# Examining Differences in Perceived Importance and Training Needs of Stakeholder Groups Involved in Controlled Environment Agriculture Education

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## Introduction/Need for Research

Controlled environment agriculture (CEA), including hydroponics, aquaponics, and vertical farming, is increasingly promoted as a strategy to enhance food security and resource efficiency while mitigating climate-related production risks (Heuvelink et al., 2025). However, CEA systems are technically complex and require expertise in system design, crop production, pest and disease management, and economic decision making (Li et al., 2025; GLASE Consortium, 2025; van Delden et al., 2021). Agricultural educators, Extension professionals, producers, and industry personnel play key roles in supporting CEA adoption and implementation (Cabrera-Garcia et al., 2020), yet limited empirical research has examined whether perceptions of importance and training needs related to CEA differ across these stakeholder groups or vary when professional experience is taken into account (Klerkx et al., 2019). Therefore, this study examined differences in perceived importance and perceived training needs related to CEA across Extension professionals, agricultural teachers, producers, and industry stakeholders, and assessed whether these differences persisted after controlling for professional experience.

## Theoretical Framework

This study was guided by human capital theory, which conceptualizes education and training as investments that enhance individuals' capacity to perform effectively in complex professional roles (Becker, 1964; Goldin, 2016). In technology-intensive agricultural systems such as controlled environment agriculture (CEA), effective implementation depends not only on access to infrastructure but also on the preparedness of those responsible for education, outreach, and operational decision-making (Smith & Stwalley, 2020). From a human capital perspective, gaps in knowledge or skills constrain the effective use of advanced production systems, regardless of stakeholders' professional roles. Examining similarities and differences in perceived importance and training needs across stakeholder groups provides insight into how CEA-related human capital investments can support capacity building across different contexts.

## Methods

A cross-sectional online survey was administered to stakeholders *(n = 138)* engaged in controlled environment agriculture (CEA) education, Extension, production, and industry roles in two USDA-NIFA project implementation states. The instrument assessed perceived importance and perceived training need using 43 items across five CEA domains: (1) system design and infrastructure, (2) crop production, (3) pest and disease management, (4) economics, and (5) marketing and post-harvest management. Items were measured using four-point Likert-type scales.

Content validity was established through expert panel review, and pilot testing *(n = 16)* demonstrated strong internal consistency across domains (Cronbach's $\alpha = 0.87–0.97$). Data were collected via Qualtrics between July and September 2025, following IRB approval. Of the 138 respondents contacted, 60 fully completed responses were retained for analysis. A one-way between-subjects ANOVA was used to compare stakeholder groups, and ANCOVA included professional experience as a covariate. Statistical analyses were conducted using IBM SPSS Statistics *(Version 29)*.

## Results/Findings

The final analytic sample included 60 stakeholders engaged in controlled environment agriculture with representation from agricultural educators *(n = 32)*, Extension professionals *(n = 16)*, and producers/industry professionals *(n = 12)*. Participants represented a range of professional experience levels (Mean = 15.76 years and SD = 12.01), which was included as a covariate in subsequent analyses.

Across stakeholder groups, mean ratings for perceived importance were consistently high, while perceived training need ratings ranged from moderate to high across all CEA domains. One-way ANOVA indicated no statistically significant differences in overall perceived importance across stakeholder groups, $F(2, 57) = 1.19$, $p = 0.311$, $\eta^2 = 0.04$. Similarly, no significant differences were observed for overall perceived training need, $F(2, 57) = 2.58$, $p = 0.085$, $\eta^2 = 0.08$. Effect sizes were small in both cases, and post-hoc comparisons were non-significant. At the domain level, perceived importance did not differ significantly by stakeholder group across CEA domains (all $p > 0.20$). Perceived training needs similarly showed no consistent group differences, except the *marketing and post-harvest domain* yielded a statistically significant omnibus ANOVA ($p = 0.032$), the assumption of homogeneity of variance was violated (Levene's $p = 0.022$), and robust tests (Welch; Games–Howell) were non-significant, suggesting this finding should be interpreted with caution.

ANCOVA results, after controlling for professional experience, indicated that stakeholder group effects remained non-significant for both overall perceived importance ($p = 0.299$) and overall perceived training need ($p = 0.056$), indicating a non-significant trend. Professional experience was not a significant covariate in either model, indicating that perceptions did not systematically vary by years of experience. Overall, effect sizes were small, suggesting limited practical differences across stakeholder groups.

## Conclusions

Findings indicated no statistically significant differences in perceived importance or training needs across stakeholder groups, before or after accounting for professional experience. From a human capital perspective, this suggests that foundational knowledge and skill requirements in controlled environment agriculture (CEA) are broadly shared across roles, reflecting the systemic and interdisciplinary nature of CEA systems. The absence of group differences may indicate that stakeholders, regardless of role, face similar capacity constraints when engaging with complex, technology-intensive agricultural systems. These findings reinforce the importance of investing in broadly applicable capacity development rather than tailored training.

## Implications and Future Research

Given the absence of stakeholder differences, these findings suggest that Extension and educational programs should prioritize integrated CEA curricula to build shared technical foundations while supporting collaboration across stakeholder roles. Professional development efforts may be most effective when designed around core technical and decision-making competencies that are relevant across stakeholder roles and encourage interdisciplinary problem-solving. This study was limited by a modest sample size drawn from two states, which constrained statistical power for detecting small group differences. Future research should examine how shared training needs evolve across adoption stages and institutional contexts and incorporate qualitative approaches to better understand contextual drivers of CEA training demand. Such approaches may accelerate workforce readiness by building shared competencies needed for effective CEA adoption and scaling.

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