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ABSTRACT

In response to economic and environmental concerns, Water-Recycling Technologies (WRT) have been developed to reduce water consumption and surface run-off in horticultural operations. Water recirculation provides the potential for water conservation and may also reduce grower costs in the long run. However, WRT comes with increased risk of disease from water-borne pathogens such as Pythium and Phytophthora, which can cause devastating plant losses. In addition, WRT entail infrastructure investment costs to capture, treat, and recirculate water. These cost and disease concerns dissuade some growers from adopting WRT. More information is needed about producers' irrigation and disease management practices and their attitudes toward containment and recirculation of irrigation runoff. A mail survey was administered in February 2013 to horticultural nursery growers in Virginia, Maryland, and Pennsylvania. Information was gathered about the firm and respondents' demographic characteristics, plus production, irrigation, and disease management practices. The survey incorporates a choice experiment analyzing willingness to accept water recycling based upon hypothetical disease outbreak and water shortage probabilities and associated percentage cost increases. This information is related to the respondent's recycling choices using a conditional logit model to evaluate the effects of disease probability, drought probability, and water recirculation cost on producers' willingness to adopt water-recycling technologies.

Key words: Choice experiment, conditional logit, horticulture, nursery, technology adoption

1. Introduction

The United States horticultural industry is a broad sector consisting of businesses involved in all aspects of the production and marketing of ornamental and food plants. The horticultural industry represents a 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[1] 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 Census of Horticultural Specialties in 2009 covers horticultural firms selling more than $10,000 per year, and includes most of the horticultural operations that irrigation. 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 nursery crop producers; 133 who produce under protection, and 177 who produce in the open[2] (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 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).

Warmer weather in recent years has given rise to increased plant water demand, thus placing greater stress on irrigation water supplies. With warmer temperatures and increased water demand, horticultural producers may find it advantageous to recirculate water as a way of stretching limited irrigation water supplies. Due to increasing urban populations and faced with threats of water shortages, authorities in some areas are regulating consumption of municipal water and water recycling is necessary for horticultural operations to comply with government regulations (Hong and Moorman, 2005). Horticultural operations can 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. The channels, ditches, and basins are typically designed to capture both irrigation runoff and storm water runoff. Growers 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.).

In addition to water supply, another important water issue for policy makers and horticultural producers is nutrient and pest management. Water runoff from nurseries can carry fertilizer nutrients, pesticides, herbicides and other chemicals to water bodies and aquifers. This type of non-point source pollution is an increasingly important issue in the mid-Atlantic region due to concerns about water quality in the Chesapeake Bay. Future regulations could require horticultural operations to capture all water run-off.

[1] For the purposes of this study, the Mid-Atlantic region refers to Virginia, Maryland, and Pennsylvania.
[2] Some businesses produce both under protection and in the open.

Recirculation comes with increased risk of disease caused by water-borne disease pathogens. Two species of the genus Pythium and the genus Phytopthora are among the most destructive water-borne pathogens and are of prime interest in this study. Pythium primarily affects the roots of greenhouse plants and causes root rot (Moorman, 2010-B). Phytopthora primarily affects operations that grow plants in pots outdoors, and can cause root rot as well as stem rot or cankers (Moorman, 2010A). Both diseases can affect plants at all stages of growth and are capable of killing a variety of ornamental crops. Both pathogens 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.). Because these pathogens travel via water, they are difficult to contain once they infiltrate a production area and can travel long distances, quickly causing significant plant disease and loss (Hong and Moorman, 2005). Contaminated irrigation water is a primary (if not the sole) vehicle for Phytopthora infections (Hong and Moorman, 2005). The issue of plant pathogens like Pythium and Phytophthora has come to the forefront in the effort to implement best water conservation practices. (Hong and Moorman, 2005).

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, which have certainly dissuaded some growers from adopting WRT in these difficult economic times. The costs of water recycling systems are highly variable depending on 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 for greenhouse operations because they use more water and have more land to manage.

Policymakers encourage growers to contain and recycle irrigation runoff to reduce pollution and enhance water quality. More information is needed about producers' irrigation and disease management practices, their attitudes toward containment and recirculation of irrigation runoff and the barriers to adoption of these practices. The specific objective of the research is to evaluate the effects of disease probability, drought probability, and water recirculation cost on producers' willingness to adopt water recirculation. This research is conducted as part of a United States Department of Agriculture (USDA)/Specialty Crops Research Initiative (SCRI)-funded project (Hong et al., 2010). This objective promotes the SCRI project goal of increasing adoption of water recirculation systems in the green industry. With the quantitative information regarding the likelihood of WRT adoption by horticultural producers as it is affected by these characteristics, policymakers and industry stakeholders can focus their efforts on overcoming barriers to adoption.

2. Literature review

As initially described by Rogers (1962), adoption as a whole 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, all decisions whether input factors or the timing of input factors, will influence future situations. Horticultural production can be characterized as a complex dynamic system that is affected by exogenous and endogenous factors such as weather, soil, insects, diseases, weeds, plant nutrition, input and output prices, as well as interactions among these factors uncertainty about these factors is 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) found that factors influencing producers' willingness to adopt conservation and sustainable production practices varies with industry factors such as extent of 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 on their implementation of various sustainable 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 was producer's concern of implementation difficulty and the production risk associated with new technologies.. For horticulture and nursery operations, irrigation and disease management. The more information that can be collected regarding growers' perceptions, the more effective will be future best management practices. There is a need for emerging 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)

3. Experimental design

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. Between January and August 2012, study investigators conducted eleven site visits with nursery growers in Virginia, Maryland and Pennsylvania in order to formulate the survey questions. 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 approximately two hours including a tour of operation facilities. Most of these growers recycle at least a portion of their irrigation and runoff water. The purpose of the interview was to learn about horticultural growers' experiences with water-borne diseases including costs and management options as well as water management options, and to refine questions for the mail survey. In addition, we hosted a focus group of growers and horticultural extension workers to obtain comments and suggestions on the survey instrument, as well as obtained feedback from investigators on the research project team.

Sample

According to the United States 2007 Census of Agriculture, there were 4,785 primarily[3] greenhouse, nursery, and floriculture production operations in the Mid-Atlantic region. Of those operations, 1,085 operations were primarily in Virginia, 673 in Maryland, and 3,027 in Pennsylvania (Census of Agriculture 2007, Table 45). Because our research is concerned with adoption of water recirculation, 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. The sample does not include Christmas tree growers, food crop plants growers, or any completely contained growing operation. 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).

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 department websites.[4] 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 cross-checked with public nursery listing sites such as Nursery Trees and Garden Guides.[5] Telephone callers made calls to screen operations that did not produce nursery crops and/or irrigate their crops. The final list included 2,078 operations, 458 more than the largest Census number of 1,620.

The ten variants of the survey forms (Forms 1-10) created by Ngene 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. 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. The survey was administered to 2,078 operations in February 2013. The total number of survey recipients was comprised of the operations that agreed to take the survey and provided updated address information (397 operations), and those operations where no answer was received for various reasons (1,681). We sent surveys to those operations that did not respond in case they fit our criteria; the survey included an elimination question to screen out those that did not meet our criteria. Reminder cards were sent after one week and two weeks, and a second round of surveys was sent after three weeks.

[3]Operations included in this total include farms that sell more than 50% of their total value of greenhouse, nursery, and floriculture products and are classified as NAICS (North American Industry Classification Standards) number 1114.
[4]http://www.vdacs.virginia.gov/plant&pest/pdf/91nursery.pdf
http://mda.maryland.gov/pdf/md_nurs_alpha.pdf
[5]http://www.nurserytrees.com/States/National%20Nursery%20&%20Garden%20Center%20DIRECTORY.htm
http://www.GardenGuides.com

Survey and choice experiment

The survey contains 44 questions including both open-ended and multiple choice answers within six sub-sections. The titles and information requested in each section are as follows:

1) Nursery irrigation management
2) Disease incidence and cost
3) Disease management
4) Water runoff capture and recycling
5) Recycling Scenarios (Choice Experiment)
6) General Business Characteristics

We implemented an attribute based choice (ABC) model with a choice experiment section to elicit willingness to pay for recirculation technology that reduces 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.

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 decision to recycle will be based on three main factors: 1) Probability of drought, 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 conversations with experts. The attributes and selected levels for hypothetical scenarios are illustrated below in Table 1.

Table 1. 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) 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. We used the National Weather Service monthly average cumulative precipitation for Virginia, Maryland, and Pennsylvania, from 1895-2000 to estimate precipitation probabilities. In 15% of the years between 1895-2000, average cumulative rainfall during the growing season (April through August) was 1-3/4" in the Mid-Atlantic Region. Since there is no unique definition of "drought" for all purposes, we estimate that if the average precipitation per month in April-August falls below 1-3/4" (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 1-3/4".

"Cost" refers to the percent increase in annual nursery production costs to install and operate recycling infrastructure and practices with four levels: 5%, 10%, 15%, and 20% (as a percent of annual nursery production costs). There is no baseline value for the cost attribute because if any type of new technologies is installed, there will be 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 on their individual operations.

The choice experiment software Ngene was utilized to create the experimental design for this study (Choicemetrics, 2007). 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.

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." The respondents are then posed with the question:

> "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. 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. Would you choose to invest in 100% water recycling if Condition A or Condition B occurred?"

After the introductory questions, each respondent is presented with two scenarios providing hypothetical conditions for the recycling choice (Condition 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. See Figures A and B in the Appendix for the survey choice experiment pages.

4. Empirical Model

We have developed and implemented an attribute-based choice model based on Holmes and Adamowicz in Champ et al (2003) to elicit a producer's probability of adoption and their willingness to pay for water recycling technology. Choice modeling is used to model 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:

$$U_{ij} = V_{ij} + \varepsilon_{ij} \tag{1}$$

where an individual's utility that can be observed and measured 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:

$$U_{ijt} = \beta_i V_{ijt} + \varepsilon_{ijt} \tag{2}$$

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 j if the utility he gets from j is higher than the utility he or she could obtain from other choices (I). When compared to a different object choice, i, this means that person will choose option i over j when:

$$U_i > U_j \forall j \neq i \tag{3}$$

or

$$V_i + \varepsilon_i > V_j + \varepsilon_j \forall j \neq i \tag{4}$$

The probability of choosing a particular object is then:

$$P(i) = P\{V_i + \varepsilon_i > V_j + \varepsilon_j : \forall j \in C\} \tag{5}$$

Where C is the set of all possible alternatives.

Logit models assume that ε_j is logistically distributed and is independently and an Logit models assume that ε_j is logistically distributed and is independently and an identically distributed (IID) extreme value (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 modeling of utility 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.

In this choice experiment, $V_i V$ 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 alternative becomes

$$P\{i\} = \frac{e^{sVi}}{\sum_{j \in C} e^{sVj}} \tag{6}$$

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

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 water recycling technology becomes the model dependent variable and each attribute coefficient's parameter weight is estimated from the pooled responses (Collins et al 2007).

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

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

where “cost” is a continous variable for the percentage change in total nursery costs (cost attribute) multiplied by the nursery cost for each operations. “Water1” through “Water5” are dummy variables for each level of the water attribute, 10%, 13%, 17%, and 20% respectively, where the baseline level “Water3” (15%) is ommitted. “Disease2” through “Disease6” are dummy 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 variable for choice that denotes whether the respondent chose to adopt water recycling technologies under the respective conditions, where 1=adopt and 0=opt out.

The implicit price for a firm to adopt water recycling technologies is then calculated by:

$$Implicit\ price\ =\ \frac{\beta 4(water4)}{\beta cost} \tag{8}$$

Where "βcost" is a continouos variable created by multiplying by the percent increase in cost (“percentcost”) by “Water4,” an increased probability of drought.

It is hypothesized that the coefficients for the “cost” variable will be negative, 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 variables dummies “disease2” through “disease6” and hypothesized to be negative, as the probability of disease outbreak increases, the probability of adoption decreases. It is hypothesized that the maginitude 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.

5. **Results**

Out of 2,078 surveys mailed, 437 surveys were returned. Of these, 179 surveys were discarded because the operation does not irrigate or do not participate in nursery production. Most demographics and operation questions were completed by 258 respondents, of which 63 were from Virginia (24%), 38 from Maryland (15%), and 157 from Pennsylvania (61%).

Table 1 below reports the gross annual income for all usable surveys:

Table 1. Gross annual revenue

Gross revenue (Dollars)	Frequency	Percentage (%)
Less than 25,000	20	22.7
25,001 to 100,000	21	23.9
100,001 to 250,000	12	13.6
250,001 to 500,000	11	12.5
500,001 to 750,000	9	10.2
750,001 to 1,000,000	3	3.4
1,000,001 to 2,000,0000	2	2.3
2,000,001 to 4,000,000	6	6.8
4,000,001 to 6,000,000	1	1.1
$6,000,001 to $8,000,000	2	2.3%
Greater than $10,000,000	1	1.1%

Table 2 indicates the nursery production costs as reported in valid surveys by percentiles. The survey responses included operations with nursery costs ranging from $100 to $7,215,899. The mean nursery production costs were $418,277.60.

Table 2. Total annual nursery costs

Nursery Cost Range ($)	Count	Percentiles (%)
100 - 1,000	10	10
1,001 - 2,400	14	20
2,401 - 4,300	9	30
4,301 - 11,338	15	40
11, 339 - 19,000	11	50
19,001 - 52,000	13	60
52,001 - 99,000	11	70
99,001 - 238,860	13	80
238,861 - 809,000	12	90
809,001 - 7,215,899	12	100

Table 3 below illustrates the breakdown of respondent job titles: 86% of respondents were the owners of their operation, 7% were the head grower/production manager, 2% were a staff grower, 3% were the business manager, and 2% reported their job title fell under "other."

Table 3. Respondent job title

Title	Frequency	Percentage (%)
Owner	76	86.3
Head grower/production manager	6	6.8
Staff grower	2	2.2
Business manger	2	2.2
Other	2	2.2

The focus of this analysis concerns the firms' irrigation and disease management practices. Table 4 below contains the reported irrigation water use on typical summer days. 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 one nursery.

Table 4. Irrigation water use reported by nurseries

Irrigation water use (gallons)	Frequency	Percent (%)
0-100,000	74	82.22
100,001 – 200,000	4	4.07
200,001 to 300,000	0	0
300,001 to 400,000	1	1.11
400,001 to 500,000	2	2.27
500,001 to 1,000,000	3	3.40
1,000,001 or more	8	8.88

Six of the valid responses were directed to skip the choice experiment section because they indicated that they already practice 100% water recycling. There were 90 valid responses to both the choice experiment questions, and reported nursery and production costs.[6] With 90 respondents who answered two choice questions per survey, and three response options per question, the total observations equal 1,512.[7] The majority of respondents stated that they wouldn't adopt, but about a fourth made the choice to adopt, as seen below in Table 5.

Table 5. Response to choice questions #1 and #2

	Percentage adopt under conditions A or B (%)	Percentage opt out (%)
Question #1	29.5	70.5
Question #2	27.7	68.3

The cost willingness variable was considered in two forms for the choice analysis. The initial conditional logit models included a cost variable scaled to the size of the firm[8], but coefficient signs and magnitudes were insignificant, and this cost formulation was discarded. We chose instead to use the percentage cost increase as indicated in the survey, because it results in a better model. An additional dummy variable was created to represent the baseline disease probability for the nested models, representing any increase in disease level for the choice responses for models 2 and 3.

Three model nested variations were also estimated to determine whether the various levels of water and disease that were originally specified as dummy variables, would be better specified as single collapsed dummy variables if the different levels of disease and water had similar magnitudes of effects

[6] 53 respondents skipped the choice experiment section, another 115 did not include their cost information, and six operations already implement 100% irrigation recycling at their operation, so they legitimately skipped the choice experiment section.
[7] For the condition logit model, data is coded in the "long" format in order to measure the impact of the varying attributes in the choice experiment questions (alternative specific variables), where each option for each choice is a separate row (observation). 90 respondents x 2 choice experiment questions x 3 choices each = 540.
[8] Percentage cost increase multiplied by the total nursery cost for each firm

on the probability of adoption. The nested models were created to test the hypotheses that model 1 could be rejected as being fit significantly better than the smaller, simpler models with less variables.

Table 6 shows estimated coefficients for conditional logit models using STATA 10. Four models were estimated; models 3-4 are nested within Model 1:

Table 6. Estimated conditional logit models

	Model 1		**Model 2**		**Model 3**		**Model 4**	
Variable	**Coefficient**	**SD**[9]	**Coefficient**	**SD**	**Coefficient**	**SD**	**Coefficient**	**SD**
Percentcost	-13.563**	3.337	-13.613***	2.785	-9.345***	1.946	-9.942***	1.866
Water1	1.486	0.938	1.481**	0.692	N/A	N/A	N/A	N/A
Water2	1.116	0.879	1.106*	0.568	N/A	N/A	N/A	N/A
Water4	0.962*	0.556	0.947**	0.470	0.318	0.355	0.220	0.308
Water5	0.668	0.499	0.717	0.446	N/A	N/A	N/A	N/A
Diease2	-1.077*	0.559	N/A	N/A	-0.895*	0.482	N/A	N/A
Disease3	-1.186**	0.596	N/A	N/A	-1.144**	0.544	N/A	N/A
Disease4	-1.185**	0.555	N/A	N/A	-0.812*	0.471	N/A	N/A
Disease5	-1.143**	0.580	N/A	N/A	-0.611	0.431	N/A	N/A
Disease6	-1.145	0.769	N/A	N/A	-0.250	0.336	N/A	N/A
Diseasedum[10]	N/A	N/A	-1.138***	.352	N/A	N/A	-0.597**	0.236
Log likelihood	-134.463		-134.477		-136.093		-137.464	

Notes: * = significant at the p <0.10 level, **=significant at the p <0.05 level, *** significant at the p <0.01 level

For all four models, 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 water variables were only significant in model 2 The coefficients for the water dummies below the baseline level, “water1” and “water2,” were all positive, which is not consistent with our hypothesis of negative coefficients and unexpected because this would indicate that when levels of water scarcity drop below the baseline, water recycling technology adoption would increase. The coefficients for the water dummies above the baseline level, “water4” and “water5,” were all negative, which is consistent with the hypothesis that as levels of water scarcity increase, adoption would increase. The coefficients for disease probability were significant in all models and negative as consistent with the hypothesis that when the probability of disease outbreak increases from the baseline, respondents are less likely to adopt.

Likelihood ratio tests were performed to compare models 2, 3, and 4 to model 1 to determine whether any of the nested models fit significantly better than the full model, and should be preferred. The likelihood ratio test between Models 2 and 1 tests the null hypothesis restriction that collapsing the dummy variables “disease2” through “disease6” into one dummy variable will significantly reduce the fit of the model. Likelihood ratio test between model 3 and 1 tests the null hypothesis restriction that

[9] Standard deviation
[10] The variable “diseasedum” is a dummy variable that is a collapsed version of the dummy variables “Disease2” through “Disease6”

“water1,” “water2,” and “water5” are equal to zero. The likelihood ratio test between Models 4 and 1 tests the null hypothesis restrictions from both models 2 and 3, that collapsing the dummy variables “disease2” through “disease6” into one dummy variable and that “water1,” “water2,” and “water5” are equal to zero. The results of the likelihood ratio tests are seen below in Table 7, the three likelihood ratio tests all produced insignificant results, so we can assume that the variables that were set equal to zero in the nested models produced no significant difference from the original specification of model 1.

Table 7. Likelihood ratio tests

Models	Probability > Chi^2	Conclusion
Model 2 and 1	0.9999	Fail to reject null
Model 3 and 1	0.3533	Fail to reject null
Model 4 and 1	0.5396	Fail to reject null

It is possible that the coefficients for water have unexpected signs due to variation in our small sample. The large operations could be overshadowing the effects of the smaller operations. The nested models are possibly all not significantly different from model 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 25% of operations chose to adopt when presented with the the choice experiment questions, which makes estimation even more difficult with a sample size of 90 usable surveys.

6. Conclusions

We can justify using the nested models due the rejection of the null hypotheses all three likelihood ratio tests for models 2, 3, and 4. The biggest issue with our results is that we were not able to successfully model the continuous scaled nursery production cost variable “cost.” We can attribute the problems with this variable to scaling problems due to a skewed distribution. As seen in Table 2, there is more than a $7,000,000 range between the production costs of the smallest versus the largest firm (the median total production cost is $52,000 compared to the mean of $418,277.60, and the median total nursery costs is $20,000 compared to a mean value of $365,084.90).

The signs of the coefficients were as expected for all four models[11], except for the coefficients for a two dummy variables for decreased probability of water shortage. 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 244 valid responses, 175 operations (68.63%) have never experienced a water shortage, although 22 respondents had experienced a water shortage 3 or more times previously. The majority of respondents get irrigation water from a well (180 of 255), and the proportion of their total irrigation water coming from a well is also very high (84%), so water availability is not an immediate concern.

[11] The signs were as expected even though not all variables were significant in each model.

Of 241 valid responses, 196 (77%) respondents considered disease as a very important or somewhat important risk of financial loss. Ninety-two respondents stated that they experience less than 1% of nursery sales loss annually from plant disease. On the other hand, 90 firms experience at least 3% loss from disease and 23 experienced a loss greater than 10% of sales revenue per year. Because the magnitude of the coefficients for the probability of increased levels of disease detection (“disease2” through “disease6” in model 1 are almost the same (-1.077**, -1.186**, -1.185**, -1.143**, and -1.145 respectively), the increased level of disease detection does not matter to them, they want to avoid disease outbreaks in the operation all together. The collapsed dummy variable (“diseasedum”) for all levels of increased disease detection as seen in Models 2 and 4 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. The scaling issue is evident in other survey questions; for example, 10 operations spend more than $10,000 each on fungicides, while half of the nurseries reported here spend less than $250.

Future research should focus on either large or small nursery operations, because results of the current research indicates that nursery operations are too diverse in terms of their operating costs and size to be grouped together for analysis of their willingness to adopt water-recycling technologies. The survey results collected provide valuable insight into irrigation and disease management practices for nursery operations in the Mid-Atlantic region. We conclude that at this time, this topic is not suited for a willingness to pay analysis. Until 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 are 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, but fails to support hypotheses relating likelihood of disease detection, water shortages, and cost of recycling to the adoption of recycling technology.

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Appendix

Figure A: Choice Experiment Section from Survey "Recycling Scenarios" page 2

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.

Figure B: 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.