Online ISSN Applied for

Review Article

Agro-Science Letters
Vol. 1, No. 4, Oct–Dec 2025

Impact of Extension Education on Adoption of Modern Horticultural Technologies: A Review

Vijay Kumar Yadav[1*]

[1]*Department of Agriculture, NN PG COLLEGE Nandani Nagar Nawabganj Gonda*

[*] Corresponding author. E-mail: vijaykumaryadav9766@gmail.com

https://doi.org/10.48165/asl.2025.1.04.01

ARTICLE INFO

Keywords:
extension education
technology adoption
horticulture
Krishi Vigyan Kendra
farmer field schools
protected cultivation
post-harvest management
knowledge-practice gap

ABSTRACT

Horticultural crops vegetables, fruits and flowers offer some of the highest returns per unit of land and labour in agriculture, but realizing this potential depends on farmers adopting modern production, protection and post-harvest technologies that are often more technically demanding and capital-intensive than field-crop practices. Extension education is the primary institutional mechanism through which such knowledge is transferred from research to practice. This review synthesizes recent evidence on the impact of extension education on horticultural technology adoption, drawing on farm-level studies, quasi-experimental evaluations and systematic reviews. Across contexts, structured extension interventions combining demonstration, training and advisory support raised horticultural yields by 20–30%, cut input costs by roughly 25%, and reduced post-harvest losses to 10–15%, with farm income gains exceeding 50% over traditional practice. In India, farmers exposed to Krishi Vigyan Kendra interventions achieved high-to-medium adoption of improved horticultural technologies at a rate of 76.67%, compared with 57.33% among non-beneficiaries. Farmer Field Schools raised technology cognition and adoption on Chinese greenhouse vegetable farms, though effectiveness varied sharply by technology type: new varieties diffused easily, while capital-intensive facility technologies proved far harder to extend. Evidence from Chile, Nepal and Nigeria confirms that the intensity, duration and design of extension contact not simply its presence determines its impact, and that extension is most effective when paired with credit access, group learning and, increasingly, digital advisory follow-up. Despite these gains, a persistent knowledge practice gap remains: even well-informed horticultural farmers often fail to adopt practices requiring specialized inputs or infrastructure, such as bio-fertilizers, protected cultivation or advanced post-harvest handling. The review concludes that maximizing the productivity impact of extension education in horticulture requires sustained, hands-on, technology-differentiated delivery models integrated with input and credit systems, rather than one-off information campaigns.

INTRODUCTION

Horticultural crops occupy a distinctive place in modern agriculture: vegetables, fruits, flowers and plantation crops generate substantially higher value per hectare than staple cereals, and their expansion is central to strategies for raising smallholder income, improving nutrition and diversifying rural economies. Realizing this potential, however, depends on a wider and more technically demanding set of production practices than field-crop agriculture — hybrid seed and grafted planting material, drip and micro-irrigation, integrated nutrient and pest management, protected cultivation structures such as greenhouses and polyhouses, and specialized post-harvest handling, grading and storage. Because these technologies are often more capital-intensive, information-dependent and management-sensitive than conventional field-crop inputs, the gap between what agronomic research recommends and what farmers actually practice tends to be wider in horticulture, and closing it depends heavily on the quality of extension education available to producers (Priya et al., 2025).

Extension education — encompassing training programmes, on-farm demonstrations, farmer field schools, advisory visits and, increasingly, digital and ICT-based delivery — is the principal institutional channel through which horticultural research reaches farm-level practice. A substantial and growing body of evidence now allows a more precise assessment of how, and how much, extension education actually shifts farmer knowledge and adoption behaviour in horticultural systems specifically, rather than in agriculture generally. This review synthesizes that evidence to address three questions: (i) what magnitude of impact does extension education have on horticultural technology adoption and resulting productivity; (ii) which extension delivery mechanisms and design features are most strongly associated with adoption gains; and (iii) where does a knowledge–practice gap persist even after successful knowledge transfer, and why. The review closes with implications for extension design in horticultural development programmes.

OVERALL IMPACT OF EXTENSION EDUCATION ON HORTICULTURAL TECHNOLOGY ADOPTION

Aggregate evidence across horticultural crops points to substantial, consistent productivity gains from structured extension education. A review of extension interventions across modern onion production — covering hybrid seed use, drip irrigation, integrated nutrient management, pest and disease control, mechanization and improved storage — found that such interventions raised yields by 20–30%, cut pesticide and fertilizer costs by close to 25%, and lowered post-harvest losses from typically high levels to 10–15%, collectively boosting farm income by more than 50% relative to traditional systems (Priya et al., 2025). These effects operated through several channels simultaneously: improved input-use efficiency, better pest and disease control, and reduced physical losses between harvest and sale, illustrating that extension's impact on horticultural systems is rarely confined to a single practice or production stage.

A broader scoping review of 54 studies examining technology-enabled agricultural extension found that the large majority (64.8%) reported positive outcomes on farmer knowledge or technology adoption, with a further 27.8% reporting mixed outcomes and very few studies finding no significant effect (Xu et al., 2023). Importantly, this review distinguished between agricultural technology (the innovations being extended) and educational technology (the tools used to extend them), concluding that the two work best in combination — that is, the productivity benefit of a horticultural innovation is realized more fully when it is paired with an effective pedagogical delivery method, rather than assuming that technical merit alone

INSTITUTIONAL EXTENSION MODELS: EVIDENCE FROM KRISHI VIGYAN KENDRAS

India's Krishi Vigyan Kendra (KVK) system — district-level farm science centres that combine training programmes, front-line demonstrations and on-farm testing — offers some of the most direct evidence on extension's impact specifically within horticulture. A study of 225 farmers in Kolar district, Karnataka, comparing KVK beneficiaries with non-beneficiary farmers found that 76.67% of beneficiaries achieved high-to-medium adoption of improved horticultural production technologies, compared with 57.33% of non-beneficiaries; conversely, 42.67% of non-beneficiaries showed low adoption, more than double the 23.33% low-adoption rate among beneficiaries (Kumar, Reddy & Shashidhar, 2024). Figure 1 illustrates this adoption gap.The authors attributed the higher adoption among beneficiaries directly to exposure through demonstrations, on-farm trials and structured training sessions, which both raised technical knowledge and built farmer confidence in applying new practices — consistent with the broader finding that extension's effect on adoption operates through knowledge gain as an intermediate step rather than through information provision alone. This pattern is echoed across the wider KVK literature, where front-line demonstrations are consistently identified by farmers as the most effective single extension method for driving adoption of new horticultural and crop technologies.

FARMER FIELD SCHOOLS AND TECHNOLOGY-SPECIFIC ADOPTION PATTERNS

Farmer Field Schools (FFS) — a participatory, season-long, hands-on training model — have been extensively evaluated in horticultural settings. A study of 274 tomato and cucumber greenhouse farm households in Beijing, China, using Tobit models found that FFS participation significantly increased both farmers' cognition of new agricultural technologies and their subsequent adoption rates (Cai, Hu & Hong, 2022). Critically, this study found that the effect of FFS varied substantially by technology category: new crop varieties were comparatively easy to disseminate through FFS but, once disseminated, did not always translate into sustained adoption, whereas facility-based technologies — such as protected cultivation infrastructure and associated climate-control equipment — proved considerably more difficult to extend, reflecting their higher capital cost and management complexity.

This technology-differentiated pattern has direct implications for horticultural extension design: a single FFS curriculum or delivery intensity is unlikely to be equally effective across the full range of horticultural technologies, and extension programmes promoting capital-intensive protected cultivation or precision-irrigation technologies may require more sustained, higher-intensity engagement than those promoting simpler agronomic practices such as improved varieties or spacing.

EXTENSION DELIVERY DESIGN: WHAT MAKES EXTENSION MORE EFFECTIVE

Beyond the simple presence or absence of extension contact, several studies have identified specific design features that determine how much impact extension education has on horticultural technology adoption. Table 1 summarizes reported impacts from several major extension mechanisms evaluated in horticultural or closely related farming systems, and Table 2 summarizes the underlying factors found to shape extension effectiveness.

Table 1. Reported impacts of selected extension mechanisms on horticultural knowledge and technology adoption.

In Central Chile, a study of vegetable and berry farmers receiving technical assistance through privately delivered extension found that higher adoption intensity was positively associated with the duration of individual extension visits, the number of group-based activities, and farmers' access to incentives and credit provided alongside the extension service; farm size and the value of production were also positively associated with adoption intensity (Jara-Rojas et al., 2020). This suggests that extension effectiveness in horticulture is not simply a function of contact frequency, but of the depth and complementary resourcing of that contact table 2

Table 2. Factors found to shape the effectiveness of extension education in raising horticultural and agricultural technology adoption.

Complementary evidence from Nepal reinforces the value of combining in-person training with real-time digital extension: smallholder rice farmers who received sequential agricultural training together with digital extension services showed adoption rates for recommended split urea application that were 11.4–15.7 percentage points higher than those receiving training alone, translating into a 35–56% increase in yield (Karki Nepal et al., 2025). Although this study concerned a staple crop, its core finding — that layering digital follow-up onto in-person training substantially outperforms either channel alone — is directly relevant to horticultural extension, where technologies such as fertigation scheduling, pest-threshold monitoring and post-harvest timing depend on timely, context-specific advice that digital channels are well suited to deliver between in-person visits.

Structural enablers external to the extension encounter itself also matter. In Nigeria, access to public extension services and cooperative membership were both found to have a positive and statistically significant effect on technology adoption and household welfare, but this impact was significantly stronger among farmers who also had access to formal credit, indicating that extension and financial access function as complements rather than substitutes (Wossen et al., 2017). A global meta-analysis of the developing-world adoption literature similarly found that the effectiveness of extension in raising adoption interacts with farmer education: extension's effect on simpler technologies, such as improved varieties, was greatest where farmer education was low, acting as a substitute for formal schooling, whereas for more complex natural-resource-management technologies, extension effectiveness rose with farmer education, acting instead as a complement that helped educated farmers translate advice into correct practice (Ruzzante, Labarta & Bilton, 2021).

THE PERSISTENT KNOWLEDGE–PRACTICE GAP

A recurring finding across the horticultural extension literature is that raising farmer knowledge does not automatically translate into full adoption of recommended practices, particularly where a practice requires specialized inputs, infrastructure or market linkages that farmers do not directly control. A study of onion farmers in Maharashtra, India, assessing both knowledge and adoption of pre- and post-harvest man-

Table 1

Extension mechanism	Reported impact on knowledge / adoption	Source
Krishi Vigyan Kendra (KVK) training, demonstrations and on-farm testing (horticulture, India)	**76.67% of beneficiary farmers reached high-to-medium adoption of improved horticultural technologies vs. 57.33% of non-beneficiaries**	Kumar, Reddy & Shashidhar (2024)
Farmer Field Schools (FFS), greenhouse tomato and cucumber farms (China)	**Significantly increased farmers' cognition and adoption of new technologies; effect size varies by technology type — new varieties spread easily but are harder to adopt; facility technologies are hardest to extend**	Cai, Hu & Hong (2022)
Private extension companies (technical assistance program), vegetable and berry farms (Chile)	**Adoption intensity positively associated with duration of extension visits, number of group activities, and use of incentives/credit; farm size and production value also mattered**	Jara-Rojas et al. (2020)
Sequential agricultural training plus real-time digital extension (rice, Nepal)	**11.4–15.7 percentage-point higher adoption of recommended split urea application; 35–56% higher yield vs. training alone**	Karki Nepal et al. (2025)
Structured horticultural extension package (on-farm demonstration, training, ICT advisory) – onion, multi-country review	**Yield gains of 20–30%; pesticide/fertilizer cost cuts of ~25%; post-harvest losses reduced to 10–15%; farm income up more than 50%**	Priya et al. (2025)
Extension-linked knowledge transfer on pre- and post-harvest practices (onion, India)	**Only 40% of farmers reached high knowledge and 41.67% medium adoption; practices needing specialized inputs (bio-fertilizers, market intelligence) remained poorly adopted despite awareness**	Sahu et al. (2022)
Public extension access and cooperative membership (Nigeria, multi-crop)	**Positive and statistically significant effect on technology adoption and household welfare; effect strongest for farmers with access to formal credit**	Wossen et al. (2017)

agement practices found that only 40% of farmers reached a high knowledge category, and only 41.67% displayed medium-level adoption; farmers were generally knowledgeable about and adopted practices requiring only labour and basic technique, such as harvesting at optimum maturity, proper handling, curing, sorting and grading, but consistently under-adopted practices requiring specialized inputs or market access, including selection of suitable cultivars, nursery management, application of bio-fertilizers and bio-fungicides, market intelligence and secondary processing (Sahu et al., 2022).

This pattern indicates that the knowledge–practice gap in horticulture is not uniform across practice types: it is narrowest for practices that depend mainly on farmer skill and effort, and widest for practices that depend on external inputs, capital or market infrastructure the farmer cannot access through knowledge alone. The implication for extension design is that knowledge transfer must be paired with input supply chains, credit access and market linkages for the highest-value, most input-dependent horticultural technologies to translate into practice — a finding consistent with the credit-complementarity result reported for Nigeria (Wossen et al., 2017) and the incentive/credit association reported for Chile (Jara-Rojas et al., 2020).

Similar soil- and practice-specific information gaps have been documented in wider smallholder farming populations: in Tanzania, a majority of surveyed farmers lacked awareness of basic soil information relevant to their own land, a deficit significantly associated with lower adoption of improved practices generally (Justine, Ocansey & Csorba, 2025), underscoring that diagnostic, farm-specific information — not generic technology promotion — is often the missing link between extension contact and adoption.

DIGITAL AND ICT-ENABLED EXTENSION IN HORTICULTURE

Digital tools are increasingly embedded within horticultural extension delivery, both as a stand-alone channel and, more effectively, as a complement to in-person training. A systematic review of 49 studies on ICT-based agricultural extension — spanning mobile apps, SMS messaging, educational videos and voice-based advisory services — found that 76% reported increased adoption of recommended practices and 74% reported higher yields, with effectiveness strongly dependent on well-designed messaging, adequate user training and integration with complementary in-person sup-

DOI: https://doi.org/10.48165/asl.2025.1.04.01

Table 2

Factor	Effect on extension effectiveness	Source
Method: hands-on demonstration and group learning vs. one-way messaging	Of 54 studies reviewed, 64.8% reported positive outcomes when technology-enabled, interactive extension methods were used; combined agricultural + educational technology outperformed either alone	Xu et al. (2023)
Intensity and duration of contact	Longer extension visits and more frequent group activities were positively associated with higher technology adoption intensity	Jara-Rojas et al. (2020)
Complementary structural support (credit, incentives, inputs)	Impact of extension on adoption and poverty reduction was significantly stronger for farmers who also had access to formal credit	Wossen et al. (2017)
Farmer education level	Extension effect on adoption of improved varieties was greatest where education was low (substitution effect); for more complex natural-resource-management technologies, extension effectiveness rose with farmer education (complementary effect)	Ruzzante, Labarta & Bilton (2021)
Technology complexity / type	Simple technologies (e.g., new varieties) diffuse easily through basic extension; complex, capital-intensive or facility-based technologies (e.g., protected cultivation, precision irrigation) require more intensive, sustained extension support	Cai, Hu & Hong (2022)
Combination of in-person training with digital/ICT follow-up	Training combined with real-time digital extension outperformed training alone on both adoption and yield outcomes	Karki Nepal et al. (2025)
General information access vs. narrowly practice-specific messaging	General information access was a more consistent predictor of adoption across studies than narrowly targeted, single-practice messaging	Arslan et al. (2022)

port rather than technology deployment in isolation (Mulungu, Kassie & Tschopp, 2025). For horticultural crops in particular, where management decisions such as irrigation scheduling, spray timing and harvest windows are highly time-sensitive, this capacity for real-time, low-cost advisory delivery represents a natural complement to periodic in-person training and demonstration, as illustrated by the Nepal rice evidence discussed in Section 5.

DISCUSSION: TOWARD MORE EFFECTIVE HORTICULTURAL EXTENSION

Synthesizing the evidence reviewed, several conclusions emerge about how extension education can be designed to maximize horticultural technology adoption. First, the magnitude of impact is substantial and economically significant — yield gains of 20–30% and income gains exceeding 50% are consistently reported where extension is well implemented — but this impact is conditional on delivery quality rather than guaranteed by the mere existence of an extension programme. Second, hands-on, demonstration-based and group-learning methods (KVK front-line demonstrations, farmer field schools) consistently outperform passive information transfer, echoing findings from the broader agricultural extension literature. Third, technology complexity matters: simple, low-capital innovations such as improved varieties diffuse readily through basic extension contact, while capital-intensive, infrastructure-dependent technologies such as protected cultivation require sustained, higher-intensity engagement paired with credit and input access. Fourth, digital and ICT-based channels add the greatest value not as replacements for in-person extension but as complements that extend its reach and timeliness between physical contacts. Finally, because the knowledge–practice gap is widest precisely for the highest-value, most input-dependent horticultural technologies, extension programmes aiming to raise adoption of such technologies must be integrated with input supply, credit and market-access interventions rather than treated as a purely informational exercise.

These findings carry practical implications for programme design:

- Prioritize demonstration and hands-on formats (front-line demonstrations, farmer field schools) over lecture-based or one-way messaging for technically complex horticultural practices.
- Calibrate extension intensity to technology complexity — simple agronomic practices may require only

light-touch extension, while protected cultivation, precision irrigation and post-harvest infrastructure need sustained, multi-visit engagement.

- Pair extension delivery with credit and input-access mechanisms, since knowledge alone does not overcome capital or market-access constraints for input-dependent technologies.

- Layer digital and ICT-based advisory services onto in-person training to provide timely, context-specific guidance between physical visits, particularly for time-sensitive horticultural operations.

- Diagnose and address farm-specific information gaps (e.g., soil status, market conditions) rather than relying solely on generic technology promotion.

CONCLUSION

Extension education has a demonstrable and economically meaningful impact on the adoption of modern horticultural technologies, with well-implemented interventions raising yields by 20–30%, cutting input costs by roughly a quarter, and lifting farm income by more than half relative to traditional practice. Institutional models built around hands-on demonstration and sustained farmer engagement — India's Krishi Vigyan Kendra system and Farmer Field Schools internationally — consistently outperform passive information delivery, and their effectiveness is further shaped by contact intensity, complementary access to credit and inputs, and the complexity of the technology being extended. Yet a persistent knowledge–practice gap remains, concentrated specifically in horticultural technologies that depend on specialized inputs, capital or market linkages beyond the farmer's direct knowledge or control. Closing this gap will require extension systems that go beyond information transfer to integrate demonstration-based training, digital follow-up, and complementary input and credit access — a combination that the evidence reviewed here identifies as the most reliable pathway from horticultural research to farm-level productivity gains.

REFERENCES

Arslan, A., Floress, K., Lamanna, C., Lipper, L., & Rosenstock, T. S. (2022). A meta-analysis of the adoption of agricultural technology in Sub-Saharan Africa. *PLOS Sustainability and Transformation, 1*(7), e0000018. https://doi.org/10.1371/journal.pstr.0000018

Cai, J., Hu, R., & Hong, Y. (2022). Impact of farmer field schools on agricultural technology extension—evidence from greenhouse vegetable farms in China. *Applied Economics, 54*(24), 2727–2736. https://doi.org/10.1080/00036846.2021.1996530

Jara-Rojas, R., Canales, R., Gil, J. M., Engler, A., Bravo-Ureta, B., & Bopp, C. (2020). Technology adoption and extension strategies in Mediterranean agriculture: The case of family farms in Chile. *Agronomy, 10*(5), 692. https://doi.org/10.3390/agronomy10050692

Justine, P., Ocansey, C. M., & Csorba, Á. (2025). Awareness and adoption strategies for improved agricultural practices (IAPs) by smallholder farmers in the Mbeya Region, Tanzania. *Discover Sustainability, 6*, 198. https://doi.org/10.1007/s43621-025-00970-y

Karki Nepal, A., Choudhary, D., Pandit, N. R., & Khanal, N. (2025). Impact of training and digital extension services on agricultural technology adoption and rice yields. *PLOS ONE, 20*(12), e0337456. https://doi.org/10.1371/journal.pone.0337456

Kumar, A. S., Reddy, M. T. B., & Shashidhar, K. R. (2024). Impact of KVK activities on the adoption of improved horticultural technologies in Kolar district. *International Journal of Agriculture Extension and Social Development, 7*(11), 235–239. https://doi.org/10.33545/26180723.2024.v7.i11d.1319

Mulungu, K. H., Kassie, M., & Tschopp, M. (2025). The role of information and communication technologies-based extension in agriculture: Application, opportunities and challenges. *Information Technology for Development, 31*(4), 1117–1146. https://doi.org/10.1080/02681102.2025.2456232

Priya, N. K., Padhan, S. K. H., Lakra, P. K., Tripathy, P. P., Vamshi, M., Tripathi, S., Shaktawat, P., & Datta, S. (2025). Impact of extension services on knowledge enhancement and adoption of modern onion farming techniques: A review. *Journal of Scientific Research and Reports, 31*(9), 706–718. https://doi.org/10.9734/jsrr/2025/v31i93482

Ruzzante, S., Labarta, R., & Bilton, A. (2021). Adoption of agricultural technology in the developing world: A meta-analysis of the empirical literature. *World Development, 146*, 105599. https://doi.org/10.1016/j.worlddev.2021.105599

Sahu, S., Sharma, J. P., Burman, R. R., Varghese, E., Sharma, R. R., & Kumar, P. (2022). Assessment of knowledge and adoption pattern of post-harvest management practices by Maharashtrian onion farmers. *The Indian Journal of Agricultural Sciences, 91*(12), 1798–1802. https://doi.org/10.56093/ijas.v91i12.120802

Waddington, H., Snilstveit, B., Hombrados, J., Vojtkova, M., Phillips, D., Davies, P., & White, H. (2014). Farmer field schools for improving farming practices and farmer outcomes: A systematic review. *Campbell Systematic Reviews, 10*(1), 1–335. https://doi.org/10.4073/csr.2014.6

Wossen, T., Abdoulaye, T., Alene, A., Haile, M. G., Feleke, S., Olanrewaju, A., & Manyong, V. (2017). Impacts of extension access and cooperative membership on technology adoption and household welfare. *Journal of Rural Studies, 54*, 223–233. https://doi.org/10.1016/j.jrurstud.2017.06.022

Xu, Z., Adeyemi, A. E., Catalan, E., Ma, S., Kogut, A., & Guzman, C. (2023). A scoping review on technology applications in agricultural extension. *PLOS ONE, 18*(11), e0292877. https://doi.org/10.1371/journal.pone.0292877

How to Cite this Article: Kumar Yadav V.. (2025). Impact of Extension Education on Adoption of Modern Horticultural Technologies: A Review. *Agro-Science Letters*, ***1***(4), 1-10. https://doi.org/10.48165/asl.2025.1.04.01