



Adoption Behavior and Outcomes of KVK-Led Capacity-Building Interventions for Vegetable Cultivation in Areas Affected by Saline Irrigation Water in Western Rajasthan, India

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Abstract: Soil salinity poses a significant challenge to agricultural productivity, particularly in arid and semi-arid regions where vegetable cultivation is vulnerable to stress conditions. This study examined adoption behavior and farm-level outcomes associated with capacity-building interventions implemented by ICAR-CAZRI, KVK, Pali, Rajasthan. A multistage sampling design was used to select 120 farmers, comprising 60 trained farmers who participated in KVK-led capacity-building activities and 60 untrained farmers who did not participate during the study period. The composite adoption index among trained farmers increased from 32.4% before participation to 78.6% after completion of the relevant intervention activities. The pre-post comparison indicates a marked within-group change, but because participation was not randomly assigned and comparable baseline and post-intervention observations were not available for the untrained group, the change should not be interpreted as definitive causal evidence of program impact but were treated as indicative. Among individual practices, adoption gains were greatest for drip irrigation (55.0%), salt-tolerant varieties (54.2%), raised-bed cultivation (53.7%), mulching (53.3%) and integrated nutrient management (50.2%). The study also identified major capacity-building needs and constraints under Learning, Extension and Institutional (LEI) components. Trained farmers recorded higher mean yield, gross returns, net returns and benefit-cost ratio than the untrained comparison group. The findings provide field-level evidence of differences in adoption and economic outcomes associated with KVK-led capacity-building in areas affected by saline irrigation water, while highlighting the need for controlled longitudinal studies to establish causal effects.

Key words: Soil salinity, adoption behavior, capacity building, vegetable cultivation, extension services, LEI framework.

Soil salinity is one of the most critical forms of land degradation, posing a severe threat to agricultural sustainability and global food security. It is estimated that more than 800 m

ha of land worldwide is affected by salinity, representing over 6% of the total land area and nearly 20% of irrigated lands (FAO, 2021; Hassani *et al.*, 2021). In India, approximately 6.7 m ha are salt-affected, with significant concentrations in arid and semi-arid regions (CSSRI, 2020). Salinity stress adversely affects soil physicochemical properties, including increased electrical conductivity (EC), sodium adsorption ratio (SAR), and soil pH, which collectively reduce soil fertility, microbial activity, and plant nutrient availability (Shrivastava and Kumar, 2015). In Rajasthan, particularly in districts such as Pali, Jodhpur, and Barmer, the problem is exacerbated by the widespread use of saline groundwater for irrigation and erratic rainfall patterns. Groundwater EC levels often exceed 4 to 8 dS m⁻¹, surpassing the tolerance limits of most vegetable crops (ICAR, 2021). High salinity induces osmotic stress, ion toxicity (especially Na⁺ and Cl⁻), and nutrient imbalances in plants, leading to reduced germination, stunted growth, and ultimately lower yields (Munns and Tester, 2008). Moreover, prolonged use of saline water without appropriate management practices leads to secondary salinization, further degrading soil quality and agricultural productivity (Singh and Kumar, 2025).

Vegetable crops, despite being high-value commodities with significant income potential for smallholder farmers, are particularly sensitive to salinity stress. Crops such as chilli (*Capsicum annuum*), okra (*Abelmoschus esculentus*) and leafy vegetables exhibit yield reductions even at moderate salinity levels (Kumar *et al.*, 2024; Kumar *et al.*, 2025). However, several agronomic and technological interventions have been shown to mitigate the adverse effects of salinity. These include the use of salt-tolerant cultivars, drip irrigation systems that improve water-use efficiency and reduce salt accumulation, mulching to conserve soil moisture, and integrated nutrient management (INM) to maintain soil fertility (Rengasamy, 2010; Flowers and Colmer, 2015). Adoption of such practices can significantly enhance productivity and sustainability in salt-affected agroecosystems. Despite the availability of these technologies, their adoption at the farm level remains suboptimal due to constraints such as limited awareness, lack of technical knowledge, inadequate training, and weak extension support

systems (Singh *et al.*, 2018; Singh *et al.*, 2026). In this context, agricultural extension services play a crucial role in bridging the gap between research and practice. In India, Krishi Vigyan Kendras (KVKs), established under the Indian Council of Agricultural Research (ICAR), serve as frontline extension institutions responsible for technology assessment, refinement, and dissemination through training programs, frontline demonstrations (FLDs), and farmer advisory services. Empirical evidence suggests that capacity-building interventions significantly influence farmers' knowledge, attitudes, and adoption behavior. For instance, Anderson and Feder (2007) highlighted the critical role of extension services in improving agricultural productivity in developing countries. Similarly, Davis *et al.* (2012), in a global meta-analysis, reported that farmer training programs can increase crop productivity by 7 to 25%. In the Indian context, Meena and Yadav (2021) and Singh *et al.* (2022) demonstrated that KVK-led training programs significantly improved adoption of improved agricultural practices and enhanced farm income in arid regions. However, most existing studies focus on general agricultural systems, with limited emphasis on saline environments, where the complexity of stress factors requires location-specific interventions and adaptive management strategies. The effectiveness of training programs under such stress-prone conditions remains inadequately documented, particularly in western Rajasthan. Understanding the impact of capacity-building interventions in these regions is essential for designing targeted extension strategies and promoting climate-resilient agriculture. Therefore, the present study aims to evaluate the effectiveness of capacity-building interventions conducted by KVK Pali on (i) adoption of improved vegetable cultivation practices, (ii) productivity enhancement under saline conditions, and (iii) economic returns to farmers. The findings are expected to provide valuable insights for policymakers, extension agencies and researchers working towards sustainable agricultural development in salt-affected regions.

Materials and Methods

Study area

The study was conducted in Pali district of Rajasthan, India, which forms part of the

western arid region and is characterized by low and variable rainfall, high evaporative demand and considerable seasonal variation in temperature. Annual rainfall is generally low and concentrated during the south-west monsoon, while summer temperatures frequently exceed 45°C. The soils of the district are predominantly sandy loam to clay loam and generally have low organic carbon content and limited water-holding capacity. The soils are predominantly alkaline, with reported pH values ranging from 7.8 to 9.3 (ICAR, 2021). Under these climatic and edaphic conditions, irrigation water quality is an important consideration for sustained vegetable production. The selected study area included villages where farmers use groundwater for irrigation and where saline irrigation water is recognized as an important production constraint. Salinity-related constraints can adversely affect crop establishment, nutrient availability and plant growth, thereby influencing the adoption of appropriate soil, water and crop-management practices (Rengasamy, 2010; Munns and Tester, 2008). Available area-level information indicates that electrical conductivity (EC) of soil and/or irrigation water may reach values of up to 7.4 dS m⁻¹ in parts of the study region. However, individual soil and irrigation-water EC measurements were not available for every sampled farm. Therefore, the study area is described as an area affected by saline irrigation water rather than classifying each sampled farm according to a specific measured EC value. This distinction was considered important for avoiding over interpretation of area-level salinity information.

Sampling design: A multistage sampling procedure was adopted to identify farmers for the assessment of adoption behavior and outcomes associated with KVK-led capacity-building interventions. Pali district was purposively selected because of the occurrence of saline irrigation water, the importance of vegetable cultivation and the implementation of KVK extension activities in the area. Six villages (Hemawas, Sonai Manji, Denda, Madri, Bithura Kalan and Hingola Khurd) were subsequently selected based on their involvement or exposure to KVK extension activities. A total of 120 farmers were included in the study. The respondents were classified into two groups of equal size: 60 trained farmers who had participated in one or

more KVK-led capacity-building activities and 60 untrained farmers who had not participated in these activities during the study period. The capacity-building exposure included training programs, frontline demonstrations, field days, exposure visits, advisory support and opportunities for farmer-to-farmer learning. Thus, the intervention evaluated in the present study represented a broader extension and capacity-building approach rather than formal training alone.

The two groups were not generated through random assignment. Efforts were made during respondent selection to obtain farmers with broadly comparable production and farm characteristics; nevertheless, differences in extension contact, scientific orientation and other socio-personal characteristics were observed between the groups. The untrained farmers were therefore considered a comparison group rather than a randomized control group. In view of this non-randomized design, differences observed between trained and untrained farmers cannot be attributed exclusively to KVK interventions because pre-existing differences between the groups may also have contributed to the observed outcomes. Accordingly, the findings are interpreted primarily as associations between exposure to KVK-led capacity-building activities and farmers' adoption behavior and production/economic outcomes rather than as definitive causal program effects.

Capacity-building interventions

Capacity-building interventions were implemented by Krishi Vigyan Kendra (KVK), Pali, during 2022 to 2024 following a participatory and demand-driven extension approach. The intervention package extended beyond conventional classroom-based training and comprised a combination of on-campus and off-campus training programs, frontline demonstrations (FLDs), field days, exposure visits, advisory services and opportunities for farmer-to-farmer learning. These activities were designed to provide farmers with practical knowledge and skills for selecting and implementing technologies suitable for vegetable production under conditions where saline irrigation water is an important production constraint. The combination of knowledge dissemination, field-based demonstrations and experiential learning is consistent with

established approaches to agricultural extension, in which farmers' access to information and opportunities for learning can influence technology awareness, experimentation and subsequent adoption (Anderson and Feder, 2007; Pannell *et al.*, 2006). The major technologies promoted through the intervention package included comparatively salt-tolerant vegetable crops and varieties, particularly chilli (*Capsicum annuum*), okra (*Abelmoschus esculentus*) and spinach (*Spinacia oleracea*), along with improved crop and resource-management practices. These practices included drip irrigation with fertigation, raised-bed planting, mulching, integrated nutrient management (INM) and integrated pest management (IPM). The interventions emphasized hands-on skill development, field-level validation

of recommended practices and exchange of farmers' experiences. Demonstrations and field-based activities enabled participants to observe the practical operation and management of the technologies under local production conditions, while advisory support facilitated subsequent application at farmers' fields. Such combinations of information, demonstration and experiential learning have been identified as important components of technology dissemination and adoption in agricultural extension programs (Anderson and Feder, 2007; Rogers, 2003; Pannell *et al.*, 2006). Because the intervention comprised several complementary extension activities, exposure was not restricted to a single training event or technology. Farmers could receive different combinations of activities depending on their

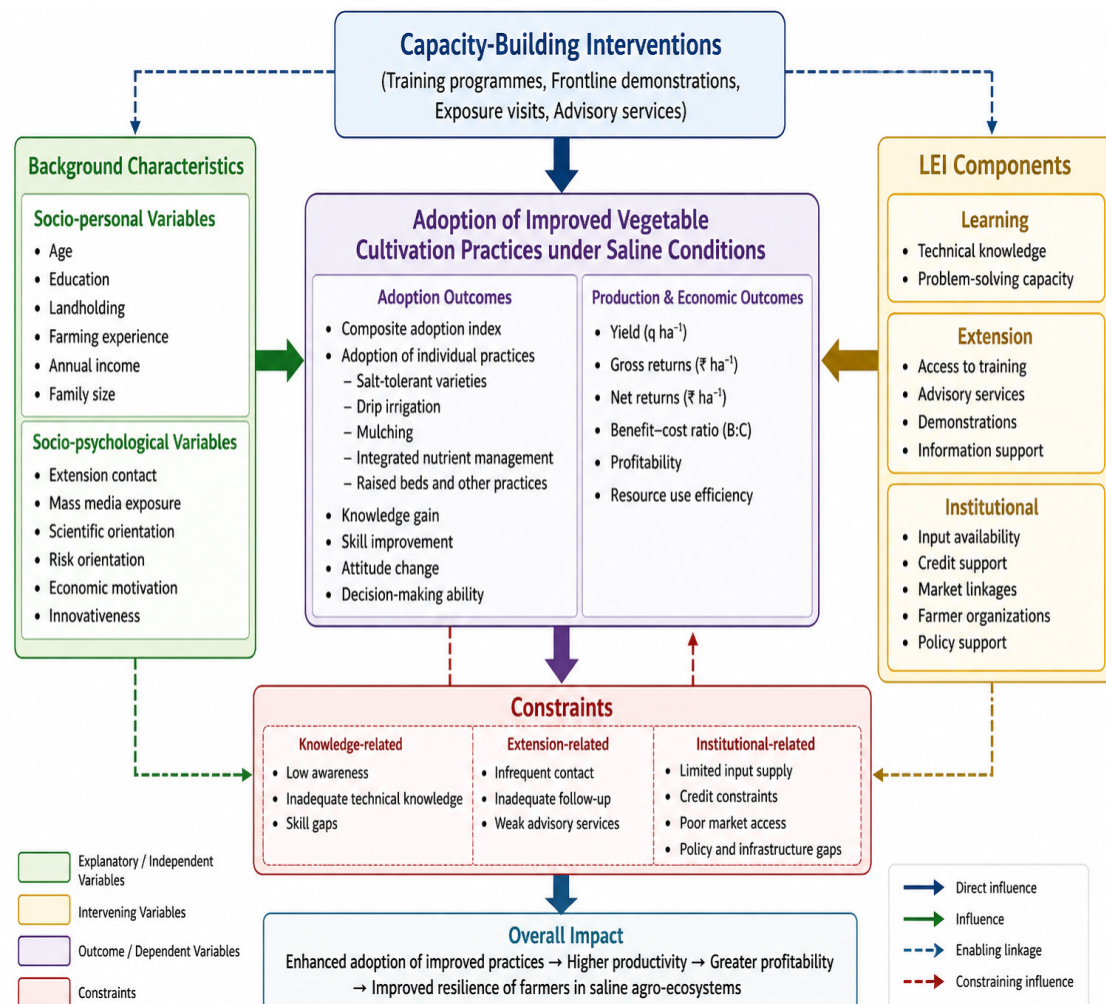


Fig. 1. Conceptual framework illustrating the relationship between KVK-led capacity-building interventions, farmers' adoption of improved vegetable cultivation practices under saline conditions, and production and economic outcomes in Pali district, Rajasthan.

participation and local needs. Accordingly, the present study considers the intervention as a KVK-led capacity-building package, rather than attributing observed differences in adoption or economic outcomes to formal training alone. The conceptual relationships among farmers' background characteristics, capacity-building interventions, learning and extension opportunities, institutional support, adoption outcomes and production and economic outcomes, together with the constraints affecting adoption, are illustrated in Figure 1. The framework draws on established perspectives on agricultural extension, technology diffusion and the adoption of agricultural innovations (Anderson and Feder, 2007; Pannell *et al.*, 2006).

Data collection

Primary data were collected using a pre-tested structured interview schedule, supported by farmer interactions, field observations and KVK records. Information was obtained on socio-economic characteristics, exposure to KVK-led capacity-building activities, adoption of recommended practices, cropping pattern, input use, crop yield, cost of cultivation and economic returns. Such combined approaches are widely used in agricultural extension studies to assess farmers' technology adoption and related outcomes (Anderson and Feder, 2007; Pannell *et al.*, 2006). For adoption assessment, the baseline (before) status referred to the farmer's adoption immediately before participation in the relevant KVK intervention, while the post-intervention status referred to adoption after completion of the relevant activities. Since farmers participated at different times during 2022–2024, assessments were made relative to each farmer's intervention exposure rather than a common calendar date. Pre-intervention information was obtained through farmer recall and, wherever available, cross-checked with field records and KVK registers. Post-intervention information was supplemented through field observations. The possibility of recall bias in retrospective baseline information was recognized. The principal outcomes were adoption of recommended practices, crop yield, cost of cultivation and economic returns. As trained and untrained farmers were not randomly assigned and may have differed in pre-existing characteristics, observed differences were interpreted as associations with KVK-

led interventions rather than definitive causal effects (Pannell *et al.*, 2006; Rogers, 2003).

Analytical framework and statistical analysis

A structured analytical framework was used to assess farmers' adoption behavior and associated production and economic outcomes. The Composite Adoption Index (CAI) was used as the principal measure of overall adoption, supported by practice-wise adoption, crop productivity and economic indicators. Selected socio-personal and socio-psychological characteristics were summarized to describe the respondents and their exposure to extension information. The Learning-Extension-Institutional (LEI) framework was used to organize farmers' learning needs and major constraints related to adoption of the promoted technologies (Rogers, 2003; Pannell *et al.*, 2006).

The adoption percentage (AP) for individual practices was calculated as:

$$AP (\%) = \frac{Na}{N} \times 100$$

where, (Na) is the number of farmers adopting a particular practice and (N) is the total number of farmers assessed.

The Composite Adoption Index (CAI) was calculated as:

$$CAI (\%) = \frac{\text{Total adoption score obtained}}{\text{Maximum possible adoption score}} \times 100$$

The percentage change in adoption was calculated as:

where, (CAI pre and CAI post) represent the mean adoption index before and after the relevant KVK intervention, respectively. A paired t-test was used to examine the pre-post change in adoption among the 60 trained farmers.

Crop productivity was expressed as:

$$\text{Yield (t ha}^{-1}\text{)} = \frac{\text{Total Production (t)}}{\text{Area harvested (ha)}}$$

Economic outcomes were assessed using gross return, net return and benefit-cost ratio. Gross return was calculated as:

$$\text{Gross return} = \text{Quantity of produce} \times \text{Market price}$$

Net return = Gross return - Total cost of cultivation.

$$B:C = \frac{\text{Gross return}}{\text{Total cost of cultivation}} \times 100$$

Frequencies, percentages, means and percentage changes were used to summarize the data and describe differences between the trained and untrained groups. The paired t-test was restricted to the trained group for assessing within-group change and was not interpreted as an independent estimate of program impact. Given the non-randomized study design, differences between the two groups were interpreted as observed associations rather than definitive causal effects of the KVK-led capacity-building interventions.

Results and Discussion

The socio personal and socio psychological characteristics of respondents

The socio-personal and socio-psychological characteristics of the respondents are presented in Table 1. Among the 120 respondents, the largest proportion belonged to the middle-age category (45.0%), followed by old-age (30.0%) and young farmers (25.0%). Educational status indicated that most respondents had primary to secondary-level education, while 20.0% of the respondents were illiterate. Small and marginal farmers together constituted 63.3% of the sample, indicating the predominance of relatively small operational holdings in the study area. Farming experience was predominantly in the medium category (10 to 20 years), accounting for 48.3% of the respondents. The two groups showed broadly comparable distributions for age, education, landholding and farming experience. However, noticeable descriptive differences were observed in the extension-related and socio-psychological characteristics. Among trained farmers, 46.7% belonged to the high extension-contact category compared with 20.0% of untrained farmers. Similarly, high mass-media exposure was reported by 36.7% of trained farmers compared with 20.0% of untrained farmers. The proportion of farmers with high risk orientation was 36.7% among trained farmers and 23.3% among untrained farmers, while high scientific orientation was reported by 36.7% and 20.0% of the respective groups.

The relatively greater extension contact, mass-media exposure and scientific orientation observed among trained farmers may indicate differences in their prior access to agricultural information and willingness to engage with improved production practices. Access to information, learning opportunities and farmers' individual characteristics are recognized as important factors associated with agricultural technology adoption (Anderson and Feder, 2007; Rogers, 2003; Pannell *et al.*, 2006). The observed differences in background characteristics are also relevant when interpreting subsequent adoption and economic outcomes. Since participation in KVK-led capacity-building activities was not based on random assignment, farmers who participated in the interventions may have differed from non-participants in their previous access to information, extension services and other characteristics. Consequently, differences in adoption or economic outcomes between the two groups may reflect both intervention exposure and pre-existing differences between the respondents. The findings are therefore interpreted as observed associations rather than definitive causal effects of the KVK interventions.

LEI components and capacity-building needs of vegetable farmers

The capacity-building needs of vegetable farmers were assessed under three broad components - Learning, Extension and Institutional (LEI) and the results are presented in Table 2. Mean scores indicate the relative priority of different needs on a three-point scale. The highest-ranked needs were knowledge of salt-tolerant vegetable varieties (2.78), scientific crop management under saline conditions (2.65), and training on drip irrigation and fertigation (2.59), indicating strong demand for technical knowledge related to crop and water management under saline conditions. Within the Learning component, knowledge of salt-tolerant varieties ranked first, followed by scientific crop management and integrated nutrient management (INM) practices (2.48). Under Extension, training on drip irrigation and fertigation ranked first, followed by field demonstrations and exposure visits (2.42) and pest and disease management (2.36). The importance given to demonstrations and exposure visits suggests farmers' interest

Table 1. Socio-personal and socio-psychological characteristics of respondents (*n* = 120)

Variable	Category	Trained (<i>n</i> = 60)	Untrained (<i>n</i> = 60)	Overall (%)
Age (years)	Young (<35)	14 (23.3)	16 (26.7)	25.0
	Middle (35–50)	28 (46.7)	26 (43.3)	45.0
	Old (>50)	18 (30.0)	18 (30.0)	30.0
Education	Illiterate	10 (16.7)	14 (23.3)	20.0
	Primary	18 (30.0)	20 (33.3)	31.7
	Secondary	22 (36.7)	18 (30.0)	33.3
	Higher (>Secondary)	10 (16.7)	8 (13.3)	15.0
Land holding (ha)	Marginal (<1)	16 (26.7)	18 (30.0)	28.3
	Small (1–2)	22 (36.7)	20 (33.3)	35.0
	Medium (2–4)	14 (23.3)	14 (23.3)	23.3
	Large (>4)	8 (13.3)	8 (13.3)	13.3
Farming Experience (years)	Low (<10)	12 (20.0)	14 (23.3)	21.7
	Medium (10–20)	30 (50.0)	28 (46.7)	48.3
	High (>20)	18 (30.0)	18 (30.0)	30.0
Extension Contact	Low	10 (16.7)	28 (46.7)	31.7
	Medium	22 (36.7)	20 (33.3)	35.0
	High	28 (46.7)	12 (20.0)	33.3
Mass Media Exposure	Low	14 (23.3)	26 (43.3)	33.3
	Medium	24 (40.0)	22 (36.7)	38.3
	High	22 (36.7)	12 (20.0)	28.3
Risk Orientation	Low	12 (20.0)	24 (40.0)	30.0
	Medium	26 (43.3)	22 (36.7)	40.0
	High	22 (36.7)	14 (23.3)	30.0
Scientific Orientation	Low	10 (16.7)	26 (43.3)	30.0
	Medium	28 (46.7)	22 (36.7)	41.7
	High	22 (36.7)	12 (20.0)	28.3

in practical, field-based learning approaches (Anderson and Feder, 2007; Rogers, 2003). Among Institutional needs, access to quality seeds and inputs ranked first (2.31), followed by credit and financial support (2.25), market

linkages and price information (2.18), and soil and water testing services (2.10). These findings indicate the need for supporting services along with technical knowledge to facilitate adoption of improved practices (Pannell *et al.*, 2006).

Table 2. LEI Components and Vegetable Farmers' Needs for Capacity Building (*n* = 120)

LEI Component	Specific Need Area	Mean Score*	Rank
Learning	Knowledge on salt-tolerant vegetable varieties	2.78	I
Learning	Scientific crop management under saline conditions	2.65	II
Extension	Training on drip irrigation and fertigation	2.59	III
Learning	Integrated Nutrient Management (INM) practices	2.48	IV
Extension	Field demonstrations and exposure visits	2.42	V
Extension	Pest and disease management (IPM)	2.36	VI
Institutional	Access to quality seeds and inputs	2.31	VII
Institutional	Credit and financial support facilities	2.25	VIII
Institutional	Market linkages and price information	2.18	IX
Institutional	Soil and water testing services	2.10	X

*Note: Mean score was calculated on a three-point continuum: 3 = highly needed, 2 = moderately needed and 1 = least needed. Ranks were assigned in descending order of mean score. The ranking represents the relative priority of farmers' reported capacity-building needs and does not imply statistical significance among the mean scores.

Constraints faced by vegetable farmers in utilizing LEI components

The analysis of Learning, Extension, and Institutional (LEI) constraints (Table 3) revealed multiple interrelated barriers affecting the adoption of improved vegetable cultivation practices under saline conditions. Among learning constraints, lack of knowledge on salinity management (76.7%) was the most critical, followed by inadequate awareness of integrated nutrient and pest management practices, indicating persistent knowledge gaps. Extension-related constraints were also prominent, with farmers reporting inadequate training programs (73.3%), limited access to field demonstrations (70.0%), and weak extension contact with insufficient follow-up support (58.3%). These findings highlight deficiencies in the delivery and continuity of advisory services. Institutional constraints further limited adoption, particularly the high cost of inputs and drip irrigation systems (67.5%), restricted access to quality seeds (65.0%), and inadequate availability of timely credit (55.0%). Poor market linkages and lack of price information (51.7%) additionally constrained farmers' ability to realize economic benefits. Overall, the results indicate that adoption barriers are multidimensional, with learning and extension gaps acting as primary constraints, while institutional limitations restrict scalability and sustainability. These findings are consistent with previous studies emphasizing the role of knowledge access, extension effectiveness, and institutional support in influencing technology adoption (Pannell *et al.*, 2006; Anderson and Feder, 2007; Davis *et al.*, 2012; Meena and Yadav, 2021).

Adoption behavior of improved vegetable cultivation practices.

The adoption behavior of the trained farmers before and after participation in KVK-led capacity-building activities is presented in Table 4. Among the 60 trained farmers, the Composite Adoption Index (CAI) increased from 32.4% before participation to 78.6% after completion of the relevant intervention activities, representing a 46.2 percentage-point increase. The paired comparison showed a significant within-group change in adoption ($t = 9.85$, $p \leq 0.01$). This result indicates an improvement in adoption among the trained farmers over the intervention period; however, the paired t-test represents a within-group comparison and does not establish that the observed change was caused solely by the KVK intervention. At the practice level, the largest increase in adoption was observed for drip irrigation (55.0 percentage points), followed by salt-tolerant varieties (54.2), raised-bed cultivation (53.7), mulching (53.3) and integrated nutrient management (INM) practices (50.2). The variation in adoption gains may be related to differences in the knowledge requirements, cost, complexity, perceived risk and expected benefits associated with individual practices. Similar factors have been reported to influence farmers' decisions to adopt agricultural technologies and conservation practices (Anderson and Feder, 2007; Pannell *et al.*, 2006). Farmer training and practical learning opportunities can also contribute to improved understanding and application of recommended technologies (Davis *et al.*, 2012). The untrained farmers were included as a comparison group; however, comparable pre- and post-intervention adoption observations

Table 3. Constraints faced by vegetable farmers in utilizing LEI components ($n = 120$)

LEI Component	Constraints	Frequency	Percentage (%)	Rank
Learning	Lack of knowledge on salinity management practices	92	76.7	I
Extension	Inadequate training programs on improved technologies	88	73.3	II
Extension	Limited access to field demonstrations and exposure visits	84	70.0	III
Institutional	High cost of drip irrigation and inputs	81	67.5	IV
Institutional	Limited access to quality seeds and planting material	78	65.0	V
Learning	Poor awareness of integrated nutrient management (INM)	74	61.7	VI
Extension	Weak extension contact and follow-up support	70	58.3	VII
Institutional	Lack of timely credit and financial support	66	55.0	VIII
Institutional	Inadequate market information and linkages	62	51.7	IX
Learning	Limited knowledge of pest and disease management (IPM)	58	48.3	X

Table 4. Adoption of improved vegetable cultivation practices before and after KVK-Led capacity-building intervention among trained farmers ($n = 60$)

Practice	Before training (%)	After training (%)	Mean difference	% increase	Rank*
Drip irrigation	15.0	70.0	55.0	366.7	I
Salt-tolerant varieties	28.3	82.5	54.2	191.5	II
Raised bed cultivation	18.6	72.3	53.7	288.7	III
Mulching	12.5	65.8	53.3	426.4	IV
INM practices	30.2	80.4	50.2	166.2	V
Composite adoption index (CAI)	32.4	78.6	46.2	—	—

*Rank based on the magnitude of the percentage-point increase (after – before). Composite Adoption Index (CAI) = (sum of adoption scores obtained by a farmer / maximum possible adoption score) $\times$ 100. Adoption of each assessed practice was recorded on a three-point scale (0 = non-adoption, 1 = partial adoption, 2 = full adoption); higher CAI indicates greater overall adoption. The CAI values reported here refer to the trained farmers only.

were not available for this group. Therefore, a formal difference-in-differences analysis could not be undertaken. The observed changes should consequently be interpreted as evidence of within-group association rather than as a definitive causal estimate of the effect of KVK interventions.

Economic analysis of improved practices

The economic outcomes associated with improved vegetable cultivation practices are presented in Table 5. The trained farmers recorded higher mean yield and economic returns than the untrained comparison group. Mean yield was 142.5 q ha⁻¹ among trained farmers compared with 98.0 q ha⁻¹ among untrained farmers. Similarly, mean gross returns were Rs. 1,48,000 and Rs. 96,500 ha⁻¹, respectively, while mean net returns were Rs. 85,500 and Rs. 41,300 ha⁻¹. The higher returns were accompanied by a higher mean cost of cultivation among trained farmers (Rs. 62,500 ha⁻¹) than among untrained farmers (Rs. 55,200 ha⁻¹). The corresponding benefit-cost ratios were 2.37 and 1.75, respectively. Based on the group means, net returns were 107.0% higher and yield was 45.4% higher in the trained

group, whereas the cost of cultivation was 13.2% higher and gross returns were 53.4% higher. These results indicate differences in the observed production and economic outcomes between the two groups. However, the economic estimates are based on group means and were not subjected to retrospective significance testing because individual-farmer observations and complete inferential outputs were not available. Moreover, the trained and untrained farmers were not randomly assigned and differed in some background characteristics, particularly extension contact and information-related variables. Therefore, the higher economic outcomes observed among trained farmers cannot be attributed exclusively to KVK-led capacity-building activities (Qadir *et al.*, 2014). The findings should be interpreted as an association between intervention participation and the observed production and economic outcomes.

Study limitations and interpretation

The principal limitation is the non-randomized comparison design. The 60 trained farmers participated in a broader package of KVK activities, while the 60 untrained farmers

Table 5. Economic outcomes of improved vegetable cultivation practices among trained and untrained farmers (group means; $n = 60$ per group)

Particulars	Trained farmers	Untrained farmers	% Change*
Cost of cultivation (Rs. ha ⁻¹)	62,500	55,200	+13.2
Gross returns (Rs. ha ⁻¹)	1,48,000	96,500	+53.4
Net returns (Rs. ha ⁻¹)	85,500	41,300	+107.0
Benefit-cost ratio (B:C)	2.37	1.75	—
Yield (q ha ⁻¹)	142.5	98.0	+45.4

*Percentage change calculated as [(trained – untrained) / untrained] $\times$ 100. Values are group means and are presented descriptively; no statistical significance is implied.

did not participate during the study period. Because the groups differed descriptively in extension contact and scientific orientation and comparable baseline/post-intervention observations were not available for the comparison group, selection effects and other pre-existing differences cannot be separated from intervention-associated changes. The paired t-test therefore demonstrates within-group change among trained farmers but does not establish causal impact. Similarly, the economic comparisons are descriptive group means. Future studies should use longitudinal baseline and follow-up observations for both groups and, where feasible, randomized or quasi-experimental designs to strengthen causal inference.

Conclusions

The study indicates a marked increase in the composite adoption index among the 60 trained farmers, from 32.4% before participation to 78.6% after completion of the relevant KVK intervention activities. Practice-wise adoption gains were observed for drip irrigation, salt-tolerant varieties, raised-bed cultivation, mulching and integrated nutrient management. Trained farmers also recorded higher mean yield, gross returns, net returns and benefit-cost ratio than the untrained comparison group. However, the intervention comprised multiple components—training, frontline demonstrations, field days, exposure visits, advisory support and farmer-to-farmer learning—and farmers were not randomly assigned. Differences in extension contact, scientific orientation and other characteristics between groups may therefore contribute to the observed differences. The findings should consequently be interpreted as an association between KVK-led capacity-building participation and observed adoption and economic outcomes rather than as definitive causal effects. Future studies should collect baseline and post-intervention data for both groups and use randomized or quasi-experimental designs, such as difference-in-differences, to estimate program effects more rigorously.

Authors' Contribution

All the authors involved in this study contributed to the fieldwork, data collection, analysis, interpretation and writing of manuscript.

Conflict of Interest

All authors agree to publication and there is no any conflict of interest.

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