Disease risk refers to the probability of plants developing Pythium/Phytophthora disease if irrigation recycling were implemented on your operation. This is the probability of plants showing disease symptoms in a typical year. Recycling stored water runoff for irrigation poses the potential problem of transferring diseases back to crops. An industry baseline for disease probability is assumed to be 10%. If a producer invests in water recycling, one of the components of the system would attempt to control for Pythium/Phytophthora.

Risk of irrigation water shortage

Risk of irrigation water shortage refers to a shortfall in water supply caused by depleted private or public well water or falling stream or pond levels. In recent years, producers around the country have experienced severe heat and drought conditions that have caused irrigation water shortfall. An industry baseline for irrigation water shortfall is assumed to be 15%. In 15% of the years between 1895-2000, cumulative rainfall was at or below 1.75” in your region during April-August posing a water supply problem for some producers.

Increased cost of installing and operating recycling
Many operations are not currently equipped to comply with a “capture” regulation or recycle irrigation water without incurring additional costs.

EXAMPLE

The two recycling scenario questions on the following page seek to learn about the recycling actions you might choose/prefer to implement if capture were required.

The table below is an example of a recycling scenario question. The table describes two alternative situations where you have the option to implement water recycling at your operations with the risks defined by the given probabilities.

	Recycling Condition A	**Recycling Condition B**
Probability of annual disease detection (**Current industry probability is 10%**)	20% with recycling	No change from current probability
Probability of annual water shortage **(Current industry probability without recycling is 15%)**	No change from current probability	No change from current probability
Percent increase in annual nursery production costs for installing and operating recycling technology	5% with recycling	10% with recycling

Keep in mind the changes you would have to make in your operation to install a recycling system. You will then answer whether you would choose to install water recycling if Condition A or B were to occur, or if you would choose not to invest in recycling.

26) **Would you choose to invest in 100% water recycling if Condition A or Condition B occurred?** (Circle one number response below the table.)

	Recycling Condition A	**Recycling Condition B**
Probability of annual disease detection (**Current industry probability is 10%**)	18%	12%
Probability of annual water shortage **(Current industry probability without recycling is 15%)**	No change from current probability	No change from current probability
Percent increase in nursery production costs for installing and operating recycling	5%	20%

1 I would invest in recycling if Condition A occurred.
2 I would invest in recycling if Condition B occurred.
3 I would not invest if either Condition A or B occurred.

27) **Would you choose to invest in 100% water recycling if Condition A or Condition B occurred?** (Circle one number response below the table.)

	Recycling Condition A	**Recycling Condition B**
Probability of annual disease detection (**Current industry probability is 10%**)	14%	16%
Probability of annual water shortage **(Current industry probability without recycling is 15%)**	17%	13%
Percent increase in nursery production costs for installing and operating recycling	10%	15%

1 I would invest in recycling if Condition A occurred.
2 I would invest in recycling if Condition B occurred.
3 I would not invest if either Condition A or B occurred.

28) **If you selected response number 3 (I would not invest if either Condition A or B occurred) in either of the preceding questions, is it because your operation could not afford to implement 100% recycling?**

1 Yes

2 No

3 Not sure

29) **How confident are you in your answers for questions #26 and #27, the recycling scenarios?** (Circle one number: 1 = very sure, 2 = sure, 3 = somewhat unsure, 4 = unsure)

1 2 3 4

30) **How important is each of the factors to your decision to recycle?** (Circle one number: 1 = very important, 2 = somewhat important, 3 = somewhat unimportant, 4 = not important)

Probability of disease	1	2	3	4
Probability of water shortage	1	2	3	4
Increase in nursery production costs for installing and operating recycling	1	2	3	4

General Business Characteristics

Answers to the following will help us understand the differences between grower respondents. If your operation has multiple locations, please answer questions for your main operation.

31) **Which of the following best describes your type of nursery sales?** (Circle one number.)

1 Wholesale

2 Retail

3 Re-wholesale or resale

4 Other

32) **What types of production operations do you operate?** (Circle all that apply.)

1 Greenhouse

2 Container nursery (including Pot-in-Pot)

3 Field nursery

4 Hoop houses

5 Other

33) Please fill in the information below for only the horticultural production portion of your operation in 2012. Do not include area taken up by roads, buildings, buffers, etc.

How many acres (square feet) do you operate for each operation type (all locations)? Please select unit and use the appropriate column.

Ornamental Greenhouse	_____	Acres	or	_____	square feet
Ornamental Container Nursery	_____	Acres	or	_____	square feet
Ornamental Field Nursery	_____	Acres	or	_____	square feet
Other Farmed Land	_____	Acres	or	_____	square feet

34) **What were your production costs in 2012 for your operation?**

$______________________

35) **What were your 2012 costs for just nursery production in your operation?**

$______________________

36) **What approximate percentages of your <u>ornamental</u> plant sales in 2012 were from the following plant types?** Answers should sum to 100.

Trees	_____ %
Evergreen shrubs	_____ %
Deciduous shrubs	_____ %
Annual bedding/garden plants	_____ %
Potted flowering plants	_____ %
Herbaceous perennial plants	_____ %
Other	_____ %
Total	100%

37) **What percentages of your plant revenue were from the following products in 2012?** Answers should sum to 100.

Containerized (above ground)	_____ %
In-ground containers (pot-in-pot)	_____ %
Balled and burlapped	_____ %
Balled and potted or process balled	_____ %
Bare root	_____ %
Field grow bag	_____ %
Other type (please specify________________)	_____ %
Total	100%

38) **What was your operation's gross revenue for all products and services in 2012?** (Circle one number.)

1 Less than $25,000
2 $25,001 to 100,000
3 $100,001 to 250,000
4 $250,001 to 500,000
5 $500,001 to 750,000
6 $750,001 to 1,000,000
7 $1,000,001 to 2,000,0000
8 $2,000,001 to $4,000,000
9 $4,000,001 to $6,000,000
10 $6,000,001 to $8,000,000
11 $8,000,001 to $10,000,000
12 Greater than $10,000,000

39) **What % of operation revenue comes from ornamental crops? __________** %

40) **Which category best describes your job title? (**Circle one number.)

1 Owner
2 Head grower/production manager
3 Grower
4 Business manager
5 Other (please specify _________________)

41) **What is your highest level of education?** (Circle one number.)

1 Less than high school
2 High school/GED
3 2 year degree
4 4 year degree
5 Post-graduate

42) **If you have a 4 year degree or higher, is your degree(s) in plant pathology, horticulture, agronomy, or a related field?**

1 Yes
2 No
3 Not applicable. I do not have a 4-year degree.

43) **How many years have you worked in the horticulture industry?** _______ years

44) **Do you have any other questions or concerns regarding disease or irrigation management?**

____

____

____

Thank you for completing this survey!

Appendix H. Survey Reminder Letter

Ornamental Nursery Survey of Irrigation Practices and Disease Management
Center for Survey Research
ATTN: Darrell Bosch
Virginia Tech
Blacksburg, Virginia 24061

February 2013

Dear Nursery Grower:

Last week we mailed you a survey asking about irrigation and disease management practices in your nursery operation. If you have already completed and returned the survey, please accept our sincere thanks. If you have not completed and returned it, please take a few minutes to do so today. The survey will take less than 15 minutes to complete. Your anonymous response will make a valuable contribution to the accuracy of this study and our ability to advise policymakers and the green industry on ways to maintain industry competitiveness and environmental quality.

If by some chance you did not receive a survey or misplaced it, please contact me at (540) 231-5265 or by e-mail at *bosch@vt.edu*. I will put another one in the mail to you. Thank you.

Sincerely,

Darrell Bosch
Professor

Appendix I: Conditional Logit Model STATA Codes

```
*Rename variables*
rename cost percentcost

*Generate new variables*
gen cost = percentcost*nurserycost
gen relativecost =  cost*nurserycost
gen proportionnurcost =  nurserycost/ prodcosts

*Clean data*
drop if (choice==99)
drop if (choice==88)
drop if (prodcosts==0)
drop if (prodcosts==99)
drop if (prodcosts>8000000)
drop if (nurserycost==0)
drop if (nurserycost==99)
drop if (nurserycost==88)
drop if( proportionnurcost >1)

*Generate binary variables for water and disease*
tabulate water, gen(water)
tabulate disease, gen(disease)
gen diseasedum=1
replace diseasedum =0 if (disease1==1)
gen watermore=0
replace watermore=1 if (water4==1)
replace watermore=1 if (water5==1)

*Create case variable for model*
egen catid=concat(respid choiceid)
destring catid, gen(caseid)

* Specify variables*
*zlist is the z variables which are the alternative-specific regressors for model, x variables are not needed for model, they are case specific*

*Model 1.1
global zlist cost water1 water2 water4 water5 disease2 disease3 disease4 disease5 disease6
clogit choice $zlist, group (caseid)

*Model 1.2
global zlist cost watermore diseasedum
clogit choice $zlist, group (caseid)
```

*Model 2.1

global zlist percentcost water1 water2 water4 water5 disease2 disease3 disease4 disease5 disease6
clogit choice $zlist, group (caseid)
estimates store m1

*Model 2.2

global zlist percentcost watermore diseasedum
clogit choice $zlist, group (caseid)
estimates store m2

**Test 2*
lrtest m1 m2

Appendix J: Institutional Review Board (IRB) Approval Letters

VirginiaTech

Office of Research Compliance
Institutational Review Board
2000 Kraft Drive, Suite 2000 (0497)
Blacksburg, VA 24060
540/231-4606 Fax 540/231-0959
email irb@vt.edu
website http://www.irb.vt.edu

MEMORANDUM

DATE: December 21, 2012

TO: Darrell Bosch, Jim Pease, Kevin Boyle, Chuanxue Hong, Alyssa Cultice

FROM: Virginia Tech Institutional Review Board (FWA00000572, expires May 31, 2014)

PROTOCOL TITLE: Ornamental Nursery Survey of Irrigation Practices and Disease Management

IRB NUMBER: **12-1062**

Effective December 21, 2012, the Virginia Tech Institution Review Board (IRB) Chair, David M Moore, approved the New Application request for the above-mentioned research protocol.

This approval provides permission to begin the human subject activities outlined in the IRB-approved protocol and supporting documents.

Plans to deviate from the approved protocol and/or supporting documents must be submitted to the IRB as an amendment request and approved by the IRB prior to the implementation of any changes, regardless of how minor, except where necessary to eliminate apparent immediate hazards to the subjects. Report within 5 business days to the IRB any injuries or other unanticipated or adverse events involving risks or harms to human research subjects or others.

All investigators (listed above) are required to comply with the researcher requirements outlined at:

http://www.irb.vt.edu/pages/responsibilities.htm

(Please review responsibilities before the commencement of your research.)

PROTOCOL INFORMATION:

Approved As:	**Expedited, under 45 CFR 46.110 category(ies) 7**
Protocol Approval Date:	**December 21, 2012**
Protocol Expiration Date:	**December 20, 2013**
Continuing Review Due Date*:	**December 6, 2013**

*Date a Continuing Review application is due to the IRB office if human subject activities covered under this protocol, including data analysis, are to continue beyond the Protocol Expiration Date.

FEDERALLY FUNDED RESEARCH REQUIREMENTS:

Per federal regulations, 45 CFR 46.103(f), the IRB is required to compare all federally funded grant proposals/work statements to the IRB protocol(s) which cover the human research activities included in the proposal / work statement before funds are released. Note that this requirement does not apply to Exempt and Interim IRB protocols, or grants for which VT is not the primary awardee.

The table on the following page indicates whether grant proposals are related to this IRB protocol, and which of the listed proposals, if any, have been compared to this IRB protocol, if required.

Invent the Future

VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY
An equal opportunity, affirmative action institution

Date*	OSP Number	Sponsor	Grant Comparison Conducted?
12/21/2012	10144201	USDA NIFA	Compared on 12/21/2012

* Date this proposal number was compared, assessed as not requiring comparison, or comparison information was revised.

If this IRB protocol is to cover any other grant proposals, please contact the IRB office (irbadmin@vt.edu) immediately.

Office of Research Compliance
Institutational Review Board
North End Center, Suite 4120, Virginia Tech
300 Turner Street NW
Blacksburg, Virginia 24061
540/231-4606 Fax 540/231-0959
email irb@vt.edu
website http://www.irb.vt.edu

MEMORANDUM

DATE: April 25, 2013

TO: Darrell Bosch, Jim Pease, Kevin Boyle, Chuanxue Hong, Alyssa Cultice

FROM: Virginia Tech Institutional Review Board (FWA00000572, expires May 31, 2014)

PROTOCOL TITLE: Ornamental Nursery Survey of Irrigation Practices and Disease Management

IRB NUMBER: **12-1062**

Effective April 25, 2013, the Virginia Tech Institution Review Board (IRB) Chair, David M Moore, approved the Amendment request for the above-mentioned research protocol.

This approval provides permission to begin the human subject activities outlined in the IRB-approved protocol and supporting documents.

Plans to deviate from the approved protocol and/or supporting documents must be submitted to the IRB as an amendment request and approved by the IRB prior to the implementation of any changes, regardless of how minor, except where necessary to eliminate apparent immediate hazards to the subjects. Report within 5 business days to the IRB any injuries or other unanticipated or adverse events involving risks or harms to human research subjects or others.

All investigators (listed above) are required to comply with the researcher requirements outlined at:

http://www.irb.vt.edu/pages/responsibilities.htm

(Please review responsibilities before the commencement of your research.)

PROTOCOL INFORMATION:

Approved As:	**Expedited, under 45 CFR 46.110 category(ies) 7**
Protocol Approval Date:	**December 21, 2012**
Protocol Expiration Date:	**December 20, 2013**
Continuing Review Due Date*:	**December 6, 2013**

*Date a Continuing Review application is due to the IRB office if human subject activities covered under this protocol, including data analysis, are to continue beyond the Protocol Expiration Date.

FEDERALLY FUNDED RESEARCH REQUIREMENTS:

Per federal regulations, 45 CFR 46.103(f), the IRB is required to compare all federally funded grant proposals/work statements to the IRB protocol(s) which cover the human research activities included in the proposal / work statement before funds are released. Note that this requirement does not apply to Exempt and Interim IRB protocols, or grants for which VT is not the primary awardee.

The table on the following page indicates whether grant proposals are related to this IRB protocol, and which of the listed proposals, if any, have been compared to this IRB protocol, if required.

Invent the Future

VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY
An equal opportunity, affirmative action institution

Date*	OSP Number	Sponsor	Grant Comparison Conducted?
12/21/2012	10144201	USDA NIFA	Compared on 12/21/2012

* Date this proposal number was compared, assessed as not requiring comparison, or comparison information was revised.

If this IRB protocol is to cover any other grant proposals, please contact the IRB office (irbadmin@vt.edu) immediately.