RESEARCH POSTER

Proven Technology, Partial Adoption: Understanding Soil Disinfestation Decisions Among High-Tunnel Growers in the Mid-Atlantic Region, USA

Aastha Adhikari
The Pennsylvania State University
386 Shortlidge Rd, 009 Ferguson Building
University Park, PA 16802
814-610-3412
Afa6653@psu.edu

Dr. Suzanna Windon
The Pennsylvania State University
386 Shortlidge Rd, 209B Ferguson Building
University Park, PA 16802
814-863-3825
sxk75@psu.edu

Dr. Sharifa Crandall
The Pennsylvania State University
217 Buckhout Laboratory
University Park, PA 16802
sgcrandall@psu.edu

Introduction/Need for Research:
Organic high-tunnel vegetable production systems are increasingly important across the Mid-Atlantic United States, offering opportunities to extend growing seasons and improve farm profitability (Lamont, 2019; Penn State Extension, 2023). However, intensive use creates sustained soil pressure through restricted crop rotation and repeated planting cycles, contributing to buildup of soilborne pests, pathogens, and weeds that limit yields (Carey et al., 2009; Pierre et al., 2024; USDA-NRCS, 2025). For organic growers, these challenges are difficult because many conventional chemical fumigants are prohibited (USDA, 2025). Following methyl bromide's phase-out, non-chemical practices such as Anaerobic Soil Disinfestation (ASD) and Soil Steaming Disinfection (SSD) have emerged as alternatives. Despite proven effectiveness, adoption among organic high-tunnel growers in the Mid-Atlantic remains limited (Panth et al., 2020). Research has focused on agronomic outcomes, with less attention to how farmers experience these technologies and make adoption decisions in practice. This study explores motivations and barriers to adopting ASD and SSD practices, addressing: (1) What motivates farmers to adopt these practices? (2) What are the barriers to adoption? Understanding adoption decisions informs extension education design. This study provides insights to guide effective educational programming, demonstrations, and peer-learning initiatives.

Conceptual or Theoretical Framework:
This study uses the Theory of Planned Behavior (TPB) (Ajzen, 1991) and Diffusion of Innovations (DOI) Theory (Rogers, 2003). TPB posits adoption decisions are influenced by attitudes toward outcomes (e.g., perceived effectiveness), perceived behavioral control (e.g., cost, labor, equipment access), and subjective norms (e.g., peer learning, certification expectations). DOI highlights how attributes such as relative advantage, complexity, compatibility, trialability, and observability influence technology adoption. Together, these frameworks examine why ASD and SSD are often adopted selectively and situationally rather than as routine soil management practices in organic high-tunnel systems.

Methodology:
Qualitative case study design was employed using open-ended interviews to understand perspectives on soil disinfection decision-making. Using snowball sampling, we recruited eight farmers from Pennsylvania and Maryland familiar with ASD and SSD. Participants included four women and four men with 6 to over 20 years of farming experience. Adoption status varied: one transitioning farmer adopted both practices; three certified organic and organically aligned farmers adopted soil steaming only; one organically aligned farmer adopted ASD only; and three farmers were non-adopters. Most participants were owner-operators and primary decision makers. Interviews were recorded, transcribed, and analyzed using thematic analysis. Transcripts were open-coded to identify initial concepts, organized into preliminary categories through iterative comparison, then refined into themes through cross-case analysis aligned with TPB and DOI frameworks. Trustworthiness was established through peer debriefing, cross-case triangulation, and reflexive attention to researcher positionality.

Results/findings:
Analysis of the interviews identified three motivation themes that influenced farmers' decisions to adopt ASD and SSD. Across adopters, motivations were rooted in *perceived necessity, visible*

performance outcomes, and alignment with organic values. Non-adopters also expressed conditional motivation, particularly in relation to high-tunnel vulnerability, even when adoption had not yet occurred. Adopters consistently described adoption as a response to chronic or escalating soilborne problems. One farmer explained, *"We had been struggling with root knot nematode, like, very, very badly in our soil"* (F6). In addition to perceived necessity, adopters emphasized visible and rapid outcomes, particularly for soil steaming. As one participant noted, *"The first result was like, wow, look how green and lush this is… and the second thing was, there are no weeds"* (F7). However, experiences with ASD were more variable, suggesting less consistency in perceived performance outcomes. Non-adopters acknowledged disease pressure and recognized the appeal of chemical-free approaches, but their motivation remained conditional. Hesitation was primarily linked to uncertainty about outcomes and concerns for soil health. While these farmers expressed interest under certain conditions, this did not consistently translate into adoption. Not all participants contributed statements to each theme. Five overarching barrier themes also emerged from the analysis: *economic and energy-related constraints; labor, skill, and operational complexity; logistical constraints; soil health and environmental impacts; and limited knowledge and training needs*. Adopters described these barriers as challenges that could be managed, particularly under conditions of high disease pressure. In contrast, non-adopters more often perceived these barriers as prohibitive, especially when practices conflicted with soil health values or exceeded available resources. This contrast is reflected in participant accounts. One non-adopter expressed concern about soil disruption, stating, *"Our main concern would be… disrupting… the life of the soil"* (F4). Others emphasized financial and equipment-related limitations, such as, *"I do not think we could afford a steamer"* (F4). Overall, non-adopters framed these barriers as both resource constraints and value-based conflicts, reinforcing their decision not to adopt.

Conclusions:
Adopters adopted in response to disease pressure and perceived effectiveness, whereas non-adopters cited costs, environmental impact, and uncertainty about soil biology and logistics. Farmers prioritized observable, rapid results over theoretical benefits. Compatibility with organic principles was differentially interpreted: adopters viewed these techniques as necessary tools within organic systems, while non-adopters perceived them as contradicting soil biology goals. SSD was perceived as effective but complex to trial; ASD as more compatible yet less predictable. Adoption emerged as context-dependent and episodic, shaped by urgency, values, and constraints rather than uniform diffusion. Thick contextual description supports transferability to similar organic high-tunnel production systems.

Implications/recommendations:
ASD and SSD are adopted as situational, problem-driven interventions rather than routine practices. Extension efforts should help farmers assess when and where these tools are appropriate through demonstration trials, peer learning, and experiential formats. Custom service and equipment-sharing models, particularly for soil steaming, could reduce financial, labor, and safety barriers. Cost-share programs could improve feasibility and organic alignment. The episodic, problem-driven adoption pattern challenges linear diffusion assumptions in extension methodology, suggesting diagnostic decision-making and experiential learning are more effective than traditional workshops for context-dependent sustainable technologies.

References:

Ajzen, I. (1991). The theory of planned behavior. *Organizational Behavior and Human Decision Processes*, *50*(2), 179–211. https://doi.org/10.1016/0749-5978(91)90020-T

Carey, E. E., Jett, L., Lamont, W. J., Nennich, T. T., Orzolek, M. D., & Williams, K. A. (2008). Horticultural crop production in high tunnels in the United States: A snapshot. *HortTechnology*, *19*(1), 37–43. https://doi.org/10.21273/HORTTECH.19.1.37

Lamont, W. J., Jr. (2019, July 17). High tunnels use grows in Mid-Atlantic region. *Vegetable Growers News*. https://vegetablegrowersnews.com/article/high-tunnels-use-grows-in-mid-atlantic-region/

Panth, M., Hassler, S. C., & Baysal-Gurel, F. (2020). Methods for management of soilborne diseases in crop production. *Agriculture*, *10*(1), Article 16. https://doi.org/10.3390/agriculture10010016

Penn State Extension. (2023, March). High tunnel production. Pennsylvania State University. https://extension.psu.edu/high-tunnel-production

Pierre, J. F., Jacobsen, K. L., Wszelaki, A., Butler, D., Velandia, M., Woods, T., Sideman, R., Grossman, J., Coolong, T., Hoskins, B., da Silva, A. L. B. R., Ginakes, P., Kleinhenz, M., Zhao, X., Rivard, C., & Rudolph, R. E. (2024). Sustaining soil health in high tunnels: A paradigm shift toward soil-centered management. *HortTechnology*, *34*(5), 594–603. https://doi.org/10.21273/HORTTECH05460-24

Rogers, E. M. (2003). *Diffusion of innovations* (5th ed.). Free Press.

U.S. Department of Agriculture. (2025). *National organic program* (7 C.F.R. § 205). https://www.ecfr.gov/current/title-7/subtitle-B/chapter-I/subchapter-M/part-205/subpart-G

United States Department of Agriculture, Natural Resources Conservation Service. (2025). *EQIP high tunnel initiative*. Retrieved October 19, 2025, from https://www.nrcs.usda.gov/programs-initiatives/eqip-high-tunnel-initiative