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Diffusing Water Conservation and Treatment Technologies to Nursery and Greenhouse Growers

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Abstract

Nursery and greenhouse operations require significantly large amounts of water to maintain product quality and often use more than what is needed by the crop being grown. The nursery industry's use of water is highly criticized and adds to arguments against agricultural water use with increasingly limited water resources available globally. The purpose of this study was to explore the barriers and motivators associated with nursery and greenhouse growers' adoption of water conservation and treatment technologies. In-depth interviews were conducted with 24 operators across the U.S. to identify their perceptions of new water-saving technologies and treatments based on the five attributes of an innovation identified by Rogers (2003). The findings revealed growers are aware of water-saving technologies and the rate of adoption depends on a variety of factors including: perceived cost, lack of ability of their workforce to use the new technology due to its complexity, and belief that their product will be worth more if it is grown in an environmentally-friendly manner. Barriers to adoption included the high cost of replacing equipment, incompatibility with existing systems, and the perception that new technologies do not fit in with the traditional hands-on approach to horticulture. Suggested extension programs to reach growers include developing materials that highlight the economic benefit of adoption and cost recovery, YouTube videos that reduce issues with perceived complexity growers can use with their workers, and programs that emphasize how technology fits in with the culture of the horticulture industry.

Keywords: adoption, water conservation, water treatment, diffusion, technology, nursery and greenhouse industry

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Introduction

It is predicted that by 2030 the world will face a 40% global water deficit (2030 Water Resource Group, 2009) "under the business-as-usual scenario" (UNESCO, 2015, p. 11) due to urban and economic development. Water scarcity significantly threatens the nursery and greenhouse industry (Kratsch, Ward, Shao, & Rupp, 2010) with the need for industry engagement in water-saving techniques described by Mezzitt (1992) as an "international challenge requiring local solutions" (p. 82). Fortunately, water conservation efforts are expanding. Schaible and Aillery (2012) found more than two billion dollars were invested in new agricultural irrigation systems that conserve water between 2003 and 2008 within the nursery and greenhouse industry. In the U.S. alone it was estimated that between 2006 and 2013 nearly 760 billion gallons of water were conserved due to alterations in agricultural irrigation systems within the industry (USEPA, 2014). Unfortunately, those water savings are not enough to overcome future demand and efforts must expand to ensure a water supply that will meet future demands (Kratsch et al., 2010).

Water conservation technologies such as drip irrigation and soil moisture sensors have been developed to apply water more precisely to crops (Chappell, Dove, van Iersel, Thomas, & Ruter, 2013; Lea-Cox et al., 2013). These innovations allow for efficient irrigation scheduling and are more effective than traditional watering methods (e.g. overhead sprinklers and hand-watering) (Lichtenberg, Majsztrik, & Saavoss, 2013; Mitchell, Shrestha, Klonsky, Turini, & Hembree, 2014). While growers are "positioned in a uniquely environmentally oriented sector of our economy" (Mezitt, 1992, p. 82) most nursery and greenhouse growers produce a large number of varietals, with varied water use requirements, making it difficult to conserve water by applying the precise amount of water required by each species (Lea-Cox et al., 2013; Regan, 1996).

Although the volume of water and application efficiency are vitally important to conserving water, water quality experts are also concerned about the presence of pathogens and agrichemicals in irrigation runoff from these same operations (Raudales, Parke, Guy, & Fisher, 2014; White, 2013b; Wilson, Riiska, & Albano, 2010). For example, in the U.S. there is a concern that contaminated water could impact plant communities in areas such as the Florida Everglades, the Chesapeake Bay watershed, the Great Lakes Basin, and the San Francisco Bay (White, 2013a; Wilson & Boman, 2011; Wilson & Foos, 2006). Water treatment technologies have been developed to reduce or eliminate possible biological contaminants from water including chlorine gas, sodium hypochlorite, ozone, ultraviolet radiation (UV), copper ionization, and heat treatments (Fisher, Raudales, & Meador, 2010). Not only does the use of these treatments ensure quality water is returned to the natural environment, but recycled water can also be used to irrigate plants, thus reducing fresh water use (Raudales et al., 2014). Despite these concerns, the nursery and greenhouse industry has been slow in its adoption of new treatment technologies that would ensure a quality water supply (Yeager, Million, Larsen, & Stamps, 2010).

It is important that extension professionals help growers overcome barriers to adopting water conservation and treatment technologies (Hartstone, Knight, & Riley, 2006; Heaton, Barnhill, & Hill, 2012; Majsztrik et al., 2013) with water resources becoming more strained and water quality issues increasing (USEPA, 2013). However, the barriers to adoption are largely unknown due to a lack of research in this area. Understanding the barriers to growers' adoption of water conservation and treatment technologies can assist extension professionals in developing programs and corresponding educational opportunities that resonate with growers resulting in increased adoption (Huang & Lamm, 2016).

Theoretical Framework

The theory of Diffusion of Innovations was used as the overall framework for this study (Rogers, 2003). The specific portion of the theory focused on was the five distinct characteristics of an innovation identified by Rogers (2003) that have been found to directly impact rate of adoption. While there are many other variables such as the type of innovation-decision, communication channels, nature of the social system, opinion leaders, champions of change and the impact of change agents that can impact the rate of adoption, Rogers (2003) identified specific characteristics of an innovation itself that can directly contribute and alter adoption rates. These characteristics were examined in this study to provide recommendations to scientists developing new innovations that appeal to nursery and greenhouse growers and extenionists working to increase the adoption of new scientific innovations. The five characteristics include relative advantage, compatibility, complexity, trialability, and observability of the innovation (Rogers, 2003).

Relative advantage is the perception that the introduced innovation (new technology or practice) is better than what is currently being used or done (Rogers, 2003). Adopters must feel there is an advantage to adoption which may come in the form of financial or social gain as a result of adopting the innovation. Previous research has shown nursery or greenhouse growers are financially driven. Jara-Rojas, Bravo-Ureta and Diaz (2012) found growers were more receptive to the idea of adopting a new technology or practice if the expected outcome was a larger margin of profit.

The compatibility of an innovation is also important. Rogers (2003) emphasized the need for an innovation to work within the current contextual or social system. This means the new innovation needs to work with the technology or infrastructure that already exists but that it must also fit within the social schema of the individual adopting (Rogers, 2003). Chapman, Newenhouse and Karsh (2010) conducted a longitudinal study aimed at increasing adoption of safer nursery crop production practices. Over a three-year period, researchers developed print ads, radio and television commercials, internet materials, and used public events to encourage growers to adopt safety practices. At the conclusion of the study, growers in the target audience did increase their awareness of safety practices; however, the innovative technology was not compatible with some growers' practices at the time. These growers reported their nursery was too small for the innovation and the safety equipment was of no use for their crops and did not adopt (Chapman et al., 2010).

Rogers (2003) also emphasizes that complexity of an innovation is a major influence on adoption. King and Rollins (1995) conducted a study to identify perceived barriers and possible incentives to assess the usefulness of the pre-sidedress nitrogen test, an agricultural innovation introduced to improve water quality. King and Rollins (1995) found the financial cost and complexity of the soil nitrogen test were the primary barriers to adoption. Llewellyn (2007) noted that adoption of an innovation is often limited by time and the capacity to integrate new, often complex, information.

According to Pannell (1999), trialability was the most important factor in a grower's decision to adopt an agricultural innovation. Trialability is the ability to try something before actual adoption (Rogers, 2003). Experimenting with an innovation on a small scale allows potential adopters to assess how much risk is involved with the new technology (Rogers, 2003). The risk assessment during the trial phase allows the potential adopter to gain an opinion related to the relative advantage, compatibility and complexity of an innovation (Pannell, 1999). In an effort to understand the factors that influenced the rate of drip irrigation adoption, Alcon, de Miguel and Buron (2011) concluded that farmers who had the opportunity to test drip irrigation technology were more likely to adopt because they improved understanding of the technology through use.

The last characteristic of an innovation, observability, refers to whether or not an individual considering adoption can observe the direct results of its implementation (Rogers, 2003). Chappell et al. (2013) reported three case studies where wireless sensor networks were used by growers to monitor soil moisture and they were allowed to observe the technology in action. The growers observing the use of the technology not only adopted, but expanded their use to include irrigation control because of the value-added benefits of reduced crop cycles, reduced disease pressure and crop loss, decrease in fungicide use, and ability to expand production areas using current water resources (Chappell et al., 2013).

Previous literature shows that the five characteristics of an innovation can have a direct effect on nursery and greenhouse growers' adoption of specific technologies and treatments related to conserving and protecting water resources. However, research has not been conducted to examine the barriers and enablers associated with the widespread adoption of innovative water-saving technologies and treatments on a broader scale to inform the development of extension programs. Through a deeper exploration of the perceived characteristics of water conservation and treatment technologies as innovations, stronger (more targeted) extension programs can be created, resulting in increased adoption.

Purpose and Research Question

The purpose of this study was to develop an understanding of the barriers and motivators related to nursery and greenhouse growers' adoption of water conservation and treatment technologies. It was guided by the following research question: How do nursery and greenhouse growers perceive the relative advantage, compatibility, complexity, trialability, and observability of water conservation and treatment technologies?

Methods

A qualitative research approach was employed to obtain a deep understanding of nursery and greenhouse operators' perceptions of water-related issues and to add to the body of knowledge on the topic of water conservation technology engagement. The study was designed to formulate a hypothesis about why nursery and greenhouse operations ultimately adopt or do not adopt alternative water sources and water treatment technologies (DiCicco-Bloom & Crabtree, 2006). An interview guide was developed based on the five characteristics of an innovation (Rogers, 2003) and was created to encourage interviewees to describe the nature of their operation, their role within the operation, and water management decisions. Interview questions encouraged participants to share current water conservation and water treatment activities, explain the water conservation and treatment technologies they were aware of but did not use, and why they chose not to adopt, as well as perceived benefits associated with treating and reusing water. A panel of experts made up of academics with specializations in water quality and conservation, water treatment technologies, extension programming, and social science research methods reviewed the interview guide.

Data were collected through semi-structured interviews. Semi-structured interviews were chosen because it allowed the researchers to probe for more information to get a better understanding of the topic (Bryman, 2004). Semi-structured interviews also allowed researchers to ask questions that were not on the interview guide during the course of each interview but ensured the germane research questions were asked at all interviews (Bryman, 2004).

A total of 24 interviews that lasted approximately 90 – 120 minutes were conducted across the U.S. with a targeted group of growers, owners of operations, and upper management personnel with extensive knowledge about water usage at the facility. Interviews were purposively geographically dispersed in regions around the U.S. where crop production operations are densely clustered. Locations were selected in an attempt to obtain maximum diversity and participation nationwide.

To ensure data quality, the interviews were designed to be one-on-one and in-depth for a more personal experience between the interviewer and interviewee, allowing the researcher to build rapport with the interviewee. In qualitative research, building rapport is essential to "establishing a safe and comfortable environment for sharing the interviewee's personal experiences and attitudes as they actually occurred" (DiCicco-Bloom & Crabtree, 2006, p. 316).

The researcher who conducted the interviews and analyzed the data was a trained social scientist. The interviewer did not have an already established relationship with any of the interviewees and had little knowledge about water conservation technologies prior to initiating the study. While a lack of background in the subject matter area limited understanding of concepts during some of the interviews, it also allowed the researcher to ask descriptive follow-up questions of the interviewee that would have been deemed as unacceptable by someone with in-depth knowledge of the field of inquiry. This allowed for the responses to the semi-structured interview guide to yield unanticipated, nuanced information that the researchers had not anticipated which could then be used to inform future research as suggested by Caplan, Tilt, Hoheisel, and Baugher (2014).

All interviews were recorded and transcribed verbatim. Pseudonyms were assigned to each participant and used throughout content analysis and reporting to ensure participant anonymity. Data were analyzed through content analysis using MAXQDA (v. 12.0.0, VERBI Software, Berlin, GER). Content analysis enabled the researcher to make "reliable, valid inferences from qualitative data" (Krippendorff, 2013, p. 418). Data were stratified *a priori* (Casullo, 1999) using Rogers' (2003) diffusion of innovations theory to group data into the five attributes discussed in the preceding theoretical framework section.

Before and after content analyses, the five attributes were reviewed by the researcher to ensure correct identification of themes reducing researcher bias and ensuring rigor (Lincoln & Guba, 1985). The integrity and credibility of the data were maintained by creating an audit trail throughout the entire coding process and formulating a report following review of each interview (Lincoln & Guba, 1985). A peer review of the coding process was completed at the conclusion of data analysis to ensure the data was translated the same by multiple qualitative researchers (Lincoln & Guba, 1985; Mays & Pope, 1995). Mays and Pope (1995) suggested that one goal of all qualitative research should be to

> create an account of method and data which can stand independently so that another trained researcher could analyze the same data in the same way and come to essentially the same conclusions; and to produce a plausible and coherent explanation of the phenomenon under scrutiny (p. 110).

The study participants included advisory board members and collaborating growers participating in the Clean WateR^3 project. Additional growers (not Clean WateR^3 collaborators) were also interviewed to ensure an adequately diverse pool of responses were obtained from which inferences could be made (Table 1). Only two of the participants were female and both women reported using recycled water and water treatment technologies. Only three of the operations were not using recycled water. The operations that were not engaged in using water treatment technologies were primarily in the west and south/southeastern parts of the U.S.

Table 1
Description of Study Participants

Pseudonym	Gender	Geographical Location within the U.S.	Operation uses recycled water	Water treatment used
Rhonda	Female	Northeast	Yes	Acid and Chlorine
Edward	Male	Northeast	Yes	Chlorine
Jason	Male	Northwest	Yes	Chlorine
Tyler	Male	Northwest	Yes	Chlorine
Calvin	Male	West	Yes	Chlorine Dioxide
Frank	Male	West	Yes	Chlorine Dioxide Equipment installed- “not yet running”
Herber	Male	West	No	None
Isaac	Male	West	Yes	None
Joseph	Male	Southeast	Yes	Chlorine
Phil	Male	Southeast	Yes	Chlorine
Richard	Male	South	Yes	Chlorine
Brett	Male	West	Yes	None
Greg	Male	West	Yes	None
Adam	Male	South	Yes	Chlorine
Lance	Male	South	Yes	Chlorine
Katherine	Female	Midwest	Yes	Hydrogen Dioxide
Ben	Male	South	Yes	None
Daniel	Male	South	Yes	None
Jimmy	Male	South	No	None
Kenneth	Male	West	No	None
Matt	Male	South	Yes	None
Noah	Male	South	Yes	None
Robert	Male	South	Yes	None
Steve	Male	Southeast	Yes	None

Results

Relative Advantage

Participants perceived irrigation water saving innovations as less wasteful and more advantageous than traditional watering methods. Drip irrigation systems were more “efficient” for water conservation compared to overhead sprinklers (Adam and Frank, interview). Rhonda justified her operation’s use of specific technologies by saying, “We use booms, and sub-irrigation, and [drip], so that [watering techniques] are not wasteful. We don’t have sprinklers [because] it’s not an efficient watering method.” Kenneth provided details regarding the upfront efforts and advantages of using drip irrigation at his operation when he stated, “it's a lot of initial install, but we save on fertilizer, watering time, manual labor all by using the drip irrigation.”

The most common water conservation practice was recycling and re-using water. The recycle and re-use technique was found to be beneficial for many reasons. Brett explained that his operation recycled and re-used water in order to, "save money, not to let runoff water to the neighbors… [and] save in electricity." Calvin revealed his operation's economic rewards associated with recycling water when he stated,

> "If we reuse and recycle 150 million gallons of water [per year], that's about $600,000, huge financial [benefit]. It also provides us with insurance against a disruption in the water supply, and provides us with the additional water that we need to keep all of our acres in production."

While these technologies were perceived to be less wasteful and more advantageous, the financial costs associated with purchase and installation of water conservation and treatment technologies reduced the relative advantage of adopting the innovation. Phil who still uses overhead irrigation specifically identified "time and money" as a barrier to adopting low flow irrigation. When asked about challenges associated with conserving water at their specific operation, James explained, "a big challenge would be the cost that it takes [to install], and the labor and cost associated with that, as well as direct cost of equipment, whatnot, to make it economical." Steve affirmed,

> "Cost is the biggest [barrier] associated with conserving water. I increase my drip production every year, but I never seem to be able to keep pace with it. I'd like to do more."

Herbert stated, "The biggest challenge is enough capital available to continually improve our irrigation systems." Herbert went on to explain that large operations with high profits are sometimes not eligible to receive government grants for installation of water conservation technology, specifically "The problem is that we don't qualify for any financial assistance, to actually install water-saving systems."

In many cases, the actual treatment process was perceived as a challenge. While explaining the water recycling process, Lance specified, "the same water may be touched three or four times before it goes back out on the plant… the treatment of the water is also an issue." Edward expressed, ", one of the biggest challenges with that is treating that recycled water." Although viewed as a challenge, the process of treating water is believed to be a necessary step for operations that want to ensure they are irrigating their crops with clean water. Lance went on to say, "it's just a part of doing business."

It was found that increased social prestige motivated operators to adopt water conservation practices and treatment technologies. Herbert enthusiastically stated, "we are an environmentally conscious company… there is a certain image that we like to project to our customers that we are doing our share… public image is very important to us." The social aspect of water conservation was not limited to how customers perceived an operation, but also how operations compared themselves to their counterparts. Richard confidently stated, "We are heads and tails above 99 percent of the people, out there…we can show that we are doing above and beyond what the average person is doing, and contributing to water conservation."

Stewardship of natural resources was the most frequently mentioned motivator for water conservation. Participants explained that decisions about technology selection were informed by the environmentally conscious nature of their operation. Brett stated "we want to be good stewards of our land because if we didn't have water and environmental resources, we wouldn't have a business." Jason made a similar remark when he asserted, “we are stewards of the environment, and that's our biggest motivation.” Jimmy believed bad press associated with how water is managed could lead to a decline in business for the operation. He explained, “we would rather have no publicity than bad publicity. We don’t want to have something running down stream that ends up in the newspaper…” Jimmy also expressed his desire to be the first operation in his locality to have a sustainable water recycling system.

Compatibility

Existing nursery and greenhouse operation designs were associated with barriers of compatibility of newer technologies. Jason expressed his desire to use more micro-irrigation, however the infrastructure of his operation does not permit the implementation of such technology. Jason explained, “we developed the automated system in 1992, and the rest of the nursery was built prior to that time, retrofitting that has been prohibitively expensive.”

Redesigning structures of an operation to make water conservation practices and technologies compatible also emerged from the data. Joseph stated, “From a conversion standpoint, the first step [is] redesigning your nursery to make sure that you can recapture as much [water] as possible...” Katherine described the re-design of her operation to collect water for recycling and re-use purposes. Katherine said, “the property has been graded; it slopes into this ditch that runs the length of the property…That water is retained as much as possible.” Edward explained how his operation was converted from a farm to a nursery. Edward said,

> It was turned into a nursery in the '90s. They used the latest technology at the time to make it as efficient and environmentally friendly as possible… irrigation channels were developed to direct that runoff back towards the pond.

Adoption of water conservation and treatment technologies was not always compatible with growers’ traditional views of horticulture. Some growers felt that technology cannot replace the human aspect of horticulture and were less inclined to adopt new technologies. These views were consistent with Rogers’ (2003) generalization that compatibility with beliefs and values may influence adoption of a new technology. Those who began working in crop production in previous decades took pride in the manual labor that went along with their industry. Phil said, “I didn’t grow up in a technology world, so I don’t look at things that way… I try to tell [younger growers] that is this is not a technology business.” Phil went on to say “You could use technology, but this is a manual business.” When automated irrigation systems were mentioned Lance proclaimed that he has, “never been a firm believer” of that type of system. Lance explained several factors that shaped his opinion regarding certain technologies such as his father would always say, “The best [horticulture techniques] in the world is the master's [owner’s] footsteps, wandering around and making those decisions." Tyler shared his opinion by saying, “technology is really helpful, but horticulture is so manual.”

However, some growers expressed an opposing viewpoint. These growers felt the recycling and re-use process was so important they even redesigned their nursery property to make their operations more compatible so they could save water. This implies there are innovators who are willing to break from tradition and try something new if their actions will protect the environment and ensure a future water supply.

Complexity

Participants thought that many of the water conservation and treatment technologies were too technologically advanced or tedious for their operation. Steve, Rhonda, Robert, and Tyler have all postponed implementing technologies due to their comfort level. In regards to drip tape, Steve stated "Consistency's an issue…We have not felt comfortable about that style of production to make it happen." Robert believed that a soil moisture system was too technical and not user-friendly for the average grower. Robert did not hesitate to say, "A lot of the guys that work for us did not feel comfortable working with this system. It needs to be easy to use for just a general person."

Soil moisture sensors and their real-time data that could be used to manage irrigation applications (water conservation) were perceived to be very complex systems by the growers. The main goal of the sensors was to alert growers when water is needed. Rhonda explained,

> …a sensor, or something like that actually takes empirical evidence and decides whether it needs water versus a feel or a grower's style of watering. We're working towards going that way. We just need to get comfortable with the equipment. We have it here and we're working with it. It's just it's a big program, it's a big system, there's a lot of variables, so it's not something that you can easily switch over to. There's a lot of details we need to get right in order to be comfortable with it being effective.

Tyler expressed his opinion about technical software and programs developed to enhance conservation efforts in horticulture when he stated, "Some of the stuff gets so technical and that's what the concern is… It's so technical, you got to have an IT person that's babysitting that project."

Trialability

The trialability of an innovation contributed to the rate of adoption of a water conservation and treatment technology. Herbert explained that his operation constantly tests sprinkler systems to determine their effectiveness before implementing them in his operation. Herbert said, "we have the overhead spinners in our shade houses. We actually trialed those, because of the more uniform distribution and the lower flow rate, [which] was a better way to water." Robert recalled conducting research on the Internet in an attempt to find effective watering technology. Robert stated, "I remember chatting with somebody online about this technology, a local irrigation store got me some samples, I felt comfortable, I tried it for a while, I turned one house into that overhead irrigation [system]."

Participants who had the opportunity to work with scientists to test water conservation and treatment technologies shared their thoughts about innovations that were tested at their operation. Jason described how innovations are trialed at his operation by saying, "We work with the scientific community [testing] water irrigation technology, and we do a lot of research here on the nursery. Frankly, most of our information has come from research here on the nursery [with scientists]." When specifically asked about filter socks as a treatment technology Joseph said, "…they are potentially effective." He explained that his operation trialed filter socks over a period of a summer with researchers from a university. The short-term experience with the bio socks shaped his decision to defer adoption of the innovation. Joseph went on to say that in order for him to implement bio socks at his operation he would, "have to see improvement in the areas that [he] earlier defined as a deficiency."

In an optimistic tone Calvin stated, "We're currently working on developing a sensor-based system. We did quite a bit of testing earlier this year…We got a couple little bugs to still work out on it, but we are pretty confident that it's going to work." By trying the sensor based system Calvin was able to form a favorable opinion about the innovation. In fact, Calvin's operation, "hoped to have [a sensor based system] in place before next spring…until we're able to roll out the more scientific sensor based technology, we know we're going to be wasting water."

Lance, who had an opportunity to try sensors through a university study stated, "I'm not totally sold on the sensor technology." When asked to elaborate more Lance explained from his limited time with sensor technology, "… the sensors have shown us how efficient we are with our water… we can't just say, okay, you're going to water so many hours every day. We have to monitor our crops and water as needed."

Observability

Observability of water conservation and treatment technologies also contributed to growers' decision to adopt or not adopt an innovation. Phil acknowledged that he has observed water-related technologies at other growers' operations and eventually implemented them. Phil assertively stated, "…you visit nurseries, you see things, you steal ideas, back and forth. I don't know if that's innovative or what it is…When I go, I'm looking at their irrigation system." Phil went on to say, "We'll have people that come, and that's all they want to see is our pump houses." Jason said, "We look at research that's been done in other places and see how it can apply to our nursery. We also sometimes invite researchers to come and do research on our property."

Trade shows were a common place for growers to see ideas at work. Ben shared that his operation uses pulse drip irrigation to conserve water, which is a scalable irrigation method designed to save water. When asked if there was anything that he observed at a trade show and implemented in his operation Ben said, "Yeah, matter of fact, that's the main way we learned about the pulse watering… It was at trade shows." Ben explained that this was how he learned, "[an] advantage to that pulse type watering is you're not putting as much water on [crops]. You're not leaching as many of your nutrients out of it, and so because of that, you're conserving nutrients."

Conclusions, Implications, and Recommendations

There is great diversity in perceptions related to water saving technologies across the nursery and greenhouse industry. Recycling and re-using water was the most common water conservation practices used by the growers interviewed in this study independent of the U.S. regions within which they operated. Participants reported that engaging in water recycling or re-use reduced their use of additional water (e.g. municipal and ground water) and benefited their business economically. This aligns with Jara-Rojas et al. (2012) that found the primary relative advantage growers perceived of new technology adoption was a larger profit margin.

In addition to financial benefits, the majority of the participants believed water conservation and treatment technologies were advantageous from an environmental perspective when compared to traditional irrigation techniques. They asserted that pulse drip irrigation, ebb and flood systems, and soil moisture sensors were innovative methods of irrigation that superseded previous methods indicating the relative advantage of adoption of water saving technologies are broadly accepted among growers in the U.S. Despite potential benefits it was found financial cost was a primary barrier to adoption and that beyond water re-use and recycling new technologies were not always seen as economically advantageous. However, many of the participants affirmed that while the cost of implementing water saving systems were high, the benefits of increased performance that these technologies offered were worth the financial investment. When educating growers about water conservation, extension professionals should emphasize the importance of water conservation as well as the relative financial advantage of adopting new technologies despite their upfront costs.

Participants were also found to be resistant to new technologies because of their perceived complexity that it did not fit within their traditional parameters. Participants expressed that many technologies developed to assist in water savings were not user-friendly for the average grower or irrigation specialist. Hall, Dennis, Lopez & Marshall (2009) determined that for floriculture growers, ease of implementation was the most influential factor influencing adoption of sustainable practices. Their findings, along with those in this study, suggest that as new technologies emerge, simplicity needs to be emphasized. Extension professionals should consider how to simplify a new process prior to introduction. A less complex water conservation technology that is efficient and effective could build confidence and comfort in using additional technical innovations. The development of short videos and/or infographics, made accessible online, showing step-by-step instructions on how to integrate and operate new technologies while emphasizing their advantages may also help alleviate concerns regarding the complexity of "new" technologies.

Several participants also reported testing an innovation for a short period of time without a required commitment gave them an opportunity to form an opinion about a new technology and in several cases allowed them to overcome their preconceived notions about complexity. However, findings from this study also confirmed those of Chapman et al. (2010). Several participants suggested trialability of water conservation and treatment technologies had both a positive and negative effect. The growers who had tried new technologies before adopting felt the experience gave them the opportunity to form their own opinions. However, in some cases, trying the technology resulted in their disliking the product and returning to prior methods. Based on this feedback, extension professionals should consider the technology when deciding whether or not they want to offer an option to try it out prior to full adoption. In some cases, trying a new technology in a small setting may make it seem inappropriate and result in non-adoption, whereas had a grower adopted the technology fully, they would have been able to take full advantage and seen the large-scale benefits of the technology.

On the other hand, participants that were able to observe new technologies being used successfully by other facilities, rather than trying it personally, had an improved perception of adoption. This finding aligns with Chappell et al. (2013) when they found growers that observed technology were not only more likely to adopt the technology they were observing but also expand their adoption to other technologies being discussed at the time of observation. Based on this finding, extension professionals should consider attending trade shows and commodity group meetings or hosting field days with demonstrations of new technologies to provide a platform for growers to observe new technology use, interact with their various settings and functions, and learn how the technology could be implemented at their own operations.

Future research should be conducted to further examine the decision-making process growers go through when considering the adoption of new water conservation and treatment technologies. A survey with a random sample of growers would provide generalizable results that could be used to further inform the practice of extension with this important audience. In addition, interviews, focus groups or surveys covering the adoption of water conservation and treatment technologies should be conducted in other countries that have an urgent need for water conservation to determine if need, cultural differences, or industry norms impact rate of adoption. The findings could then be compared across nations to develop extension programming that would be transferable and create global impact.

Research should also be conducted on the suggested extension programming. For example, once videos are developed and shared online to reduce perceived complexity, scientists should examine if they have the desired effect and increase the rate of adoption. The same could be done to determine if offering opportunities that engage growers in observing technologies enhances their rate of adoption. Finally, since the financial advantages of adoption were found to the be the largest influence in this study and the previous literature on the topic, research should be conducted to determine if communication messages and extension programming focused on the financial gain growers would obtain through adoption of new technologies had a dramatic change on adoption. Continuing this research line would add to the literature base with this important audience (nursery and greenhouse growers) that uses an excessive amount of water, but would also assist in informing the theoretical aspects of technology diffusion in the U.S. and around the world.

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