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Digital Literacy, Pesticide Safety, and Food Quality Among Food Crop Farmers in Punjab, Pakistan: A Cross-Sectional Study

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Abstract

Pesticide mismanagement among food crop farmers threatens public health and environmental sustainability across developing agricultural economies. Mobile technology represents a paradigm change in access to safety information for farmers while traditional extension efforts focus on formal education and farm size. This paper investigates the impact of functional digital literacy (capacity to access, assess and utilize digital information for farm decisions) on pesticide safety practices and food quality awareness among food crop farmers in Punjab, Pakistan (N = 1,100). Digital literacy, pesticide safety practice and food quality awareness were assessed using composite indices and analysed using multiple linear regression, one-way ANOVA and chi-square test in a cross-sectional survey conducted in six agriculturally intensive districts. The mean Digital Literacy Score was 3.17 out of 7.00 meaning that there were widespread functional deficits. Digital literacy was the most significant predictor of pesticide safety practice and food quality awareness as high-literacy farmers were significantly more likely than low-literacy farmers to correctly measure the dose, read the label, store the chemical correctly, and observe Pre-Harvest Interval guidelines. These findings show that the main modifiable factor affecting pesticide safety behaviour and food quality awareness of the food crop farmers in Punjab is digital competency. Policy should focus on functional digital-skill development, safety content that is adapted to local contexts and delivered via video, and complementary regulations that promote safer practices through incentives.

Keywords: Digital literacy, Extension services, Risk communication, Pesticide safety, Pre-harvest interval.

1. INTRODUCTION

Pesticide mismanagement is a recurring problem in agriculture in developing countries which has led to soil degradation, groundwater pollution and a rising public-health burden (Salazar & Rand, 2020; Hossain et al., 2022). In low and middle-income countries (LMICs), the extension service is considered chronically under-resourced, meaning that digital technologies have emerged as the most scalable way of disseminating knowledge on safety to small holder farmers (Porciello et al., 2022).

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These tensions are clearly apparent in Pakistan. Agriculture accounts for approximately 24% of GDP, also it is the source of employment for more than 37% of the population, while Punjab accounts for around 75% of national cereal output and also has a base in horticultural production for local and export markets (Gulati et al., 2021; GOP, 2026). The use of pesticides in the country increased from 18,000 tonnes in the year 2000 to more than 80,000 tonnes in early 2020s, with approximately two-thirds being used in Punjab (Rashid et al., 2022; GOP, 2026). The effectiveness of spraying is done on the basis of disappearance of visible pests, not considering the safe limits of spraying which indicates the lack of hazard information in farmers' mindsets rather than being negligent (Mehmood et al., 2025).

One of the most significant gaps is that many farmers do not follow Pre-Harvest Intervals (PHI), which is the wait period between the last pesticide use and harvesting the crop to ensure that any residues have dissipated to safe levels (Arshad et al., 2025; Welelaw et al., 2026). Punjab farmers are often under pressure to bring their produce to markets at sub-optimal time, which may leave an amount of residue higher than the safe limit, putting consumers at risk and farmers at risk of getting rejected by supply chains (Mehmood et al., 2025). The Punjab Food Authority has also found illegal residues in wholesale markets and the European Commission has twice banned consignments of Pakistani vegetables due to the residues. Traditionally farmer age and lack of education have been identified as the cause, but recent evidence indicates that farmers are willing to adopt safer practices but do not receive reliable technical guidance (Muhammad et al., 2025; Mehmood et al., 2025).

Mobile advisory platforms have been set up in Pakistan since 2019, and uptake has been limited due to lack of full coverage in rural areas, where a lot of areas were transitioning from 3G to 4G (Raza, 2022). This shift is important analytically because, SMS-based advisories were more of a literacy burden, which many farmers were unable to carry out, while video and voice platforms like Plantix and Kissan Pakistan enabled by 4G are accessible to farmers who were previously excluded from the literacy-restrictive SMS platforms (Siraj, 2010; Shahil-Feroz et al., 2024). But access to the internet does not lead to better decisions being made: functional digital literacy, the capacity to find, assess and use digital information, is most important (van Deursen & van Dijk, 2019; Olak et al., 2021). This is significant because pesticide retailers are the most active in producing social media content that promote pesticides, with little information on recommended usage levels or potential impacts to human health, and farmers with limited evaluative abilities are the least likely to assess the quality of this advice (Zhang et al., 2023; Wang et al., 2025).

Existing literature on Pakistan has broadly considered smartphone ownership and digital literacy to be synonymous and has not considered the difference between access and the ability to assess information; there is limited literature that correlates digital engagement with outcomes in food quality, including PHI compliance and awareness of food residues in the Punjab context. The majority of quantitative evidence, however, is from China, where the agricultural systems and digital infrastructure are vastly different from the recently scaled up smallholder-dominated context in Pakistan. This study aims to fill those gaps by conducting a survey of 1,100 farmers in six districts of Punjab, and treating digital literacy as a separate variable to formal education to isolate its unique contribution to food-quality outcomes and pesticide application behaviour (Figure 1).

1.1 Objectives

The main goal is to determine the influence of farmers' Digital literacy on pesticide application practices and food quality in food crops farmers of Punjab. These specific objectives are: (1) to measure farmers' functional digital literacy; (2) to identify the association between functional digital literacy and safe pesticide practices (dosage accuracy, label reading, PPE use, safe storage); (3) to determine the association between functional digital literacy and food quality outcomes (PHI compliance, market rejection history, residue awareness); (4) to compare outcomes of farmers with low, medium, and high digital literacy; and (5) to isolate the effect of functional digital literacy while controlling for age, farming experience, and farm size.

1.2 Theoretical Framework

This study is based on the Knowledge-Attitude-Practice (KAP) model, which suggests that behaviour change is a process that starts from knowledge acquisition and proceeds to attitude formation to practice adoption (Bettinghaus, 1986). Functional digital literacy is knowledge; food quality awareness is attitude and the food safety behaviours measured are practice. The process is a three-faceted one: access to the digital safety information, critical evaluation of that information (especially in the event that the retailer is the source of advice), and application to decisions, including dosage, storage, and PHI compliance. This reflects the access/capability dichotomy of our research context: device ownership provides potential, while functional digital literacy determines if that is realised. We complement KAP with the Health Belief Model which links health threat to protective behaviour (Rosenstock, 1974).

Each hypothesised relationship follows from this framework. Digital literacy is expected to improve pesticide application practice because it substitutes for under-resourced extension services, giving farmers direct access to dosage, storage, and protective-equipment guidance that would otherwise come only from commercial retailers. It is expected to improve food quality awareness because digital platforms expose farmers to residue-risk, Pre-Harvest Interval, and market-rejection information that is largely absent from traditional advisory channels. Demographic characteristics such as age, education, and land size may proxy for information access only where formal schooling or conventional extension is the dominant channel; whether they retain explanatory power once functional digital literacy is accounted for is examined empirically in this study.

1.3 Hypothesis

H1: Higher digital literacy is associated with safer pesticide application practices and greater food quality awareness. This hypothesis is represented as two paths in Figure 1 (H1a: DLS → PPS; H1b: DLS → FQS), corresponding to the two outcome variables.

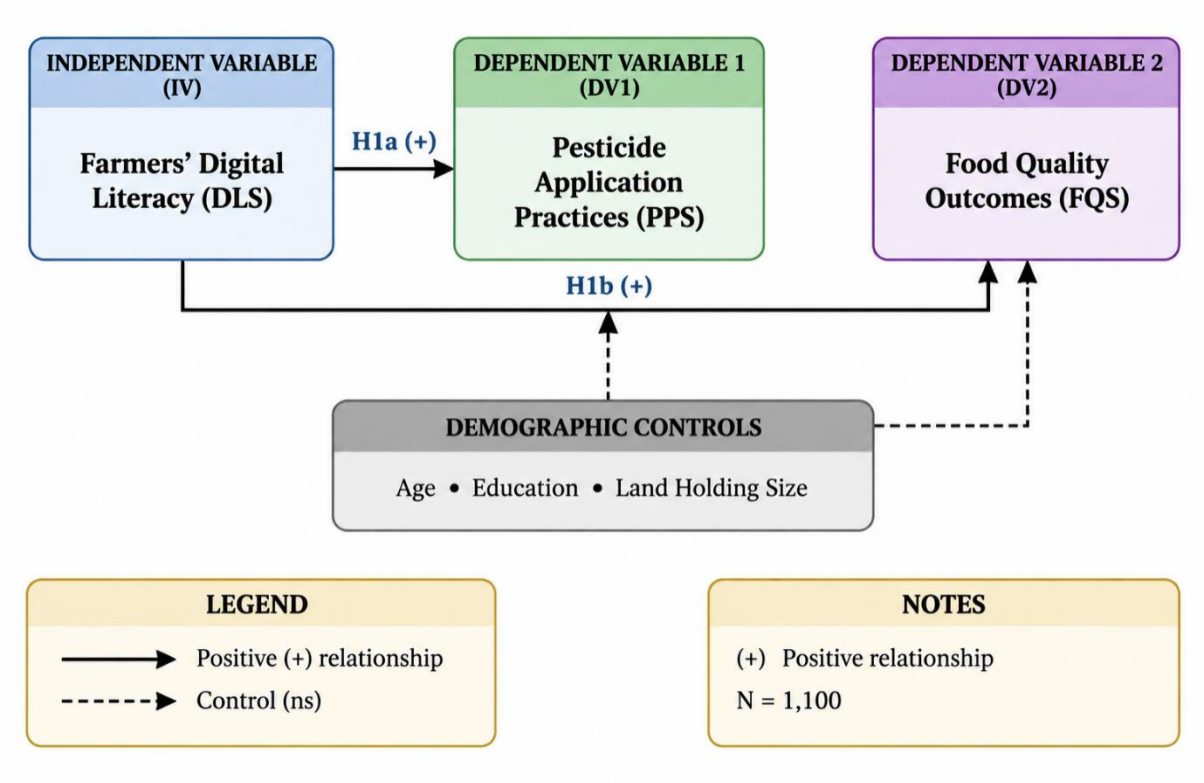


Fig. 1. Relationships between digital literacy, pesticide safety practices and food quality outcomes.

2. MATERIALS AND METHODS

2.1 Research design and study area

To investigate the relationship between digital literacy, pesticide use management practices and food quality awareness among food crop farmers in the province of Punjab, a cross-sectional survey design was used. Punjab accounts for more than 70 percent of total agricultural production of Pakistan and is the major source of wheat, rice and vegetables (GOP, 2026). Six districts (Faisalabad, Sahiwal, Multan, Gujranwala, Sargodha and Bahawalpur) were selected purposively on two grounds, namely: (1) diversity of cropping systems namely cereal crop system, cotton-wheat system and horticultural crop system, and (2) intensity of pesticide use. These districts are also geographically distinct in terms of rural digital infrastructure, which nationally has been found to be unevenly distributed with the transition from 3G to 4G (Raza, 2022) which creates a variation for the study of digital literacy under variable connectivity situations.

2.2 Sampling and data collection

The sample size was calculated based on Cochran's (1977) formula for large population which was appropriate since there was no comprehensive sampling frame of the smallholder farmers. Assuming that the true population proportion is p = 0.5, with 95% confidence level and precision of 3%:

$$n0 = Z^2pq/e^2 = (1.96)^2(0.5)(0.5)/(0.03)^2 = 1,067$$

The sample size for each stage was determined by Cochran's formula and the three remaining stages used random selection to maintain within-district representativeness. The random procedure involved four stages: 6 districts were purposively selected; 2 tehsils were randomly selected from each district (12 tehsils); 5 villages were randomly selected within each tehsil (60 villages); and within each village, 18-20 farmers were systematically selected from farmer lists (1100 farmers). The questionnaire was created in English and translated into Urdu, the main language used for conducting surveys in the province of Punjab. The translation was then reviewed by bilingual research assistants and a pilot test with 25 farmers was performed to achieve clarity prior to data collection. The study was approved by the Institutional Review Board of Yangzhou University (approval no. 008899) and the informed consent of all participants was obtained before the data collection.

2.3 Study variables

Dependent variables: Two outcome variables were constructed as composite indices. The Pesticide Practice Score (PPS, five items) measured spray frequency, dose accuracy, label reading, PPE use, and safe storage. The Food Quality Score (FQS, four items) measured PHI awareness, PHI observance, market-rejection history, and perceived health risk from residues.

Core independent variable: The Digital Literacy Score (DLS, six items) was the primary explanatory variable, measuring smartphone ownership, mobile internet access, frequency of digital tool use, and the ability to apply online information to decisions such as pesticide dosage and safety checks.

Control variables: Three covariates were included to account for confounding: farmer age (years), formal education (ordinal, 1 = no formal to 6 = graduate and above), and landholding size (acres). Farming experience was excluded because it correlated very highly with age ($r = 0.94$). Full item wording and index scoring are provided in Appendix A.

2.4 Data analysis

The sample was summarised with descriptive statistics and the internal consistency was determined using Cronbach's alpha ($\alpha = 0.898$ for DLS, $\alpha = 0.864$ for PPS, and $\alpha = 0.692$ for FQS) (Figure 2). The FQS alpha is slightly below the generally accepted threshold of 0.70, but is acceptable for short scales (Hair et al., 2010; Taber, 2018) and is related to the number of items. All scales were therefore retained for inferential analysis. Pearson's chi-square test examined associations between digital literacy tertiles (low/medium/high) and binary safety behaviours. One-way ANOVA tested whether mean PPS and FQS differed across the three literacy groups. Two multiple linear regression models estimated the independent effect of digital literacy on PPS and FQS, respectively, controlling for age, education, and land size:

$$Yi = \beta 0 + \beta 1(DLS) + \beta 2(Age) + \beta 3(Education) + \beta 4(LandSize) + \varepsilon$$

Statistical significance was set at $p < 0.05$. Because the outcome variables are composite index scores rather than continuous measures, residual diagnostics were performed to assess the robustness of the OLS specification. Residual skewness was 0.001 and excess kurtosis was -0.282. Breusch-Pagan testing indicated heteroscedasticity in Model 1 ($\chi^2 = 29.90$, $p < 0.001$) but not Model 2 ($\chi^2 = 7.61$, $p = 0.107$). For consistency, both models were re-estimated with HC3 heteroscedasticity-robust standard errors and with Poisson regression.

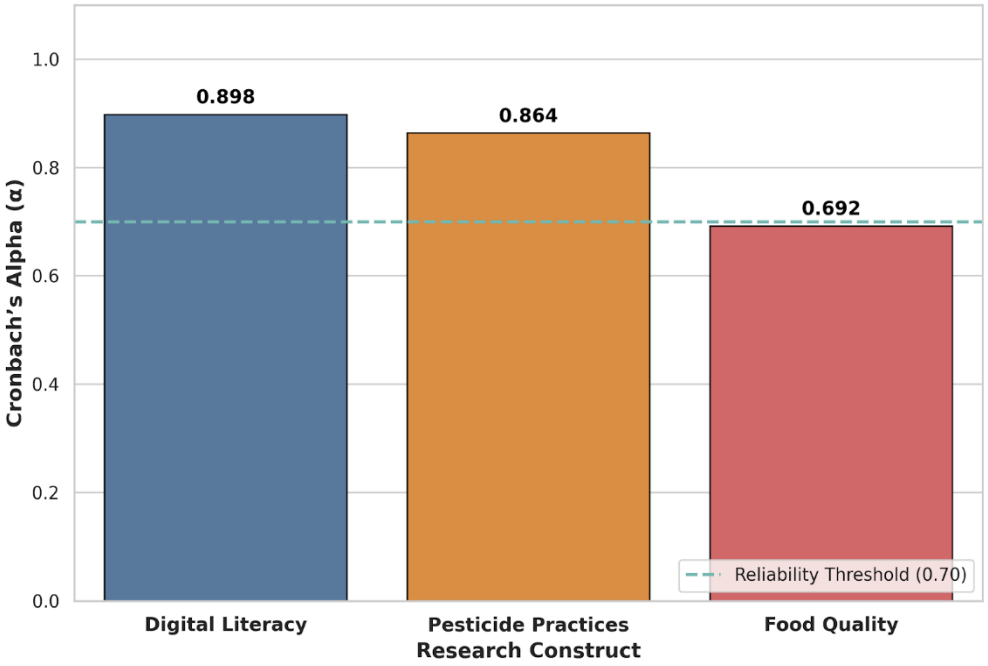


Fig. 2. Internal consistency reliability of research constructs.

3. RESULTS

3.1 Descriptive statistics

Sampled farmers had a mean age of 47.33 years (SD = 8.00, range 25–70), mean farming experience of 26.84 years (SD = 8.48), and mean landholding of 10.04 acres (SD = 7.11, range 1–50) (Table 1). Mean scores were DLS = 3.17 (SD = 2.44), PPS = 4.52 (SD = 2.16), and FQS = 4.59 (SD = 2.33). The average DLS score was below the midpoint of the scale (3.5), meaning that the average person in the sample had less than half of the digital competencies measured.

Table 1. Descriptive statistics (n= 1,100).

Variable	Mean	Std. Deviation	Minimum	Maximum
Farmer age (years)	47.33	8.00	25.0	70.0
Farming experience (years)	26.84	8.48	3.0	50.0
Land holding size (acres)	10.04	7.11	1.0	50.0
Digital Literacy Score (DLS)	3.17	2.44	0.0	7.0
Pesticide Practice Score (PPS)	4.52	2.16	0.0	9.0
Food Quality Score (FQS)	4.59	2.33	0.0	10.0

3.2 Inter-variable correlations

Pearson correlations showed strong, significant positive associations between DLS and both PPS (r = 0.72) and FQS (r = 0.77), and between PPS and FQS (r = 0.78) (Figure 3), indicating that safer pesticide handling and food quality awareness rise together with digital competency.

Correlations between DLS and socio-demographic variables were negligible: age (r = −0.04), education (r = −0.01), land size (r = −0.05), and farming experience (r = −0.05).

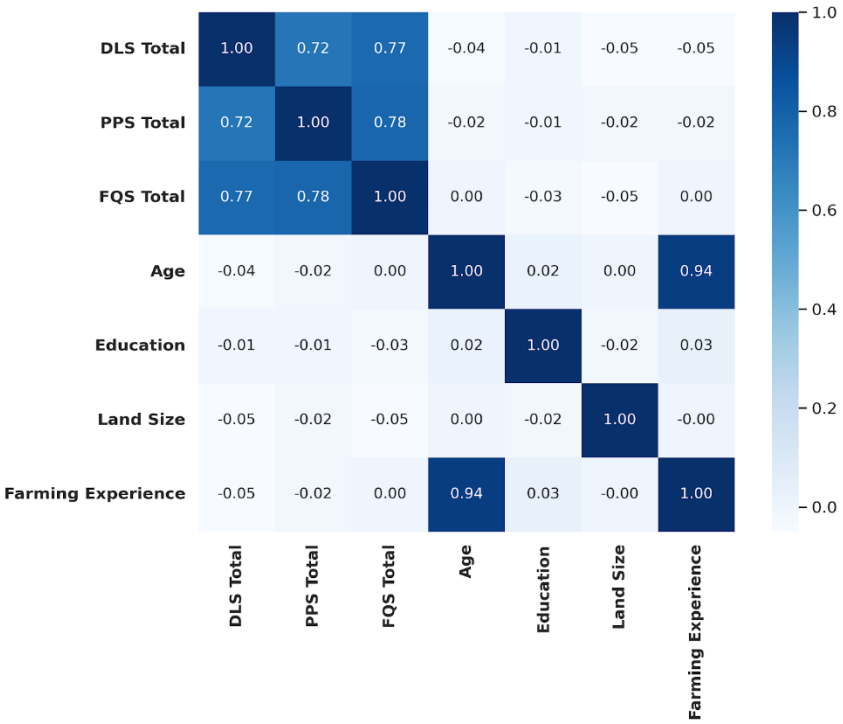


Fig. 3. The Pearson correlation matrix of digital literacy, agricultural safety and socio-demographic variables.

3.3 Performance by digital literacy level

One-way ANOVA showed significant differences in PPS and FQS across low, medium, and high digital literacy groups (Table 2, $p < 0.001$ for both). PPS rose from 2.73 (low) to 6.48 (high; $F = 476.25$), and FQS rose from 2.57 (low) to 6.90 (high; $F = 614.00$), with high-literacy scores also more tightly clustered (Figure 4). Tukey HSD post-hoc comparisons confirmed that all pairwise differences were significant at $p < 0.001$, indicating that each literacy group differed from the others on both outcomes.

Table 2. Comparison of performance scores by digital literacy level with post-hoc mean differences.

Dependent variable	Low DL	Med. DL	High DL	F-statistic	High vs. Low (Δ)	High vs. Med (Δ)	Med vs. Low (Δ)
Pesticide Practice (PPS)	2.73	4.83	6.48	476.25***	+3.74***	+1.65***	+2.09***
Food Quality (FQS)	2.57	4.88	6.90	614.00***	+4.33***	+2.02***	+2.31***

Note: *** $p < 0.001$. F-statistics refer to the overall one-way ANOVA; Δ columns present mean differences from Tukey HSD post-hoc tests (all pairwise $p < 0.001$).

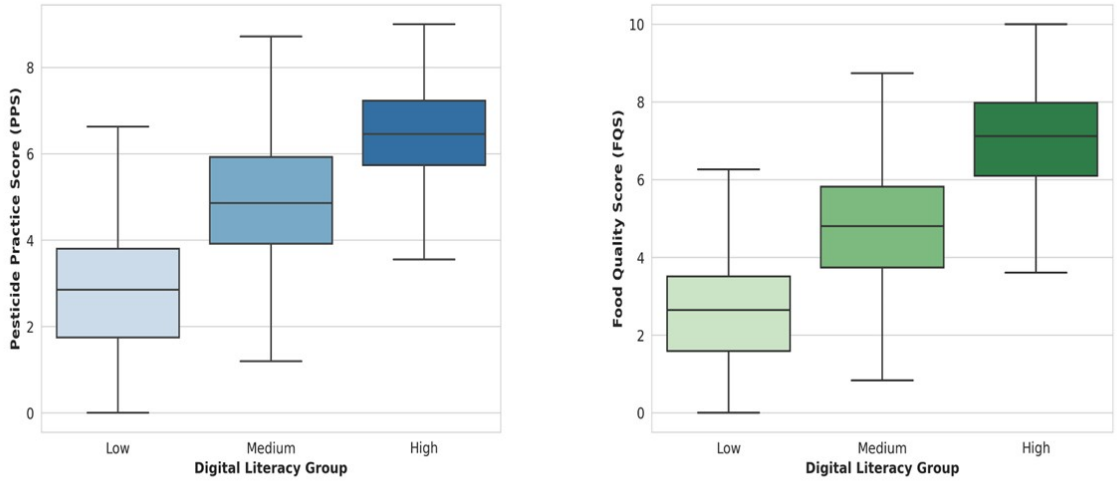


Fig. 4. Effect of digital literacy on PPS and FQS.

3.4 Behavioural analysis (chi-square)

Digital literacy was significantly associated with all five pesticide safety behaviours examined (Table 3). Correct dosage measurement rose from 34.1% (low) to 97.2% (high; χ^2 = 309.79); label reading from 0.0% to 31.4% (χ^2 = 188.72); regular PPE use from 0.8% to 28.2% (χ^2 = 163.42); safe (locked) storage from 12.9% to 86.8% (χ^2 = 370.04, the largest absolute gap); and PHI adherence from 0.0% to 22.0% (χ^2 = 142.50); all $p < 0.001$. Cramér's V ranged from 0.360 to 0.580, indicating medium to large associations under Cohen's (1988) benchmarks.

Table 3. Association between digital literacy and key farming behaviours.

Behaviour	Low DL (%)	Med. DL (%)	High DL (%)	χ^2	Cramer's V	p-value
Correct dose measurement	34.1	73.5	97.2	309.79	0.531	< 0.001
Always reads labels	0.0	5.9	31.4	188.72	0.414	< 0.001
Regular PPE use	0.8	4.7	28.2	163.42	0.385	< 0.001
Safe storage (locked)	12.9	54.2	86.8	370.04	0.58	< 0.001
Knows/follows PHI	0.0	2.8	22.0	142.50	0.36	< 0.001

Note: Cramér's V interpreted using Cohen's (1988) benchmarks for df = 2: small = 0.07, medium = 0.21, large = 0.35. All associations are medium to large.

3.5 Regression analysis

Two multiple regression models (Table 4) tested whether digital literacy predicted PPS and FQS after controlling for age, education, and land size. Digital literacy was the strongest, and only significant, predictor in both models: for PPS, $\beta = 0.639$ ($t = 34.541$, $p < 0.001$); for FQS,

β = 0.812 (t = 38.619, p < 0.001). Both models were statistically significant (both p < 0.001), explaining 52.2% and 56.1% of the variance in pesticide practice and food quality awareness, respectively. VIFs were approximately 1.0, indicating no multicollinearity.

Table 4. Multiple linear regression results for pesticide safety (PPS) and food quality (FQS).

Dependent variable	Predictor	Coefficient (β)	Std. Error	t-statistic	p-value	VIF
Model 1						
PPS	Digital Literacy (DLS)	0.639	0.018	34.541	< 0.001	1.004
	Age	0.002	0.006	0.435	0.663	1.002
	Education	-0.002	0.032	-0.053	0.957	1.001
	Land size	0.004	0.006	0.571	0.568	1.003
	Constant	2.347	0.303	7.750	< 0.001	
Model Fit	-	R^2 = 0.522	Adj. R^2=0.520	F = 298.81	< 0.001	
Model 2						
FQS	Digital Literacy (DLS)	0.812	0.021	38.619	< 0.001	-
	Age	0.012	0.006	1.850	0.065	-
	Education	-0.061	0.036	-1.692	0.091	-
	Land size	-0.007	0.007	-0.999	0.318	-
	Constant	0.721	0.344	2.094	0.036	-
Model Fit	-	R^2 = 0.561	Adj. R^2=0.560	F = 350.22	< 0.001	-

3.6 Summary of hypothesis testing

Results (Figure 5) confirm that digital literacy is positively and significantly associated with safer pesticide handling and stronger food quality awareness across all measures examined (p < 0.001), while farmer age, formal education, and land size did not independently predict either outcome once digital literacy was accounted for.

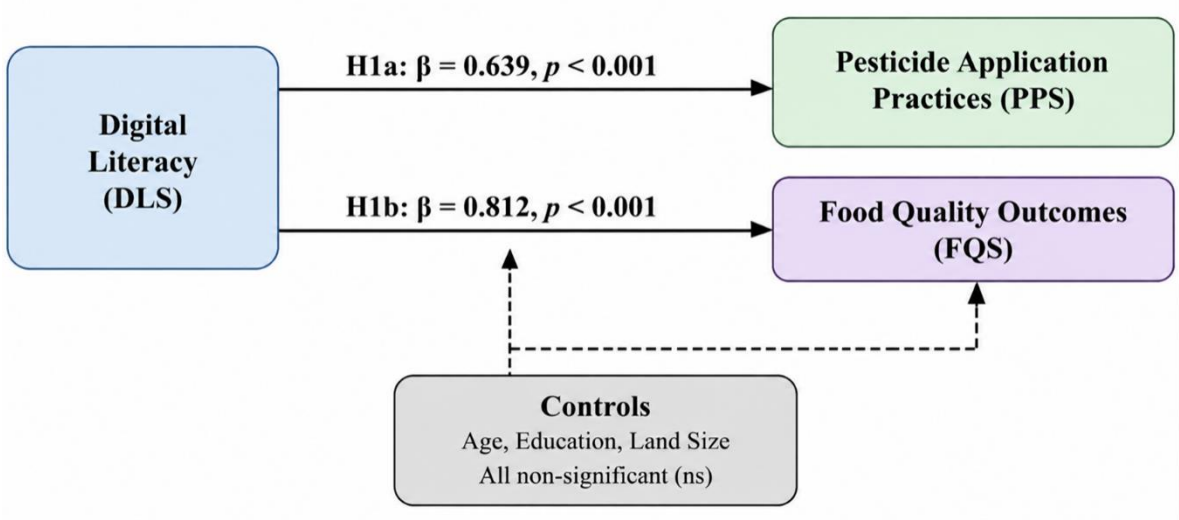


Fig. 5. Path diagram summarizing hypothesis testing results for predictors and outcome clusters.

4. DISCUSSION

Pesticide misuse can be attributed to lack of reliable technical information, commercially motivated retailer advice and limited extension service resources in Punjab's smallholder farming community. Even if there are regulatory maximum residue limits (MRLs), compliance depends on the availability of appropriate practical guidance (information) to farmers (Möhring, Ingold, et al., 2020; Mehmood et al., 2025). The low value of the measure Digital Literacy Score recorded here (3.17/7.00) was directly linked to poor pesticide safety practice and food quality awareness, as was reported in other studies for smallholders (Akter et al., 2018; Sharafi et al., 2018).

Digital literacy was most strongly associated with Pesticide Practice Score ($\beta = 0.639$, $p < 0.001$); farmers higher in digital literacy were more capable of finding and understanding safety information and using proper doses, and less likely to take retailer advice. This is consistent with results from a mobile-based pest platform in Bangladesh (Selim et al., 2026), engagement in digital water-advisory in Punjab (Khan et al., 2022), and rural China (Cui et al., 2025) where technical compliance was more strongly associated with digital engagement than formal education.

Behavioural gaps were most pronounced for dosage accuracy (34.1% to 97.2%) and label reading (0.0% to 31.4%), in line with previous evidence in Punjab, where less than 40% of cotton farmers use calibrated measuring equipment, due to the lack of independent technical guidance (Ashraf et al., 2024). However, PPE use increased with digital literacy and was still low even among high-literacy farmers (28.2%), indicating that information-based interventions alone cannot overcome the persisting barriers to adoption, which include low cost and availability of PPE, and discomfort when working in the fields (Jallow et al., 2017; Mehmood et al., 2021).

Safe storage showed the largest gap between groups (12.9% to 86.8%), directly impacting accidental child exposure and household contamination. Because domestic storage practices are highly responsive to targeted, season-specific information interventions (Brander et al., 2025), and unsafe containment is explicitly tied to poisoning episodes in rural Punjab households (Abbas et al., 2024), storage messaging tailored for low-literacy farmers represents a high-value, tractable intervention target.

Pesticide retailers remain the dominant information source for most Punjab farmers, and this dependence is most pronounced among those with limited smartphone proficiency (Horst & Watkins, 2022). Because retailer advice is a documented correlate of overuse (Sun et al., 2023),

digital literacy programmes must teach farmers to evaluate the source and motivation behind advice, not just its content.

Digital literacy showed an even stronger association with food quality outcomes ($\beta = 0.812$, $p < 0.001$) than with pesticide practice. PHI compliance, at just 22.0% even among high-literacy farmers, represents the most direct link between farmer knowledge and consumer health identified here. Because residue-related information access is associated with PHI compliance elsewhere (Welelaw et al., 2026), and Punjab residue exceedances concentrate in districts with weak extension coverage (Hussain et al., 2022) closely matching the low-literacy population identified here digital interventions targeting PHI awareness could yield food-safety benefits extending beyond individual farms to the wider supply chain.

Contrary to conventional assumptions, formal education was not significantly associated with pesticide safety or food quality awareness once digital literacy was accounted for ($p = 0.957$ for education in the PPS model). This finding is theoretically meaningful rather than a statistical null. Under the KAP framework, education functions as a proxy for knowledge acquisition only when formal schooling is the dominant information channel; where digital platforms increasingly supply that knowledge, the proxy loses explanatory power. Furthermore, digital literacy and education did not demonstrate a strong correlation in our sample ($r = -0.01$), suggesting that they are not necessarily equivalent constructs but separate skills. This is in line with evidence from Punjab and Sindh which indicates that education is linked to input uptake primarily as a proxy for information access (Ahmed et al., 2016), and evidence that older farmers can be more effectively reached with accessible video content (Zhang et al., 2025). Digital literacy, not traditional demographic factors, therefore, seems to be a good indicator of safer agrochemical handling within this population.

4.1 Policy implications

Results indicate a logical order for intervention. Functional digital skills training was a priority, as access to devices was not enough to ensure safer practice; this training should be delivered through established extension platforms and community organizations and should be video and voice in Urdu and regional languages based with a focus on low-literacy users. The second priority is behaviour-specific messaging for the biggest gaps; for example, safe storage was the most poorly scored behaviour for the low-literacy group and this gap was more pronounced than other literacy groups; and PHI compliance was also low, even among high-literacy farmers, making behaviour a good target for messaging on platforms like Kissan Pakistan and Plantix. Regulatory reinforcement: Retailer is still the main source of advice;

information-based interventions are not enough; structured training and monitoring of sales advice should be combined with testing of residues in the wholesale market and enforceable penalties on PHI, in addition to information-based interventions.

4.2 Limitations and future research

Actual safety gaps could be larger than what is reported here as this is self-reported data and could be subject to recall and social-desirability bias. The regression models adjusted for age, education and land size, but there was not a measurement of other potential confounding variables that could bias the estimated coefficients, such as access to extension services, farmer organization membership, and crop type, so results should be interpreted as associations adjusted for age, education and land size, rather than causal effects. However, the cross-sectional design does not allow making causal inferences and farmers may also be more interested in safety measures and thus more in digital skills. Future studies may be able to do this by using fixed effects panel data, instrumental variables with 4G rollout timing, or randomized evaluations. The Food Quality Score also exhibited borderline internal consistency ($\alpha = 0.692$), being just under 0.70, which is still above the cut-off value of 0.60 for short scales; it is important to note that the four items in this measure are measuring different dimensions, so it is viewed as a provisional score. The sample was taken from six purposively selected districts and may not be representative of districts with less mobile infrastructure or other agroecological environments. The assessment of food safety was conducted through a survey, and not by testing for food residues. Future research should be combined with survey data and explore the effect of peer networks and platform design on digital-literacy.

5. CONCLUSIONS

This study frames digital literacy as a food-safety issue rather than simple technology access. Functional digital competency, not formal schooling or farm size, emerged as the strongest correlate of safer pesticide handling and improved food-quality awareness. As agricultural extension shifts onto digital platforms, at-risk farmers face exclusion not from lack of devices, but insufficient critical-evaluation skills for online farming content. Realising digital benefits requires practical skill-building, user-centred content for low-literacy groups and regulatory oversight addressing commercially-biased agricultural information flows. Future work should apply causal-focused research designs, pair residue testing with behavioural surveys, and explore how platform features and farmer peer networks shape safe pesticide management.

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Appendix A

Construct/Index	Item Name	Survey Question Wording	Code Options & Scoring
Digital Literacy Score (DLS)	Smartphone	Do you own a smartphone?	1 = Yes / 2 = No
	Mobile Internet	Do you have mobile internet access on your phone?	1 = Yes / 2 = No
	Digital Engagement	Do you use WhatsApp or YouTube for farming/pesticide information?	1 = Yes, regularly / 2 = Yes, sometimes / 3 = No
	App Usage	Do you use any digital farming app?	1 = Yes / 2 = No
	Practical Test 1 (Dosage)	[Farmer shown a WhatsApp message regarding pesticide dose]. Can you identify the correct dose?	1 = Correct / 2 = Incorrect
	Practical Test 2 (Evaluation)	[Farmer presented with conflicting digital advice]. How do you proceed?	1 = Verify with expert or label / 2 = Ask another farmer / 3 = Follow any one
Pesticide Practice Score (PPS)	Spray Frequency	How many pesticide sprays do you apply per crop cycle?	1 = 0-2 times / 2 = 3-5 times / 3 = 6-9 times / 4 = 10+ times
	Dose Measurement	How do you physically measure pesticide dose?	1 = Measuring cup/spoon / 2 = Bottle cap / 3 = Guess / 4 = Digital tool/app
	Label Compliance	Do you read the pesticide label instructions?	1 = Always / 2 = Sometimes / 3 = Never
	PPE Use	Do you use PPE?	1 = Always / 2 = Sometimes / 3 = Never
	Storage	Where do you store pesticides?	1 = Locked place / 2 = Open shed / 3 = Inside home / 4 = Near food/feed
Food Quality Score (FQS)	PHI Knowledge	Do you know what Pre-Harvest Interval (PHI) means?	1 = Yes, and I follow it / 2 = Heard but don't always follow / 3 = No
	PHI Adherence	Have you ever harvested before PHI?	1 = Yes, often / 2 = Yes, sometimes / 3 = Never
	Market Rejection	Has any buyer ever rejected your produce due to residue concerns?	1 = Yes / 2 = No
	Health Risk Perception	Do you believe pesticide residues harm consumer health?	1 = Yes / 2 = No / 3 = Not sure