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TRAINING AND NEED ASSESSMENT OF FARMERS REGARDING ASEXUAL PLANT PROPAGATION TECHNIQUES IN HORTICULTURAL PLANTS: A CASE STUDY OF PATTOKI, PUNJAB, PAKISTAN

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ABSTRACT

This research investigates the training needs and knowledge gaps among farmers in Pattoki, Kasur District, Punjab, Pakistan, regarding asexual plant propagation techniques in horticultural crops. Despite favorable agro-climatic conditions for horticulture, adoption of modern propagation methods remains limited. A comprehensive need assessment was conducted involving 150 farmers to evaluate their current knowledge, skill levels, resource availability, and training preferences. Results indicate significant knowledge deficits in advanced propagation techniques, with 78% of farmers relying exclusively on seedling propagation. Major constraints include limited technical knowledge (85%), inadequate access to quality rootstocks (72%), and insufficient extension services (68%). The study proposes a multi-stakeholder training framework incorporating practical demonstrations, farmer field schools, and digital learning platforms. Implementation of targeted training interventions can enhance farmer competency, improve crop quality, and increase agricultural income by an estimated 25-40%. This research contributes to sustainable horticultural development strategies in Punjab's agricultural landscape.
Keywords: *Asexual propagation, horticultural training, need assessment, grafting, budding, farmer capacity building, Pattoki, Punjab*

1. Introduction

1.1 Background

Punjab province serves as Pakistan's agricultural backbone, contributing approximately 60% of national food production and supporting over 68% of the country's farming population (Government of Punjab, 2023). Within this agricultural landscape, Pattoki tehsil in Kasur District represents a region with substantial but underutilized horticultural potential. The area's semi-arid climate, characterized by hot summers and mild winters, combined with fertile alluvial soils, provides ideal conditions for cultivating citrus, mango, guava, and various vegetable crops (Ahmad et al., 2021).Asexual or vegetative plant propagation encompasses techniques including grafting, budding, layering, cutting, and tissue culture, which enable multiplication of plants without sexual reproduction (Hartmann et al., 2018). These methods offer critical advantages over seed propagation: genetic uniformity, maintenance of desirable traits, disease resistance, reduced juvenile period, and consistent crop quality (Baloch et al., 2019). In commercial horticulture, asexual propagation has become indispensable for producing elite planting material that ensures predictable yields and market-acceptable fruit quality.Despite documented benefits, adoption rates of advanced propagation techniques among small-scale farmers in Punjab remain disappointingly low, estimated at less than 30% in rural districts (Hussain et al., 2020). This adoption gap represents a significant constraint to horticultural productivity enhancement and income generation for farming communities.

1.2 Problem Statement

Farmers in Pattoki predominantly utilize traditional seedling propagation methods, resulting in several adverse outcomes: prolonged juvenile phases (5-7 years for mango and citrus), genetic heterogeneity leading to variable fruit quality, increased susceptibility to soil-borne pathogens, and reduced economic returns (Nasir et al., 2022). These limitations not only constrain individual farm productivity but also affect the competitiveness of Punjab's horticultural sector in domestic and international markets.The persistence of traditional methods despite proven alternatives suggests systemic barriers extending beyond simple awareness. Preliminary observations indicate multifaceted challenges including insufficient technical training, limited access to quality propagation materials, inadequate extension support, economic constraints, and socio-cultural resistance to innovation (Sheikh et al., 2021).

1.3 Research Objectives

This study aims to:

1. Assess current knowledge levels and practices of Pattoki farmers regarding asexual plant propagation techniques
2. Identify specific skill gaps and technical deficiencies in propagation methods
3. Evaluate resource availability and constraints (tools, materials, infrastructure)
4. Determine training preferences, learning styles, and logistical considerations
5. Analyze economic barriers affecting technology adoption
6. Develop evidence-based recommendations for training program design and implementation

1.4 Significance of the Study

This research addresses a critical gap in Pakistan's agricultural extension literature by providing localized, empirical data on farmer training needs in vegetative propagation. Findings will inform agricultural extension agencies, research institutions, and development organizations in designing contextually appropriate capacity-building interventions. Furthermore, successful training implementation could serve as a replicable model for other districts in Punjab and beyond, contributing to national horticultural development objectives and sustainable livelihood enhancement.

2. Literature Review

2.1 Asexual Propagation Techniques in Horticulture

Asexual propagation represents a cornerstone of modern horticultural production systems worldwide. Hartmann et al. (2018) provide comprehensive documentation of propagation principles, emphasizing that vegetative methods enable precise replication of elite genotypes, a capability impossible through seed propagation due to genetic segregation. The primary techniques relevant to Punjab's horticultural context include:

Grafting and Budding: These techniques involve joining tissues of two plants—a rootstock and scion—to create a composite plant combining desirable attributes of both (Mudge et al., 2009). In citrus cultivation, grafting onto disease-resistant rootstocks has proven essential for managing soil-borne pathogens, particularly in areas with citrus decline problems (Khan et al., 2020). Success rates depend heavily on cambial compatibility, proper timing, and technical precision during execution.

Stem Cuttings: Adventitious root formation from stem segments represents the simplest propagation method for species with high rooting potential, including guava, pomegranate, and various ornamentals (Leakey, 2004). Environmental manipulation—particularly humidity, temperature, and substrate composition—critically influences rooting success (Ali et al., 2019).

Air Layering: This technique involves inducing root formation on attached stems before separation from parent plants, particularly valuable for species with low rooting capacity such as litchi and certain mango cultivars (Rahman et al., 2017). While labor-intensive, air layering yields larger transplants with established root systems.

Tissue Culture: Micropropagation technologies enable rapid multiplication of pathogen-free planting material under controlled laboratory conditions (George et al., 2008). Although technologically advanced, tissue culture requires substantial infrastructure and expertise, limiting accessibility for small-scale farmers.

2.2 Horticultural Scenario in Punjab, Pakistan

Punjab's horticultural sector has experienced notable expansion over the past two decades, with total fruit production increasing from 1.8 million tons in 2000 to 3.6 million tons in 2020 (Pakistan Bureau of Statistics, 2021). Citrus dominates provincial fruit production, particularly the Kinnow mandarin, which accounts for approximately 95% of citrus cultivation (Iqbal et al., 2020). However, productivity levels remain below potential, averaging 8-10 tons/hectare compared to international benchmarks of 20-25 tons/hectare for well-managed citrus orchards.Several studies have documented constraints to horticultural intensification in Punjab. Ahmad and Chaudhry (2018) identified poor quality planting material as a primary limiting factor, with approximately 60% of nursery stock originating from unverified sources lacking genetic purity and phytosanitary certification. This situation perpetuates yield gaps and quality inconsistencies across the production chain.

2.3 Farmer Training and Extension Services

Agricultural extension systems in Pakistan have historically focused on cereal crops, particularly wheat and rice, resulting in relative neglect of horticultural knowledge dissemination (Chandio et al., 2021). The extension worker-to-farmer ratio in Punjab averages 1:2000, far exceeding the recommended ratio of 1:500 for effective technology transfer (Abbas et al., 2020). This resource constraint severely limits personalized technical assistance for specialized techniques like grafting and budding.Participatory extension methodologies, particularly Farmer Field Schools (FFS), have demonstrated superior outcomes in skill-based training compared to conventional lecture-based approaches (Davis et al., 2012). FFS implemented for integrated pest management in Punjab achieved adoption rates of 65-75%, substantially higher than conventional training programs (Saleem et al., 2018). These findings suggest that experiential, hands-on training formats may prove more effective for teaching manual skills required in plant propagation.

2.4 Technology Adoption Barriers

Rogers' (2003) diffusion of innovations theory provides a valuable framework for understanding agricultural technology adoption. Multiple studies in Pakistani contexts have identified key determinants of adoption including perceived relative advantage, complexity, trialability, observability, and compatibility with existing practices (Ashraf et al., 2017).Economic factors substantially influence adoption decisions among resource-constrained farmers. Initial investment requirements for propagation tools, shade structures, and irrigation systems can represent significant financial barriers (Nazir et al., 2019). Additionally, the time lag between investment and return—often 3-5 years for fruit trees—creates cash flow challenges discouraging adoption.Socio-cultural dimensions also affect technology uptake. In rural Punjab, farming practices often reflect traditional knowledge transmitted intergenerationally, creating psychological resistance to externally introduced innovations (Hussain et al., 2019). Educational levels correlate positively with innovation adoption, yet rural literacy rates in Kasur District remain at approximately 55%, limiting farmer capacity to access written technical resources (Pakistan Bureau of Statistics, 2017).

2.5 Research Gaps

While substantial literature exists on propagation techniques and extension methodologies globally, localized research addressing specific training needs in Pakistani contexts remains limited. No comprehensive need assessment has been published specifically for Pattoki or similar districts in Punjab. This study addresses this gap through systematic empirical investigation, providing baseline data essential for evidence-based training program design.

3. Materials and Methods

3.1 Study Area

This research was conducted in Pattoki tehsil, Kasur District, Punjab Province, Pakistan (31.02°N, 73.85°E). The study area encompasses approximately 125,000 hectares, with 35% under agricultural cultivation. The region experiences a semi-arid subtropical climate with mean annual rainfall of 450-600 mm, concentrated during monsoon months (July-September). Temperature ranges from 2-5°C in winter to 40-47°C in summer. Predominant soil types include loamy and sandy loam textures with moderate fertility levels.Pattoki's horticultural landscape includes approximately 8,500 hectares of orchards and vegetable cultivation, supporting an estimated 12,000 farming families. Primary horticultural crops include citrus (Kinnow mandarin, 65%), mango (20%), guava (10%), and various vegetables (5%).

3.2 Sampling Strategy

A multi-stage random sampling approach was employed to ensure representative coverage of Pattoki's farming community:

Stage 1: Selection of Union Councils - Four union councils (Pattoki Urban, Pattoki Rural, Bhopay Wal and Kothi Wala) were randomly selected from Pattoki, representing different agro-ecological and socio-economic zones.

Stage 2: Village Selection - Three villages were randomly selected from each union council, yielding 12 study villages.

Stage 3: Farmer Selection - From each village, 12-13 farmers engaged in horticultural cultivation were randomly selected from lists maintained by local agricultural extension offices, totaling 150 respondents.

Sample size determination followed Yamane's (1967) formula with 95% confidence level and 5% margin of error, yielding a minimum required sample of 145 farmers. The actual sample of 150 provided adequate statistical power.

3.3 Data Collection Instruments

3.3.1 Structured Questionnaire

A comprehensive questionnaire was developed comprising five sections:

Section A: Demographic and Farm Characteristics - Age, education, farming experience, farm size, crop portfolio, annual income.

Section B: Current Knowledge Assessment - Twenty multiple-choice questions assessing theoretical understanding of propagation principles, technique identification, timing, and troubleshooting. Knowledge scoring: 0-7 (low), 8-14 (medium), 15-20 (high).

Section C: Current Practice Evaluation - Self-reported practices in propagation, sources of planting material, challenges encountered, success rates.

Section D: Resource Availability - Access to tools, rootstocks, propagation structures, irrigation facilities, financial resources.

Section E: Training Preferences - Preferred training formats, timing, duration, content priorities, willingness to pay.

The questionnaire was initially developed in English, translated to Urdu, and back-translated to ensure linguistic accuracy. Pre-testing with 20 farmers outside the study area facilitated refinement before final administration.

3.3.2 Hands-on Skill Assessment

A practical evaluation was conducted with a subset of 50 randomly selected farmers to assess actual technical competency. Participants were asked to demonstrate grafting and budding techniques on standardized rootstock materials. Performance was evaluated using a rubric assessing:

- Rootstock preparation (scoring 0-5)
- Scion selection and preparation (0-5)
- Joining technique and precision (0-5)
- Wrapping and securing (0-5)
- Overall quality assessment (0-5)

Total skill scores ranged 0-25, categorized as: inadequate (0-10), basic (11-17), proficient (18-25).

3.3.3 Focus Group Discussions

Six focus group discussions (FGDs) were conducted, each comprising 8-10 farmers representing diverse age groups and experience levels. FGDs explored qualitative dimensions including:

- Perceptions of propagation techniques
- Cultural and social factors affecting adoption
- Specific challenges and success stories
- Suggestions for training program design

FGDs were conducted in Punjabi, audio-recorded with participant consent, transcribed, and thematically analyzed.

3.3.4 Key Informant Interviews

Semi-structured interviews were conducted with 12 key informants including:

- Agricultural extension officers (n=4)
- Nursery operators (n=4)
- Progressive farmers practicing propagation (n=4)

These interviews provided contextual insights and triangulated farmer-reported information.

3.4 Data Collection Procedure

Data collection occurred during February-April 2024, timed to avoid peak agricultural activity periods. A team of four trained enumerators, familiar with local language and culture, administered questionnaires through face-to-face interviews lasting 45-60 minutes. Practical skill assessments were conducted at demonstration farms in each union council.

3.5 Data Analysis

Quantitative data were analyzed using SPSS version 26.0. Analytical techniques included:

- Descriptive statistics (frequencies, percentages, means, standard deviations)
- Chi-square tests for categorical associations
- Independent t-tests and ANOVA for group comparisons
- Correlation analysis examining relationships between variables
- Multiple regression analysis identifying determinants of knowledge levels

Qualitative data from FGDs and interviews underwent thematic content analysis following Braun and Clarke's (2006) six-phase framework: familiarization, initial coding, theme development, theme review, definition and naming, and report production.

3.6 Ethical Considerations

The study protocol received approval from the University of Agriculture, Faisalabad Ethics Committee. All participants provided informed consent after receiving clear explanations of research objectives, procedures, and their rights. Anonymity and confidentiality were maintained throughout data collection and analysis. Participants received no monetary compensation but were provided with informational pamphlets on propagation techniques as a token of appreciation.

4. Results and Discussion

4.1 Demographic and Farm Characteristics

Table 1 presents demographic profiles of respondents (n=150). The majority of farmers were male (92%), reflecting prevailing gender patterns in Punjab's agricultural sector. Age distribution showed 38% between 31-45 years, representing farmers in their productive prime. Educational attainment remained modest, with 42% having primary education or less, and only 15% possessing secondary or higher education. Average farming experience was 18.6 years (±7.3 SD), indicating substantial practical knowledge though potentially entrenched in traditional methods.

Table 1: Demographic Characteristics of Respondents

Variable	Category	Frequency	Percentage
Gender	Male	138	92.0
	Female	12	8.0
Age (years)	≤30	28	18.7
	31-45	57	38.0
	46-60	49	32.7
	>60	16	10.6
Education	Illiterate	36	24.0
	Primary (1-5 years)	27	18.0
	Middle (6-8 years)	35	23.3
	Secondary (9-10 years)	30	20.0
	Higher Secondary+	22	14.7
Farm Size	Small (≤2.5 acres)	62	41.3
	Medium (2.6-12.5 acres)	71	47.3
	Large (>12.5 acres)	17	11.4

Farm holdings averaged 5.8 acres (±4.2 SD), with 41.3% classified as small farmers (≤2.5 acres). Horticultural crops occupied an average of 2.1 acres per farm, representing 36% of total cultivated area. Citrus dominated crop portfolios (68% of farmers), followed by mango (45%), guava (28%), and vegetables (22%), with many farmers cultivating multiple horticultural species.

4.2 Current Knowledge Levels

Knowledge assessment scores revealed concerning deficiencies in understanding asexual propagation principles (Table 2). Mean knowledge score was 8.4 (±3.6 SD) out of 20, placing the average respondent in the "low knowledge" category. Only 16% of farmers demonstrated high knowledge levels, while 58% scored in the low category.

Table 2: Knowledge Distribution Among Respondents

Knowledge Category	Score Range	Frequency	Percentage	Mean Score (±SD)
Low	0-7	87	58.0	5.2 ± 1.8
Medium	8-14	39	26.0	10.8 ± 2.1
High	15-20	24	16.0	17.1 ± 1.6
Overall		**150**	**100**	**8.4 ± 3.6**

Specific knowledge gaps emerged through item analysis:

- **Grafting compatibility:** Only 23% correctly identified compatible rootstock-scion combinations for citrus
- **Optimal timing:** 31% understood appropriate seasonal windows for different propagation techniques
- **Cambium alignment:** 19% comprehended the critical importance of cambial contact in grafting
- **Hormone application:** 15% were aware of auxin use for rooting enhancement
- **Disease management:** 28% could identify common propagation-related diseases

Statistical analysis revealed significant associations between knowledge levels and education (χ^2=28.47, p<0.001), with higher education correlating positively with knowledge scores. Age showed a negative correlation (r=-0.34, p<0.01), suggesting younger farmers possessed better knowledge, possibly due to recent exposure to agricultural education or information technology.

4.3 Current Propagation Practices

Assessment of existing practices revealed heavy reliance on traditional methods (Figure 1). An overwhelming 78% of farmers used exclusively seedling propagation for establishing orchards. Only 22% had attempted any form of asexual propagation, and within this group, success rates remained disappointingly low.

Among the 33 farmers with propagation experience:

- **Grafting:** Attempted by 18 farmers (54.5%), with reported success rates of 20-40%
- **Budding:** Attempted by 12 farmers (36.4%), with success rates of 15-35%
- **Stem cuttings:** Attempted by 15 farmers (45.5%), with success rates of 30-50%
- **Air layering:** Attempted by 8 farmers (24.2%), with success rates of 40-60%

These low success rates reflect insufficient technical proficiency and suboptimal environmental management. Comparative studies in India's Punjab region report success rates of 75-85% for grafting and 70-80% for budding when performed by trained personnel under proper conditions (Singh et al., 2019), highlighting the substantial improvement potential.

Sources of Planting Material: Farmers obtained planting material predominantly from local nurseries (67%), informal sources including neighbors and relatives (21%), government nurseries (8%), and own propagation (4%). Quality assurance remained problematic, with 73% of farmers reporting genetic variability in seedling-raised orchards and 56% experiencing disease problems traced to planting material.

4.4 Hands-on Skill Assessment Results

Practical evaluation of 50 randomly selected farmers demonstrated severe technical deficiencies (Table 3). Mean overall skill score was 7.8 (±4.2 SD) out of 25, placing average performance in the "inadequate" category. Not a single farmer demonstrated proficient-level skills, while 82% scored in the inadequate range.

Table 3: Practical Skill Assessment Scores (n=50)

Skill Component	Mean Score	Maximum Score	Percentage
Rootstock preparation	1.6 ± 0.9	5	32%
Scion selection/preparation	1.4 ± 1.1	5	28%
Joining technique	1.2 ± 0.8	5	24%
Wrapping and securing	2.1 ± 1.3	5	42%
Overall quality	1.5 ± 1.1	5	30%
Total Score	**7.8 ± 4.2**	**25**	**31.2%**

Common technical errors observed included:

- Improper blade sterilization (94% of participants)
- Incorrect cutting angles (88%)
- Inadequate cambial alignment (92%)
- Excessive handling causing tissue damage (76%)
- Improper wrapping tension (81%)
- Failure to protect graft unions from desiccation (89%)

These findings align with hands-on assessments conducted in similar contexts. A study in Bangladesh reported that untrained farmers achieved only 18-25% success in grafting compared to 75-80% for trained farmers (Rahman et al., 2020), underscoring the critical importance of practical skill development.

4.5 Resource Availability and Constraints

Resource constraints emerged as significant adoption barriers (Table 4). The majority of farmers lacked basic propagation infrastructure and materials.

Table 4: Resource Availability Among Farmers

Resource	Available	Not Available
Grafting/budding knives	12%	88%
Polyethylene wrapping	8%	92%
Shade structures	15%	85%
Mist/irrigation for propagation	11%	89%
Quality rootstock access	19%	81%
Propagation growing media	14%	86%

Financial constraints significantly limited resource acquisition. Average monthly farm income was PKR 32,400 (approximately USD 115), with 68% of farmers reporting insufficient capital for investing in propagation infrastructure. A complete basic propagation kit (knives, wrapping materials, rooting hormones, shade structure) costs approximately PKR 15,000-20,000, representing a substantial investment for small-scale farmers.Geographic isolation compounded resource challenges. Average distance to the nearest supplier of quality propagation materials was 28 kilometers, creating transportation costs and logistical difficulties. Only 19% of farmers reported easy access to certified rootstock sources.

4.6 Extension Service Coverage

Agricultural extension contact remained inadequate for horticultural knowledge dissemination. Within the previous year, 68% of farmers had received no extension visits specifically addressing horticultural practices. Among the 32% who received visits, contact averaged 2.1 visits annually, insufficient for technical skill development in complex procedures like grafting.Extension materials specifically addressing propagation techniques were scarce. Only 11% of farmers had ever received written or visual materials on vegetative propagation. This deficiency reflects broader systemic challenges in Pakistan's extension services, where limited budgets, inadequate transportation, and high agent-to-farmer ratios constrain effective outreach (Abbas et al., 2020).

4.7 Training Needs and Preferences

Respondents expressed strong interest in training, with 91% indicating willingness to participate if programs were designed appropriately. Specific training preferences emerged through survey and FGD analysis:

Content Priorities (Ranked):

1. Practical grafting and budding techniques (94%)
2. Rootstock selection and management (87%)
3. Proper timing and environmental conditions (83%)
4. Disease prevention in propagated plants (79%)
5. Nursery establishment and management (74%)
6. Economic analysis and profitability (71%)

Preferred Training Formats:

- Hands-on practical demonstrations (89%)
- Farmer Field Schools (67%)
- Demonstration plots/model nurseries (78%)
- Short-term workshops (56%)
- Video demonstrations (63%)
- Farmer-to-farmer extension (52%)

Logistical Preferences:

- Optimal training duration: 3-5 days intensive program (64%)
- Preferred timing: Post-harvest period (November-January) (72%)
- Location preference: Village-level venues (76%)
- Group size: 15-20 participants (68%)
- Follow-up support: Bi-monthly visits for 6 months (81%)

Willingness to pay for training varied by economic status. Small farmers (≤2.5 acres) expressed ability to contribute PKR 500-1000 per training program, while medium and large farmers indicated capacity for PKR 1500-3000. However, 58% emphasized that cost should not be a prohibitive barrier, suggesting need for subsidized or free training for resource-constrained farmers.

4.8 Perceived Barriers to Adoption

Through FGDs and survey responses, farmers identified multiple constraints affecting adoption of asexual propagation techniques (Figure 2, ranked by frequency of mention):

1. **Lack of technical knowledge (85%):** Farmers repeatedly emphasized insufficient understanding of proper techniques, timing, and troubleshooting.
2. **High initial investment (72%):** Capital requirements for tools, materials, and infrastructure exceeded financial capacity.
3. **Limited access to quality rootstocks (71%):** Certified, disease-free rootstock availability remained problematic.
4. **Inadequate training opportunities (68%):** Few accessible training programs addressing propagation skills.
5. **Risk aversion (64%):** Fear of failure and financial loss discouraged experimentation with unfamiliar methods.
6. **Time and labor requirements (59%):** Propagation demands intensive attention during critical periods, competing with other farm activities.
7. **Lack of immediate returns (54%):** Multi-year lag before economic benefits discouraged farmers facing liquidity constraints.
8. **Market linkages (47%):** Uncertainty about markets for propagated planting material limited commercial nursery interest.

A representative FGD quote captures prevalent sentiment: *"We know grafted plants give better fruit, but we don't know how to do grafting properly. Government nursery is far, and local nurseries charge high prices. If someone teaches us properly and helps us get rootstocks, we want to learn."* (Male farmer, 48 years, Kothi Wala)

4.9 Determinants of Knowledge Levels

Multiple regression analysis examined factors influencing propagation knowledge scores (Table 5). The model explained 47.3% of variance in knowledge levels (R^2=0.473, F=16.82, p<0.001).

Table 5: Regression Analysis - Determinants of Knowledge Levels

Variable	β Coefficient	Standard Error	t-value	p-value
Education level	0.342	0.087	3.93	<0.001***
Age	-0.218	0.095	-2.29	0.023*
Farm size	0.164	0.112	1.46	0.146
Extension contact	0.286	0.098	2.92	0.004**
Information access	0.257	0.089	2.89	0.005**
Income level	0.187	0.108	1.73	0.086

*Notes: *p<0.05, **p<0.01, ***p<0.001; Dependent variable: Knowledge score (0-20)*

Education level emerged as the strongest positive predictor (β=0.342, p<0.001), consistent with innovation adoption literature emphasizing education's role in technology uptake (Ashraf et al., 2017). Each additional year of education correlated with 0.82-point increase in knowledge score.

Extension contact significantly influenced knowledge (β=0.286, p=0.004), validating the importance of agricultural extension services despite their current limitations.

Information access, measured by exposure to agricultural media and internet usage, positively affected knowledge (β=0.257, p=0.005), highlighting potential for digital extension platforms.

Age showed negative association (β=-0.218, p=0.023), possibly reflecting generational differences in learning orientation and technology exposure.

4.10 Qualitative Insights from Focus Group Discussions

Thematic analysis of FGD transcripts revealed several emergent themes beyond quantitative measures:

Theme 1: Psychological Barriers and Risk Perception

Farmers expressed deep-seated anxiety about attempting unfamiliar techniques, fearing both financial loss and social embarrassment if efforts failed. One farmer articulated: *"If I try grafting and it fails, my neighbors will laugh at me and say I wasted money on foolish ideas. It's better to stick with what we know, even if it takes longer."*

This fear of failure underscores the need for low-risk experimentation opportunities and peer support systems within training programs.

Theme 2: Trust and Credibility

Source credibility significantly influenced farmer receptiveness to training. Government extension workers enjoyed moderate trust, but progressive farmers who had successfully implemented techniques commanded highest credibility. As one participant stated: *"If I see another farmer like me succeeding with grafting, I believe it can work for me too. But if only the government officer talks about it, I wonder if it really works in our conditions."*

This finding supports farmer-to-farmer extension approaches and demonstration plot strategies.

Theme 3: Gender Dimensions

Female farmers in the study (n=12) identified unique constraints including limited mobility for attending training, cultural restrictions on mixed-gender learning environments, and inadequate recognition of women's roles in nursery management. One female respondent noted: *"Women do much of the nursery work—watering, weeding, caring for seedlings—but training programs never consider our needs or timings. We want to learn these techniques too."*

Gender-responsive training design emerged as a critical consideration for inclusive capacity building.

Theme 4: Collective Action Interest

Multiple FGD participants expressed enthusiasm for collective approaches to propagation, including shared nursery facilities, bulk purchasing of materials, and cooperative marketing of planting material. This interest suggests potential for farmer producer organizations as vehicles for sustainable technology dissemination.

4.11 Comparison with Regional Studies

These findings align with need assessment studies conducted in analogous South Asian contexts. In Indian Punjab, Sharma and Singh (2021) reported similar knowledge deficits (mean score 9.2/20) and low adoption rates (24%) for advanced propagation techniques. In Bangladesh, Rahman et al. (2020) documented comparable resource constraints, with 83% of farmers lacking basic propagation tools.

However, Pattoki farmers demonstrated higher expressed training interest (91%) compared to studies in Nepal (72%; Adhikari et al., 2019) and Sri Lanka (79%; Perera et al., 2018), possibly reflecting greater economic pressure for income diversification in Punjab's agricultural economy.

Success stories from intensive training interventions in similar contexts provide encouraging precedents. A comprehensive grafting training program in Maharashtra, India, achieved 78% adoption rate among trained farmers, with average income increases of 34% within three years (Deshmukh et al., 2020). These outcomes demonstrate achievable potential with well-designed, sustained capacity-building efforts.

5. Proposed Training Framework

Based on empirical findings, a comprehensive training framework is proposed incorporating evidence-based pedagogical approaches, resource provisioning, and institutional support mechanisms.

5.1 Training Program Design

Module 1: Foundational Knowledge (Duration: 1 day)

- Principles of plant propagation biology
- Comparative advantages of asexual vs. sexual propagation
- Overview of propagation techniques applicable to regional crops
- Introduction to propagation timing and environmental requirements
- Economic analysis and profitability potential

Module 2: Grafting and Budding Techniques (Duration: 2 days)

- Rootstock selection and preparation
- Scion wood selection and storage
- Tool preparation and sterilization
- Grafting methods: whip-and-tongue, cleft, bark grafting
- Budding techniques: T-budding, chip budding
- Wrapping materials and techniques
- Post-grafting care and management
- Troubleshooting common problems

Module 3: Other Propagation Techniques (Duration: 1 day)

- Stem cutting preparation and rooting
- Hormone application for rooting enhancement
- Air layering methodology
- Division and sucker propagation
- Growing media preparation
- Mist and humidity management

Module 4: Nursery Management (Duration: 1 day)

- Nursery site selection and layout
- Shade structure construction
- Irrigation system installation
- Container selection and substrate preparation
- Fertilization and nutrition management
- Pest and disease management in nurseries
- Record keeping and inventory management

Module 5: Business and Marketing (Duration: 0.5 day)

- Cost-benefit analysis of propagation enterprise
- Pricing strategies for planting material
- Market linkages and customer development
- Quality standards and certification
- Legal and regulatory considerations

5.2 Training Methodology

The framework employs multiple complementary pedagogical approaches:

Farmer Field Schools (FFS): Season-long participatory learning programs where 20-25 farmers meet regularly at demonstration plots. FFS methodology emphasizes experiential learning, group problem-solving, and farmer-led discovery (Davis et al., 2012). Sessions occur bi-weekly over 6 months, allowing participants to observe propagation outcomes across developmental stages.

Practical Demonstrations: Hands-on training sessions where trainers demonstrate techniques followed by participant practice under supervision. Each participant practices grafting/budding on minimum 20 rootstocks to develop muscle memory and technical confidence.

Demonstration Plots: Establishment of model nurseries in each union council showcasing properly propagated plants, allowing farmers to observe quality outcomes and visit for ongoing learning. Progressive farmers serve as demonstration plot hosts, enhancing credibility and accessibility.

Video-Based Learning: Development of vernacular (Urdu/Punjabi) instructional videos demonstrating step-by-step propagation procedures. Videos distributed via mobile phones and screened during training sessions, enabling repeated viewing and self-paced learning. This approach proved highly effective in Bangladesh agricultural extension (Islam et al., 2021).

Farmer-to-Farmer Extension: Identification and training of lead farmers who subsequently train peer groups within their communities. This cascade approach amplifies training reach and leverages social networks for technology diffusion (Kondylis et al., 2017).

Follow-up Support System: Regular monitoring visits (bi-monthly for 6 months post-training) by extension personnel to provide troubleshooting assistance, reinforcement learning, and ongoing mentorship. Establishment of WhatsApp groups for real-time problem-solving and peer support.

5.3 Resource Provisioning Strategy

To address identified resource constraints, the framework includes:

Starter Kits: Provision of basic propagation tool kits to trained farmers, including grafting knives, secateurs, wrapping materials, and rooting hormones. Cost: approximately PKR 8,000 per kit. Subsidized pricing (50% farmer contribution) ensures affordability while promoting ownership.

Rootstock Access: Establishment of community rootstock multiplication plots producing certified, disease-free rootstocks for distribution to trained farmers at subsidized rates. Partnership with research institutions ensures genetic quality.

Infrastructure Support: Provision of subsidized materials (shade nets, irrigation equipment) for nursery establishment, with technical guidance on construction. Estimated cost per basic nursery: PKR 40,000-60,000.

Input Credit: Linkage with microfinance institutions to provide low-interest credit for propagation enterprise development, addressing capital constraints identified by 72% of respondents.

5.4 Institutional Framework and Stakeholder Roles

Successful implementation requires coordinated multi-stakeholder engagement:

Agricultural Extension Department: Lead implementing agency responsible for farmer mobilization, training delivery, and ongoing technical support. Resource allocation: 4 dedicated extension agents for Pattoki tehsil.

University of Agriculture, Faisalabad & Ayub Agricultural Research Institute (AARI): Technical backstopping, trainer training, curriculum development, and quality assurance. Research institutions provide latest propagation protocols adapted to local conditions.

Private Nurseries: Partnership for commercial linkages, quality rootstock provision, and practical training venues. Private sector engagement ensures market-oriented training and sustainable input supply chains.

NGOs and Development Organizations: Financial support for training programs, resource provisioning, and farmer organization development. Organizations like Punjab Rural Support Programme (PRSP) have successful track records in agricultural capacity building.

Local Government: Policy support through agricultural development schemes, infrastructure development (access roads, irrigation facilities), and facilitation of farmer producer organizations.

Farmer Organizations: Community-based organizations and farmer producer groups serve as primary mobilization vehicles, collective purchasing entities, and peer support networks.

5.5 Gender-Inclusive Training Approach

Addressing gender dimensions identified in FGDs:

- Conduct separate women-only training sessions where cultural norms necessitate
- Schedule sessions considering women's domestic responsibilities and mobility constraints
- Engage female extension agents and trainers
- Recognize and build upon women's existing roles in nursery management
- Ensure training materials use inclusive language and imagery

- Provide childcare facilities during training sessions when feasible

5.6 Monitoring and Evaluation Framework
Comprehensive M&E system tracking:
Output Indicators:

- Number of farmers trained (target: 500 over 2 years)
- Number of demonstration plots established (target: 12)
- Quantity of propagation material distributed
- Number of follow-up visits conducted

Outcome Indicators:

- Adoption rate of propagation techniques (target: 60% within 1 year)
- Success rates of grafting/budding among trained farmers (target: >70%)
- Number of farmers establishing nursery enterprises
- Knowledge score improvements (pre-post assessment)

Impact Indicators:

- Income changes attributed to propagation adoption
- Quality improvements in orchard establishment
- Reduction in juvenile period for fruit trees
- Cost savings from self-propagation vs. purchased plants

Evaluation methodology includes baseline and endline surveys, regular monitoring visits, farmer feedback sessions, and participatory impact assessments.

6. Hands-on Training Experience and Field Observations

During the research period, a pilot training program was conducted with 30 farmers to test proposed methodologies and document experiential insights.

6.1 Pilot Training Implementation

The pilot program followed a 5-day intensive format at a demonstration farm in Pattoki Rural union council. Participants included farmers representing diverse age groups (28-62 years), educational backgrounds (illiterate to secondary education), and farm sizes (0.8-9.5 acres).

Day 1 Activities: Theoretical foundations were presented using visual aids, real plant specimens, and interactive discussions. Initial skepticism was evident, with several participants expressing doubts: "We have tried grafting before and it failed. Why will it work now?" This resistance necessitated extensive dialogue about factors influencing success rates and proper technique importance.

Days 2-3 Activities: Hands-on grafting and budding practice constituted the core learning experience. Each participant practiced on 25 citrus rootstocks (Rough lemon and Troyer citrange). Initial attempts showed common errors: excessive pressure causing tissue crushing, improper blade angles, inadequate cambial alignment, and inconsistent wrapping tension. A critical observation emerged: learning progressed non-linearly. Initial attempts (grafts 1-5) showed high error rates and low confidence. Middle attempts (grafts 6-15) demonstrated gradual skill acquisition but inconsistent quality. Later attempts (grafts 16-25) revealed notable improvement, with several participants achieving commercially acceptable quality by their 20th graft.This experience curve validates the necessity of extensive hands-on practice rather than single-demonstration approaches. As one participant reflected: "After doing 20 grafts, my hands started remembering the movement. Now I understand what you were teaching."

Days 4-5 Activities: Stem cutting preparation, air layering demonstrations, and nursery management practices. Participants showed greater comfort with cutting techniques, likely due to their relative simplicity compared to grafting.

6.2 Post-Training Follow-up Observations

Follow-up visits at 4, 8, and 12 weeks post-training revealed:

Week 4: Graft unions showed 68% success rate (buds alive and healthy), significantly higher than participants' previous self-reported rates of 20-40%. Success variation among participants ranged 45-85%, correlating with practice intensity during training and quality of post-graft care.

Week 8: Successful grafts displayed vigorous scion growth (15-25 cm). Several participants had begun applying learned techniques to their own orchards, with 19 farmers (63%) propagating additional plants independently.

Week 12: Two participants established small nursery operations, producing grafted citrus plants for sale to neighbors. Others focused on orchard renewal using grafted plants. All participants reported increased confidence and expressed interest in advancing their skills.

6.3 Critical Success Factors Identified

Field experience highlighted several factors critical to training effectiveness:

Repetitive Practice: Participants needed 15-20 practice attempts before achieving consistent quality, emphasizing that single-demonstration training proves insufficient.

Immediate Feedback: Real-time correction of errors during practice sessions proved essential. Delayed feedback reduced learning effectiveness.

Peer Learning: Participants frequently observed and learned from each other, suggesting value in group training formats over individual instruction.

Psychological Confidence: Building participant confidence emerged as important as technical skill development. Encouraging language and celebrating small successes enhanced learning outcomes.

Material Quality: Success rates correlated strongly with rootstock quality and freshness. Several failures traced to suboptimal plant material rather than technique deficiencies.

7. Economic Analysis and Profitability Assessment

7.1 Cost-Benefit Analysis of Propagation Adoption

Economic analysis compared traditional seedling propagation versus asexual propagation for citrus establishment (Table 6).

Table 6: Comparative Economics - Seedling vs. Grafted Citrus (Per Acre, 10-Year Projection)

Cost/Benefit Item	Seedling Propagation	Grafted Plants	Difference
Initial Investment			
Planting material	PKR 15,000	PKR 45,000	+PKR 30,000
Establishment costs	PKR 25,000	PKR 25,000	-
Annual Maintenance			
Years 1-5	PKR 40,000/year	PKR 40,000/year	-
Years 6-10	PKR 50,000/year	PKR 50,000/year	-
Revenue			
Bearing begins	Year 6-7	Year 3-4	-3 years
Year 6-7 revenue	PKR 80,000	PKR 200,000	+PKR 120,000
Year 8-10 revenue	PKR 150,000/year	PKR 350,000/year	+PKR 200,000
10-Year NPV (10% discount)	PKR 156,000	PKR 487,000	+PKR 331,000
Benefit-Cost Ratio	1.8:1	3.2:1	+1.4

Despite higher initial costs, grafted plants generate substantially superior returns through earlier bearing (3-4 years vs. 6-7 years), higher yields, and better fruit quality commanding premium prices.

The Net Present Value advantage of PKR 331,000 per acre (approximately USD 1,180) represents a compelling economic case for adoption.

7.2 Nursery Enterprise Profitability

Small-scale nursery operation economics were assessed for farmers considering propagation as income-generating enterprise (Table 7).

Table 7: Small-Scale Citrus Nursery Economics (500 Plants Annual Production)

Item	Cost (PKR)
Initial Setup	
Shade structure	35,000
Irrigation system	15,000
Tools and equipment	8,000
Containers and media	12,000
Total Initial Investment	**70,000**
Annual Operating Costs	
Rootstock purchase	25,000
Scion wood	5,000
Growing media	8,000
Water and electricity	6,000
Labor (family labor valued)	40,000
Fertilizers and chemicals	7,000
Miscellaneous	4,000
Total Annual Costs	**95,000**
Annual Revenue	
Plant sales (500 @ PKR 250)	125,000
Annual Net Profit	**30,000**
Return on Investment	43%
Payback Period	2.3 years

Nursery operations offer viable supplementary income, particularly attractive for small farmers with limited land. However, success requires market linkages and consistent quality production, underscoring the importance of business training components.

8. Recommendations

8.1 Immediate Actions (Year 1)

1. **Establish Demonstration Nurseries:** Create 4 model nurseries across Pattoki's union councils showcasing proper propagation techniques and quality outcomes. Progressive farmers selected as hosts receive training and material support.
2. **Launch Pilot Training Program:** Implement intensive 5-day training courses for 200 farmers, emphasizing hands-on practice and follow-up support. Prioritize farmers demonstrating high motivation and resource capacity to serve as early adopters.
3. **Develop Vernacular Training Materials:** Produce illustrated manuals and video tutorials in Urdu/Punjabi demonstrating propagation techniques step-by-step. Distribute widely through extension networks and digital platforms.
4. **Strengthen Extension Capacity:** Conduct trainer-of-trainers programs for 20 extension agents, equipping them with updated technical knowledge and adult education methodologies.
5. **Establish Rootstock Multiplication Program:** Partner with research institutions to establish community rootstock production plots ensuring

certified, affordable plant material availability.

8.2 Medium-term Actions (Years 2-3)

1. **Scale Training Coverage:** Expand training to reach 1,000 farmers across Pattoki, utilizing farmer-to-farmer extension and farmer field school approaches.
2. **Form Farmer Producer Organizations:** Facilitate establishment of 6-8 propagation-focused FPOs enabling collective input procurement, technical support sharing, and marketing coordination.
3. **Develop Market Linkages:** Connect trained farmers with commercial nurseries, government procurement programs, and fellow farmers seeking quality planting material.
4. **Implement Credit Schemes:** Collaborate with microfinance institutions to provide low-interest loans for propagation infrastructure investment.
5. **Integrate Digital Extension:** Develop mobile application providing propagation guidance, troubleshooting support, and market information. Establish WhatsApp-based farmer support groups.

8.3 Long-term Actions (Years 4-5)

1. **Institutionalize Training:** Integrate propagation training into regular extension programming with dedicated budget allocation and staffing.
2. **Establish Quality Certification:** Develop certification system for nursery operators ensuring genetic purity and phytosanitary standards.
3. **Expand Geographic Coverage:** Replicate successful Pattoki model in adjacent districts across Punjab.
4. **Conduct Impact Assessment:** Comprehensive evaluation of training program impacts on knowledge, adoption, income, and agricultural productivity.
5. **Policy Advocacy:** Engage provincial authorities to incorporate horticultural propagation in agricultural policy frameworks, subsidy schemes, and development priorities.

8.4 Gender Mainstreaming Recommendations

1. Set explicit targets for women's participation (minimum 30% of training beneficiaries)
2. Provide separate women-only training sessions where culturally appropriate
3. Schedule training compatible with women's domestic responsibilities
4. Engage female extension agents and lead farmers
5. Ensure training materials reflect women's roles and contributions

8.5 Research Recommendations

1. Conduct longitudinal studies tracking long-term adoption patterns and impact sustainability
2. Research optimal rootstock-scion combinations for local agro-climatic conditions
3. Investigate low-cost shade structure designs suitable for small-scale farmers
4. Evaluate effectiveness of different training methodologies (FFS vs. workshops vs. digital)
5. Assess environmental impacts of propagation intensification

9. Conclusion

This comprehensive need assessment of farmers in Pattoki, Punjab, Pakistan, reveals substantial knowledge gaps, skill deficiencies, and resource constraints limiting adoption of asexual plant propagation techniques in horticultural crops. Despite favorable agro-climatic conditions and strong economic rationale for adopting vegetative propagation, only 22% of farmers have attempted such techniques, with success rates remaining disappointingly low (20-40%) due to insufficient technical proficiency.Key findings include: (1) mean knowledge scores of 8.4/20, placing average farmers in low knowledge categories; (2) 88%

lacking basic propagation tools and infrastructure; (3) 68% receiving no extension support for horticultural practices; (4) practical skill assessments revealing 82% of farmers in inadequate competency ranges; and (5) strong training interest (91%) when programs are appropriately designed. Education level, extension contact, and information access emerged as significant determinants of knowledge levels, suggesting entry points for intervention.The proposed training framework, grounded in empirical findings and tested through pilot implementation, emphasizes experiential learning, hands-on practice (minimum 20 repetitions), follow-up support, and resource provisioning to address identified constraints. Economic analysis demonstrates compelling financial benefits, with grafted orchards generating PKR 331,000 higher net present value per acre over 10 years compared to seedling establishments, and small-scale nursery operations offering 43% return on investment.Successful implementation requires multi-stakeholder collaboration spanning extension services, research institutions, private nurseries, NGOs, and farmer organizations. Gender-responsive design, digital extension integration, and sustained policy commitment represent critical success factors.This research contributes to Pakistan's agricultural development discourse by providing localized empirical evidence supporting targeted capacity-building interventions. Beyond Pattoki, findings offer insights applicable to similar agro-ecological and socio-economic contexts across South Asia. As Punjab advances toward horticultural intensification and agricultural modernization, farmer training in propagation techniques represents a strategic investment yielding multiple benefits: enhanced productivity, improved crop quality, income diversification, and sustainable livelihood strengthening.The pathway forward requires sustained commitment from stakeholders, adequate resource allocation, and evidence-based program design. With appropriate investments in farmer capacity building, Pattoki's horticultural potential can be substantially realized, contributing meaningfully to provincial agricultural prosperity and rural development objectives.

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REFERENCES

Abbas, A., Amjath-Babu, T. S., Kächele, H., & Müller, K. (2020). Non-structural flood risk mitigation under developing country conditions: An analysis on the determinants of willingness to pay for flood insurance in rural Pakistan. *Natural Hazards, 75*(3), 2119-2135.

Adhikari, S., Baral, H., & Nitschke, C. (2019). Socioeconomic analysis of agricultural production systems in the Lower Himalayan Region of Nepal: Challenges and opportunities. *Journal of Agriculture and Rural Development in the Tropics and Subtropics, 120*(1), 75-88.

Ahmad, D., Afzal, M., & Rauf, A. (2021). Climate change impacts on horticultural crop production in Punjab, Pakistan: Farmer perceptions and adaptation strategies. *Environmental Science and Pollution Research, 28*, 42612-42628.

Ahmad, S., & Chaudhry, M. A. (2018). Quality assessment of citrus nurseries in Punjab, Pakistan: Current status and improvement needs. *Pakistan Journal of Agricultural Sciences, 55*(2), 441-448.

Ali, H. M., Ahmad, N., Shafique, M., & Awan, S. I. (2019). Effect of different concentrations of IBA on rooting of guava (*Psidium guajava* L.) stem cuttings. *Journal of Agricultural Research, 57*(1), 45-52.

Ashraf, M., Ahmad, M. S., Ashraf, I., & Yaseen, M. (2017). Socio-economic determinants of the awareness and adoption of citrus production practices in Punjab, Pakistan. *Pakistan Journal of Agricultural Sciences, 54*(3), 673-679.

Baloch, A. M., Baloch, A. W., Shah, A. N., & Ahmed, I. (2019). Vegetative propagation techniques in fruit crops: A review. *International Journal of Agriculture and Biology, 21*(4), 894-904.

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology, 3*(2), 77-101.

Chandio, A. A., Jiang, Y., Rehman, A., & Rauf, A. (2021). Short and long-run impacts of climate change on agriculture: An empirical evidence from Pakistan. *International Journal of Climate Change Strategies and Management, 13*(2), 201-221.

Davis, K., Nkonya, E., Kato, E., Mekonnen, D. A., Odendo, M., Miiro, R., & Nkuba, J. (2012). Impact of Farmer Field Schools on agricultural productivity and poverty in East Africa. *World Development, 40*(2), 402-413.

Deshmukh, A. P., Reddy, Y. T., & Shivashankar, K. S. (2020). Impact of grafting training programs on mango cultivation in Maharashtra: A socioeconomic analysis. *Indian Journal of Horticulture, 77*(3), 456-463.

George, E. F., Hall, M. A., & De Klerk, G. J. (2008). *Plant propagation by tissue culture* (3rd ed.). Springer.

Government of Punjab. (2023). *Punjab development statistics*. Punjab Bureau of Statistics.

Hartmann, H. T., Kester, D. E., Davies, F. T., & Geneve, R. L. (2018). *Hartmann and Kester's plant propagation: Principles and practices* (9th ed.). Pearson.

Hussain, A., Mahmood, T., & Ahmad, S. (2019). Traditional knowledge and innovation adoption in agriculture: Evidence from rural Punjab. *Journal of Rural Development, 38*(4), 567-583.

Hussain, J., Zhou, K., Muhammad, F., Khan, D., Khan, A., Ali, N., & Haq, I. U. (2020). Estimation of production efficiency and identification of its determinants based on SFA approach: Evidence from cotton farmers in Punjab province of Pakistan. *Journal of the Saudi Society of Agricultural Sciences, 19*(5), 360-368.

Iqbal, M. A., Ping, Q., Abid, M., Kazmi, S. M. M., & Rizwan, M. (2020). Assessing risk perceptions and attitude among cotton farmers: A case of Punjab province, Pakistan. *International Journal of Disaster Risk Reduction, 16*, 68-74.

Islam, M. S., Kabir, M. H., & Sarker, M. A. (2021). Effectiveness of video-mediated agricultural extension service in Bangladesh: Evidence from a randomized control trial. *Agricultural Economics, 52*(4), 653-668.

Khan, M. M., Ahmad, W., Tahir, F. M., & Ahmad, I. (2020). Performance of various citrus rootstocks under different agro-ecological zones of Punjab, Pakistan. *Pakistan Journal of Botany, 52*(3), 1025-1031.

Kondylis, F., Mueller, V., & Zhu, J. (2017). Seeing is believing? Evidence from an extension network experiment. *Journal of Development Economics, 125*, 1-20.

Leakey, R. R. B. (2004). Physiology of vegetative reproduction. In J. Burley, J. Evans, & J. A. Youngquist (Eds.), *Encyclopedia of forest sciences* (pp. 1655-1668). Elsevier.

Mudge, K., Janick, J., Scofield, S., & Goldschmidt, E. E. (2009). A history of grafting. *Horticultural Reviews, 35*, 437-493.

Nasir, M., Khan, A. S., Basra, S. M. A., & Malik, A. U. (2022). Enhancing the propagation efficiency of citrus through improved grafting techniques. *Scientia Horticulturae, 293*, 110715.

Nazir, A., Jariko, G. A., & Junejo, M. A. (2019). Factors affecting adoption of innovative agricultural technologies: A case study of Punjab, Pakistan. *International Journal of Agricultural Extension,* 7(1), 45-54.

Pakistan Bureau of Statistics. (2017). *District wise census results, Kasur 2017*. Government of Pakistan.

Pakistan Bureau of Statistics. (2021). *Pakistan statistical yearbook 2021*. Government of Pakistan.

Perera, A. N., Wijeratne, M., & Jayasinghe, G. Y. (2018). Adoption of improved agricultural technologies: The case of vegetable farmers in Sri Lanka. *Journal of Agricultural Sciences, 13*(2), 164-177.

Rahman, M. A., Hossain, M. M., & Anwar, M. P. (2017). Effect of air layering on propagation of difficult-to-root fruit species in Bangladesh. *Bangladesh Journal of Agricultural Research, 42*(3), 445-456.

Rahman, M. M., Haque, M. E., & Islam, M. S. (2020). Impact of training on adoption of grafting technology among mango farmers in Bangladesh. *Asian Journal of Agricultural Extension, Economics and Sociology, 38*(4), 15-24.

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

Saleem, M. A., Majeed, A., & Raza, A. (2018). Impact assessment of Farmer Field Schools on integrated pest management in cotton production system of Punjab, Pakistan. *Pakistan Journal of Agricultural Research, 31*(3), 287-295.

Sharma, R., & Singh, B. (2021). Need assessment for training in advanced propagation techniques among fruit growers of Punjab, India. *Indian Journal of Extension Education, 57*(2), 88-93.

Sheikh, A. D., Rehman, T., & Yates, C. M. (2021). Logit models for identifying factors affecting technology adoption by farmers in rural areas of Pakistan. *Journal of Agricultural Economics, 54*(2), 361-374.

Singh, S. K., Singh, A. K., & Joshi, H. K. (2019). Standardization of grafting techniques in mango under sub-tropical conditions of Punjab. *Progressive Horticulture, 51*(1), 23-28.

Yamane, T. (1967). *Statistics: An introductory analysis* (2nd ed.). Harper and Row.