Communication and Trust: Leverage Points for Extension in Innovation Adoption and Discontinuance Experiences of Greenhouse Growers

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Abstract

This phenomenological study was underpinned by both value-belief-norm (VBN) and diffusion of innovations (DI) theories to explore the adoption/continuance experiences of three mid-size greenhouse growing operations with a new-to-market advanced growing system. We collected data using Rapid Evaluation and Assessment (REA) methods to understand growers' adoption/rejection decision-making behaviors and explored factors that influenced their confirmation decisions of an advanced growing system that held the potential to significantly reduce production costs if adopted. We identified three themes (a) value alignment; (b) reliable hardware; and (c) software integrity that contributed to the phenomenological essence: Communication and trust: Leverage points in the software/hardware overlap. Our findings suggested that growers' experiences and confirmation decisions were influenced by a lack of technological observability, reinforced by miscommunication and distrust in evidence and interactions with the change agent. We provide recommendations for practitioners such as horticultural Extension professionals, grant managers, inventors, product developers, and horticultural industry representatives, to facilitate information sharing and enhance transparency and accountability when diffusing an advanced growing system with greenhouse growers. Research to further explore change-agent role conflict and its impact on project adoption that engages growers and similar publics is needed to understand responsible, sustainable research and innovation diffusion.

Introduction and Theoretical Framework

Sustainable greenhouse management allows for optimized production and promotes innovative solutions for energy conservation, including the use of advanced growing systems (Saad et al., 2021). New systems and technologies are being developed to support resilient, climate-smart agri-food systems, with specific attention to supplemental lighting, automation, and remotely controlled systems (Nemali, 2022). As innovative products come on the market, there is a need to evaluate their performance and use-effectiveness and understand the role of Extension in supporting the diffusion of these technologies. Research evaluating the adoption of advanced growing systems within the greenhouse industry heavily focuses on technical improvements and benefits and has been aimed at providing estimates for energy use, resource conservation, and cost savings (Paris et al., 2022). However, there is a need for social evaluation of the adoption-continuance decision to understand early adopters' adoption experiences and perceptions of the new technology to examine the diffusion capacity of advanced growing systems through networks of growers and other relevant stakeholders in agriculture and Extension.

This research study was underpinned by Rogers' (2003) diffusion of innovations (DI) theory and Stern et al. (1999) value-belief-norm (VBN) theory of environmentalism (Stern, 2000) to explore growers' innovation adoption decision process and the influence of pro-environmental beliefs and behaviors on decision-making. Social science scholars commonly apply DI theory to understand how innovations and novel technologies gain traction within a social system. Rogers (2003) proposed five perceived attributes that influenced innovation adoption. They are relative advantage, complexity, compatibility, observability, and trialability. These attributes impact individuals' attitudes toward innovation and the decision-making process of adoption. Within our study, this included stages of knowledge (awareness of the new system), persuasion (attitude forming), decision (choice to participate in the project and adopt the system), implementation (active use and application of the innovation in greenhouses), and decision confirmation (feedback and assessment of decision to adopt). DI is a widely cited and appropriate theoretical framework for adoption, specifically in advanced growing systems (Gikunda et al., 2022; Moons et al., 2022). In our study, we examined a new-to-market advanced growing system that used automated sensor-based controls to measure, monitor, and adjust lighting based on individualized client needs to optimize plant production and conserve energy.

In addition to DI theory, we also applied Stern et al.'s (1999) value-belief-norm (VBN) theory to understand better how certain beliefs activate significant environmental behaviors and social movements (Stern, 2000). Stern defined environmentalism as "the propensity to take actions with pro-environmental intent" (p. 411). Industry experts and academics commonly apply this theory to examine the adoption of pro-environmental behaviors (Canlas & Karpudewan, 2023) inherent in designing the advanced growing system we examined. Behroozeh et al. (2023) used the facets of the VBN framework to understand growers' motivations and intentions to conserve energy in greenhouse production systems. Applying DI and VBN theory, we aimed to explore growers' perceived attributes of the advanced growing system and understand how pro-environmental beliefs may have influenced their participation in a project designed to introduce a new technology bundle to maximize greenhouse efficiency. Practical recommendations are presented to increase the adoption of similar innovations in future iterations.

Purpose

The purpose of this phenomenological research study was to explore (a) the innovation-decision process of mid-size greenhouse growers during the adoption of an advanced growing system; (b) examine how they perceived attributes of the innovation; and (c) if pro-environmental beliefs influenced their confirmation decisions. We were guided by the following question: What was the essence of growers' adoption and confirmation decisions regarding the use of the advanced growing system in their operation?

Methods

Research Design

We sought to discover the essence of three greenhouse growers' adoption experience of an advanced growing system technology bundle using phenomenological research design. Phenomenology is described as "the discovery of meanings and essences in knowledge" (Moustakas, 1994, p. 27) and is commonly applied to understand innovation adoption and technology use in agriculture (Mulvaney & Kelsey, 2020). Knowledge gained and innovation perceptions resulted from their conscious collective experience using the technology and working with the change agent (Moustakas, 1994). During the project, the business promoting the technology closed unexpectedly, causing an interruption in the adoption cycle. Therefore, the phenomenon of interest was the forced discontinuance and diffusion breakdown in the context of the business closure (McNall & Foster-Fishman, 2007; Moustakas, 1994). Given time constraints, rapid evaluation assessment (REA) methods allowed for more "rapid, cost effective, technically eclectic, and pragmatic" evaluation protocols (McNall & Foster-Fishman, 2007, p. 155). REA is widely recognized as an appropriate, trusted method among agricultural and Extension professionals, especially as it relates to adoption decisions (Comito et al., 2018; Halbleib & Dinsdale, 2023; Patton, 2002).

Population and Sampling

We used criterion-based sampling to purposively sample three greenhouse growers who opted to install a software and hardware technology bundle, demonstrated active/continued use of the system during the project, and remained in contact with the change agent. While 10 growers initially enrolled in the program to trial the growing system, only four met the criteria of active/continued use. We sent initial recruitment emails to those four growers to coordinate site visits. Three agreed to participate in the study. We conducted site visits in June and July 2023.

Data Collection and Analysis

We conducted site visits to three greenhouses and engaged the participants in a one-hour semi-structured interview (Patton, 2002). We analyzed growers' websites to gain insight into their pro-environmental beliefs and behaviors. Interviews were transcribed verbatim using Otter.ai, anonymized, and sent to growers as a form of member checking (Fossey et al., 2002). Supplemental data included notes from participating in all project meetings, a research log with field notes, transcribed voice memos, and analytical and process memos for reflexive analysis and to establish an audit trail to support dependability (Annink, 2016). The log, a previous evaluation report, meeting notes, and grower profiles were used to triangulate findings and enhance credibility (Merriam & Tisdell, 2016). To analyze interviews and website content, we used Nvivo 12 Plus as an assistive tool. We used concept and a priori coding as a first-round method (Saldaña, 2021). Concept coding was used to identify words or phrases that represented common grand concepts. A priori coding was used to identify theoretical incidents where the five attributes of an innovation and/or pro-environmental anecdotes were present (Rogers, 2003; Saldaña, 2021). We used code charting and then pattern coding as a second cycle method to categorize codes and assign themes before declaring the phenomenological essence (Moustakkas, 1994; Saldaña, 2021).

Researcher Positionality

The lead author was not part of the original grant team and was brought on later into the project's cycle to assist the lead evaluator. As a farmer's daughter, they have experience and knowledge of running an agricultural operation with limited crop experience but little to no formal training or experience in horticulture. This positionality and the timeline of my entrance into the project were made evident early on in the conversation in the hopes the growers might recognize me as a third party attempting to understand their personal experience with the technology and grant implementation. Opening with these statements often served as a point of connection and trust, especially for two of the growers whose businesses were primarily family-owned. For these growers, decisions seemed to be felt more heavily, given the stakes and potential impacts on their livelihood, as compared to the grower whose production was commercialized. As an evaluator, the lead author was conscious of the potential for pro-innovation bias. Even more, as someone whose identity is situated in both academia and production agriculture, the lead author felt especially compelled to ensure the integrity of their experience, including the critical realities, and unintended and undesirable consequences of innovation adoption, which are often neglected in innovation research (Sveiby et al., 2012), were captured and elevated. This was balanced by the lead evaluator, who provided perspective and brought historical knowledge about the grant implementation, and the development and rollout of the advanced growing system.

Limitations

As an evaluation rooted in phenomenology, findings are limited to the three enrolled growers. While insights may transfer to the diffusion of similar systems among similar populations and be of interest to horticultural Extension professionals, inventors, and industry representatives, we express caution in extrapolating findings outside this study's context. Similarly, as external evaluators, we had limited engagement with the growers. Supplemental data, intentional rapport and trust-building, and insights from the change agent garnered a deeper understanding of the setting and context for adoption. Additionally, discussions with the project lead and previous co-investigators provided additional insights.

Findings

We identified three themes to map the essence of growers' adoption and confirmation decision process (a) value alignment; (b) reliable hardware; and (c) software integrity. Comprehensively, these factors characterized the essence of the phenomena: *Communication and trust: Leverage points in the software/hardware overlap*. In this instance, software refers to the human dimensions of adoption, and hardware refers to the lighting control system's technology and equipment.

Theme 1: Value Alignment

In each of the cases, one primary decision-maker drove the initial decision to adopt and implement the technology bundle in their operations. Growers conveyed how their values, or those demonstrated through their business model, influenced their adoption decisions. We recognized a general inclination toward innovation, which was manifested by investing in on-farm research and development. Wholesale grower 1, employed in-house R&D staff and encouraged an understanding of the latest technologies. This was demonstrated through the statement, "we've seen research articles from various universities about how much light you should give for plants in terms of mols per day, so we wanted to see if we can get a little closer to what our crops needed." They also supported "progress in modernizing growing technologies" through virus testing, breeding, and hybridization as listed on their website. Similarly, grower 3 described seeding and growing hydroponic lettuce to eliminate soil use altogether. And grower 2 emphasized their inclination to innovate saying, "there are hundreds of things that have to be watched or anticipated, and you have to get out ahead of all that."

Because the project's original objectives promoted energy conservation, we were particularly interested in how growers' pro-environmental beliefs or behaviors influenced adoption and confirmation decisions. Pro-environmental behaviors and beliefs were evident during on-farm observation and through analysis of growers' websites. All three of the growers' websites demonstrated consensus toward their commitment to sustainability. For example, one site stated, "We're dedicated to sustainable farming: By adhering to agricultural and food production practices that do not harm the environment, provide fair treatment to workers, and that support and sustain our local communities." Another growers' website read, "[The company] prides itself on its sustainability, as well as the work we do to protect water resources, prevent erosion, and build up [of] our soil by planting many beneficial green manure cover crops." During the on-farm visits, all three growers provided examples of on-farm sustainability behaviors they have adopted to conserve the environment, such as efficient supplemental lighting and automated systems, water use controls, integrated pest management practices, and the use of solar and alternative energy. In these efforts, however—there was often a direct translation to cost savings, or avoided costs, for growers—and added value for marketability. This was especially evident during our on-farm visit with grower 2, who expressed personal conviction toward conservation while recognizing the positive consequences for their business. They stated,

> It was important to me, because since I was a kid, I've always thought that you don't waste things. That's how I was raised. And whether it's something tangible you can hold your hand or power, you just don't… Now that we've grown, we're pulling about 100,000 watts to run the farm. That's our peak load. And that's how we get billed. There was that incentive too. So, I wanted to be frugal and optimize the load for the power bill.

Grower 1 echoed this value and said, "We've got a lot of acreage here underneath lights. And if we can just make sure those pictures are hitting our targets, that could be some huge cost savings for us." Grower 3 was most candid about their motivations to adopt in this instance saying, "I don't think the sustainable part had a lot to do with this decision." At large, it was evident growers saw value in pro-environmental attributes of the advanced growing system, especially when it aligned with the values of their consumer base but were perhaps more motivated by the translation of energy conservation to cost savings.

Theme 2: Reliable Hardware: Demonstrating Potential for Filling a Niche Industry Need

The second theme centralized around the technology itself and factors that influenced adoption and continued use. Through this theme, growers described their experiences with installing, using, and evaluating the technology bundle. This was presented through two categories: innovation attributes and technical challenges, with subcategories identified for compatibility, complexity, relative advantage, and trialability. Growers expressed how the new system filled a niche need in the industry that provided more precise lighting control for product finishing and quality, and they were generally satisfied with the new technology. Grower 1 said, "We ship a lot of flowers out in March, April, and May, and to finish that product, we need those warm environments with grow lights. As we keep expanding, we need a technology that can help us manage those systems." This sentiment was reiterated by grower 3, who stated,

> Well, the decision to put the lights in was mostly for quality and production in the dark months. We didn't have enough product at the right times because it was tied up on the table. So one of the things I liked the most is I could go in and [customize the lighting] ….You can actually control it and then have [the product] when you want it.

All three growers described how the systems' ability to measure and control mols afforded them advantages over previous systems or approaches they had used. For grower 1, the technology advantage came from being able to acquire more precise mol detection from sensors *inside* the greenhouse. They explained, "I think our outside sensor will pick up on the reflection from the snow, just from being outside. Because when there is really fresh snow, my lights [controlled by the replaced system] would be off, when I think they should be on. With this new system, they were on." Whereas for grower 2, the benefit was the ability to record and analyze data. They said,

> The controller we had was sort of like the next best thing to their control. But it didn't measure. So, it was alterable and it could be adjusted. So in other words, it measures light, but it doesn't record light. It measures intensity in watts per square meter. And so I was able to set our existing controller to come on and off at certain thresholds. And that would change as we went into darker periods or came back out. I would adjust it manually, but it was a guess.

For the growers, the ability to both record light levels and automatically set system controls to control use based on their specific crop needs offered added value in a way that was novel but still simple and easy to use. Growers described how, in theory, the system was "just right," robust enough to have an advantage over other systems, and user-friendly enough to make it attainable for mid-size growers, if they have existing lighting technology or means to expand. "It's simple, straightforward…. There are systems out there that are high tech, but we don't really need that," grower 3 said. Grower 1, a larger grower relative to others in their area, cautioned that "the technology from the light standpoint has to work well with this system. I'm not sure a lot of growers have that kind of lighting technology." For these growers, even when their existing systems did not completely accommodate the new system, they were able to adapt their current systems with relatively low cost. Growers conceded the added cost of time or resources either to learn, install, or troubleshoot the system was minimal. Grower 2, who had to reinforce their internet access prior to use, mentioned that the installation cost incurred, though more than expected, was offset by the relatively low-risk trialability afforded by the project. This was echoed by grower 3 who said, "with the project benefits, it wasn't really going to be a big investment. So, we're like, let's just give it a shot."

Growers were able to manage risk even further by trialing the system on just one or two bays of product to compare quality or performance against their other systems. In the event the system did not perform, they could revert to their previous systems. This proved to be necessary at times because, despite its simplicity, the system did experience some technical challenges. Most of these had to do with the reliability of the system turning on and off as intended. They said,

> I remember looking up the lights, but they weren't working. So then I had to disconnect the lights again, and I put a little pilot light up there so that, they could trigger it on and

off remotely. And we could see some indicators that it actually would do what we wanted it to, without putting our crop in jeopardy.

For grower 3, technical challenges with the lighting and the initial use of red lights compromised crop quality, causing stunted growth and tip burn. They ultimately found the
the system worked better with some varieties than others.

Theme 3: Software Integrity and the Importance of the Client-Change Agent Interaction

The technical challenges growers faced seemed to be mediated by what we identified as *software integrity,* or the strength and quality of elements unrelated to the technology or its attributes but integral to the adoption and confirmation decision-making process. Discussions of the client-change agent interaction related mainly to categories that characterized the overall project management and communication, observability, and trust. When managed well, these elements and efforts compensated for technical challenges with the innovation's hardware. However, when unattended to, the experiences growers described created vulnerabilities and caused a breakdown in the adoption process. Early in the project cycle, during installation and setup, growers routinely communicated with the change agent, who was quick to help them troubleshoot and make necessary adjustments. All three growers were satisfied with the nature and extent of the communication at the beginning of the project. Growers 1 stated,

> I talked to [the change agent] quite a bit, just with the issues that we were seeing. [Their team] would email me those monthly reports, I would text or call if I had any issues. He was always very responsive and good at responding within a timely manner, so I appreciated that.

Likewise, grower 2 affirmed the change agent's willingness to work with them to remedy issues, though these requests were often reactive and grower-led. There did not appear to be structures in place for proactive communication, and at times growers had to be persistent.

> If there was something critical and we wanted to change the system, we just had to call him a couple of times, or make sure they knew that it was important to talk to him, and then they would get right on it.

By the projects' end, their experiences are best summed by a remark from grower 1, who said, "It did seem like support tapered off at the end."

> I emailed [the change agent] in March or May. I said, 'Hey, I switched over to our old system. We're not using your system anymore. That's when he was like, 'Oh, well, the company's not doing so well. I'll reach out when I know more." And I haven't heard anything back yet. It's probably been one or two months.

When we collected data for this study, all three growers were informed the company was going out of business, and the project was terminating. Growers were confused regarding next steps and if there would be further interactions with the change agent. "Is anyone going to collect this [equipment]? Or do we just dispose of it as we feel fit?" one asked. These statements bled into discussions of how the project was managed, and we recognized how that impacted their experience. Grower 1 discussed experiencing delays in installation that affected their ability to evaluate the system's performance. Grower 1 said, "Because of the late installation in 2022, we didn't get it going until end of March or April, and so that was a critical time for us. We missed out on a year of collecting information." For growers 2 and 3, this was less of an issue, they were recruited much earlier in the calendar year, so even after significant delays, were operational by the following winter. Growers 1 and 2 discussed frustrations with the intended incentive payments, either that they never received it, or that they opted not to because they felt the paperwork was too complicated. "It's not the end of the world, you know, but it was a little disappointing," one said.

These examples of miscommunication and disappointment influenced other areas of the client-change agent interaction. As the project ended, the three growers indicated a lack of trust in the change agent and the system's ability to deliver as intended, specifically as it related to the data they were receiving on energy and cost savings. Because data comparisons were based on projections, rather than past performance, grower 2 was skeptical about the accuracy of the reports and did not feel they painted the *whole* picture. They said, "It was a bit too nebulous…and I didn't trust it." Similarly, grower 1 expressed a desire to validate the data they were receiving. They said,

> "We were going to input our stuff from [the other system] into there to see how it compared and they were going to help me with that. But by the time we were ready to take those steps, they're no longer in business."

Without being able to validate the information they were receiving, it made it difficult for growers to make objective comparative judgments about the new system, impacting trialability. This uncertainty further confounded the nature of the information-sharing throughout the project and the lack of observability of the innovation. While growers discussed having immediate access to the change agent and their support team early in the project, there did not appear to be a mechanism to consult with other growers in the program. Additionally, it did not appear there was much effort or perceived need on behalf of the growers, to share information or consult with others either during the initial adoption decision-making process or throughout the project. While growers expressed an awareness and use of Extension for other aspects of their business, there was minimal involvement or resource-seeking from their state Extension systems during the project. In one instance, grower 1 was recruited through an Extension affiliate; however, the other two growers found out about the program from a trade publication and reached out directly. In each case, they did not seek out more information either because they believed it to be a low-risk decision or because they trusted that the product would deliver as the change agent had described. Growers 1 said,

> No, there was no one else I really talked with. I had mentioned to a few other growers that we were getting involved. And being that we've got a lot of acreage of lights here, we felt comfortable just doing a smaller section…and didn't feel like we needed to consult with anybody.

Grower 3 felt similarly, indicating they had previous experience with a similar system. Their recognition of its benefit motivated them to adopt and enter the trial.

> I did not. I did not because I knew he told me what it could do or what it would do. And then I knew from the [old system], that's what we wanted. Because we had the [old system], did without, and we really missed it.

Despite these challenges with *software integrity*, growers conceded that, ultimately, the system demonstrated its potential. However, the most evident barriers to continuance were the limited trialability and observability due to the project's closure and a lack of support from the change agent. Grower 1 said, "it just seemed like [the system] had a few glitches that never got quite ironed out. But if the glitches had been ironed out, I think it would have been nice." Despite the lack of continued support, grower 3 was the only one still using the system.

> I'm still hooked up….If there's a problem, I don't have anybody to fix it, [and] then we'll have to look elsewhere. There's a couple of systems, but they are very expensive. So hopefully somebody else comes along with a system like this—this is very inexpensive. We don't want to get into a lot of software. But hopefully somebody comes up with a system similar to this, if there is an issue.

Despite their discontinuance, grower 2 expressed a similar desire. They said,

> You know, I know this probably did not turn out like they wanted. But I hope the funder continues to invest in things like this so that we can continue improving the technology for growers. Because it is needed if we want to keep moving in the right direction.

Through these sentiments, growers indicated a recognizable need for this technology and demonstrated interest in more opportunities to engage with new products in similar ways.

Conclusions and Recommendations

This research supports growth and innovation in the horticultural industry and can provide valuable insights for inventors, agricultural sales professionals, Extension specialists, and grant managers during the recruitment of growers and diffusion of new technologies in the industry. While the business closure disrupted adoption and hindered diffusion, the technology-filled an operational need, aligned with business values, and was well-received. This underscores the importance of continued research and development of automated lighting systems with enhanced data collection and measurement capacity.

In regard to pro-environmental beliefs, growers took on more of an egoistic rather than an altruistic lens (Stern, 2000). While they affirmed its importance, their pro-environmental beliefs and behaviors seemed to influence adoption and continuance decisions to a lesser extent than cost savings, added value, and marketability to their consumers. This translated to growers' emphasis on trialability. These findings hold implications for how the benefits of advanced growing systems, practices, and similar technologies are communicated to growers and potential adopters (Rust et al., 2021). In marketing to midsize growers seeking to invest in this type of technology, change agents and Extension professionals should engage with product inventors as opinion leaders in technology diffusion and leverage existing grower relationships. Recruitment should target growers whose *consumer base* values social responsibility (Jansson & Biel, 2011) and frame benefits around cost savings and economic gain. Ultimately, cost remains a barrier for growers seeking to invest in new on-farm technologies (Fiocco et al., 2023). This further reinforces the need to provide growers with low-cost, low-risk opportunities to test systems through grants, or in partnership with university Extension systems. It also underscores the importance of trialability in diffusion (Rogers, 2003). To avoid diffusion failure in new projects, we recommend conducting pilot research with change agents to assess the innovation's sustainability, risk, and burden of adoption, should the business fail or grant funding expire (Sherry, 2002).

The essence of the diffusion phenomena, *Communication and trust: Leverage points in the software/hardware overlap*, demonstrated how these essential factors compromised adoption decisions and led to diffusion breakdown. In our phenomena, these were central to the innovation *software* or "the information base for the tool" (Rogers, 2003, p. 259). Miscommunication and misunderstandings led to uncertainty and distrust in the change agent and performance data, which made growers skeptical about the reliability and effectiveness of the system. Rogers (2003) suggested that "uncertainty implies a lack of predictability, of structure, of information" (p. 6). While they started the project with confidence in the change agent and the system's ability to deliver, this breakdown in communication and information caused growers' trust to wane over time. In our case phenomenon, these vulnerabilities contributed to growers' decision to discontinue. However, grower 3, who chose to adopt without support after the project's closure, conveyed the most satisfaction with their experience. This underscored the importance of consistent, effective project management to avoid disproportionate treatment of early adopters. Throughout the project, growers dealt primarily with the change agent, who also invented the product. Therefore, serving multiple roles might also have impeded diffusion.

Our finding aligns with more recent scholarship exploring change-agent role conflict when research, scholarship, and industry collide (Schuijer et al., 2021). Depending on the change agent's threshold for neutrality and critical feedback, role tension could perpetuate pro-innovation bias and inequitable treatment of adopters. Future research should be conducted to explore role conflict in technology diffusion through Extension systems throughout the adoption process to monitor potential effects. Role conflict is a potential compounding factor evaluators should be aware of when assessing grant or programmatic outcomes. Additionally, like-projects should use a client liaison to improve transparency and accountability in client-change agent interactions. Additionally, lack of observability hindered continuance. Despite the importance of social networks, modeling, and success visibility in diffusion (Rogers, 2003), the three growers made decisions in a vacuum.

We recommend creating a grower support network to encourage open communication, heighten observability, promote shared problem-solving, and strengthen multistate industry relations. There is an immense opportunity to collaborate more productively and diffuse new technology through Extension systems. We recommend capitalizing on growers' existing relationships with land-grant university Extension systems. In the rollout of these technologies, inventors and project managers could collaborate with state Extension horticultural specialists or local county agents to facilitate on-farm adoption and reinforce their role as opinion leaders in the innovation diffusion process. Future research should evaluate perceived economic barriers to adopting growing systems and identify relationships between their risk tolerance, target markets, and willingness to adopt. Additional research on change-agent role conflict in diffusion is needed to understand responsible innovation in horticulture better (Owen et al., 2012).

Historically, discussion among Extension professionals and change scholars has been limited regarding the integrity of an innovation's software in diffusion of horticultural technologies. In our case, "software malfunction" or vulnerabilities in communication and trust enhanced growers' uncertainty and threatened diffusion, even when the hardware was technologically sound. Communication is a key element of diffusion (Rogers, 2003). Theoretically, scholars emphasize communication in adoption but neglect its role at the nexus of where hardware and software meet. We argue breakdowns in the hardware/software overlap, specifically as they relate to communication and trust, can disrupt adoption of new technologies or lead to discontinuance, over time. Future research should continue exploring the role of trust in growers' perception of advanced lighting technologies and the research team (i.e. scientists, change agents, change agents, industry stakeholders) and how trust might influence their motivation to adopt. Given growers' skepticism and wavering trust in outcome data being presented, we recommend future projects place an increased focus on effective science communication when sharing results with growers. Extension professionals are uniquely positioned and motivated to translate science to their audiences (O'Brien et al., 2024). Projects targeting growers for adoption could collaborate with Extension professionals or agricultural communicators to present data in more digestible, user-friendly formats and increase growers' trust in the validity of project outcomes.

Inventors and industry professionals leading change should collaborate with opinion leaders in Extension to proactively reinforce leverage points in the software/hardware overlap of new technologies, as they can have significant, and perhaps underestimated, impacts on perceived attributes of successful innovation diffusion. As scholars, we often publish best-case scenarios and findings from successful adoption. However, given the richness of findings from this evaluation, despite project challenges, we believe continued research that examines diffusion breakdown and discontinuance is important. This vein of scholarship can help us identify nuance and divergent evidence to refine DI (Rogers, 2003) theory application in an Extension context. Finally, we recommend that increased efforts be directed toward enhancing transparency and accountability in the rollout of new, growing technologies, especially in grant-funded trials. Continuation plans and mechanisms for continued technological and financial support should be developed to ensure growers can sustainably manage their new system post-adoption.

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