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Digital Literacy Intervention and Pesticide Safety Practices Among Vegetable Farmers in Gowa, Indonesia

Running title: Digital Literacy for Pesticide Safety

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Abstract

Background: Agricultural workers are directly exposed to pesticide hazards, and unsafe handling remains an occupational and environmental health concern in vegetable farming. Objective: To describe changes in knowledge, attitudes, and pesticide-safety practices following a digital literacy intervention among vegetable farmers in Kanreapia Village, Gowa Regency, Indonesia. Methods: A quasi-experimental pretest-posttest study with a comparison group included 68 male farmers (34 intervention; 34 comparison) from January to April 2024. Knowledge, attitudes, and practices were reported as adequate or inadequate and summarized as counts, percentages, and percentage-point changes. Results: In the intervention group, adequate knowledge increased from 55.9% to 97.1%, adequate attitudes from 29.4% to 88.2%, and adequate practices from 14.7% to 41.2%. Corresponding changes in the comparison group were 17.6% to 41.2%, 8.8% to 26.5%, and 17.6% to 14.7%, respectively. Conclusion: The intervention group showed larger descriptive improvements, particularly in attitudes and practices. Individual-level paired reanalysis is required to quantify statistical uncertainty and intervention effects.

Keywords: digital literacy; pesticides; occupational health; agricultural workers; risk communication

Research Highlights

- Adequate knowledge increased from 55.9% to 97.1% in the intervention group.
- Adequate attitudes increased from 29.4% to 88.2%, while adequate practices increased from 14.7% to 41.2%.
- The findings support further evaluation of digitally delivered pesticide-safety education using paired individual-level analyses.

1 Introduction

Pesticides remain important tools for agricultural production, but they are intrinsically hazardous and can produce acute or chronic health effects when exposure exceeds safe levels. Agricultural workers who mix, load, spray, clean equipment, or re-enter treated areas are among the populations with the greatest potential for direct exposure. The World Health Organization emphasizes that people applying pesticides should be adequately protected and that pesticide use should follow good agricultural practices. The FAO/WHO International Code of Conduct on Pesticide Management similarly frames pesticide safety as a shared responsibility that extends from regulation and distribution to handling, application, storage, and disposal [1,2].

Unsafe pesticide handling is particularly relevant in smallholder and horticultural settings, where repeated spraying, limited access to appropriate protective equipment, insufficient risk communication, and routine work practices may interact. Indonesian studies have documented gaps between knowledge and practice in pesticide safety. Yuantari et al. reported that farmers could recognize the importance of personal protective equipment while actual protective behavior remained inconsistent [3]. A broader Indonesian study on Good Agricultural Practices also identified a gap between farmers' knowledge of safe pesticide use and implementation in routine practice, underscoring that information alone may not be sufficient to change behavior [4].

Local evidence from Gowa Regency strengthens the relevance of pesticide-safety interventions in the study setting. Habibi et al. reported pesticide-intoxication symptoms among vegetable farmers and identified spraying methods, personal hygiene, and use of personal protective equipment as factors associated with reported symptoms [5]. These findings indicate that pesticide risk in vegetable farming is not only a matter of toxicological hazard but also of behavioral, occupational, and communication conditions that influence exposure.

Digital technologies offer a potential channel for strengthening agricultural extension and risk communication. Digital agriculture can broaden access to information, support repeated exposure to educational content, and link farmers with extension resources beyond conventional face-to-face encounters [6]. For pesticide safety, digital approaches may be particularly useful when they translate technical recommendations into practical, locally understandable messages on label interpretation, personal protection, mixing and application, storage, disposal, re-entry, and recognition of health risks. However, access to a smartphone or online information does not guarantee correct interpretation or sustained behavior change; digital content must be credible, usable, context-sensitive, and connected to practical support.

Evidence from agricultural training suggests that educational interventions can improve knowledge and selected safety behaviors, although changes in practice are not always proportional to changes in knowledge. Training of vegetable farmers has been associated with improved pesticide-management practices and food-safety awareness [7]. More recently, a cluster-randomized trial among smallholder farmers found improvements in pesticide-related knowledge after training, while changes in general practice were more limited, highlighting the importance of behavior-change design and implementation support [8]. A multi-channel social and behavior change communication campaign among farmers also reported improvements in several pesticide-management indicators, suggesting that repeated and context-specific communication may complement conventional training [9].

Despite this emerging evidence, there is limited published information on digital literacy interventions specifically addressing pesticide safety among vegetable farmers in rural South Sulawesi. The original study was therefore designed to compare pretest and posttest knowledge, attitudes, and practices between a group receiving a digital literacy intervention and a comparison group in Kanreapia Village, Gowa Regency. Given limitations in the aggregate statistical information available in the submitted manuscript, the present revision focuses on the observed descriptive changes and avoids causal interpretation. The objective was to describe changes in pesticide-safety knowledge, attitudes, and practices following the intervention and to compare the magnitude of those changes descriptively between groups.

2 Materials and Methods

2.1 Study design and setting

This study used a quasi-experimental pretest-posttest design with an intervention group and a comparison group. The study was conducted in Kanreapia Village, Tombolo Pao District, Gowa Regency, South Sulawesi, Indonesia, from January to April 2024. A total of 68 vegetable farmers participated, with 34 assigned to the intervention group and 34 to the comparison group. Because the source manuscript did not document the group-allocation procedure in sufficient detail, the final submitted version should specify how participants were assigned and whether any steps were taken to minimize contamination between groups.

2.2 Population, sampling, and sample size

Participants were recruited using purposive sampling. Eligibility criteria reported in the source manuscript were: active involvement in vegetable farming with pesticide use; age 18-60 years; residence in Kanreapia Village; willingness to participate; and ability to operate a smartphone or willingness to learn basic digital skills. The source manuscript did not report exclusion criteria, the number of farmers screened, reasons for non-participation, attrition between pretest and posttest, or an a priori sample-size calculation. These items should be completed from the study records before final submission because they are required to assess selection processes, study power, and reproducibility.

2.3 Digital literacy intervention

The intervention was described in the source manuscript as a digital literacy intervention intended to improve farmers' access to and use of information on pesticide safety. However, the submitted text did not specify the digital platform, instructional content, number and duration of sessions, facilitator qualifications, learning materials, participant engagement, adherence, or fidelity assessment. Those intervention components should be reconstructed from the original protocol, training module, or field records before submission so that another research team could reproduce the intervention. No corresponding digital literacy program was reported for the comparison group during the study period.

2.4 Variables and measurements

Three pesticide-safety domains were assessed before and after the intervention. Knowledge was measured using a 20-item multiple-choice questionnaire on pesticide safety, with scores reported on a 0-100 scale and higher values indicating greater knowledge. Attitudes were assessed using a five-point Likert-type questionnaire ranging from strongly disagree to strongly agree and covering perceptions of pesticide risks, safety measures, and willingness to adopt safer practices. Practices were assessed using a 15-item checklist addressing personal protective equipment, pesticide handling, and storage; the source manuscript described practice assessment as both observed and self-reported. For the results presented in the source document, each domain was subsequently classified as adequate or inadequate. The exact scoring rule and threshold used for this dichotomization, as well as evidence of instrument validity, reliability, pilot testing, and assessor procedures, were not provided and should be documented in the final manuscript.

2.5 Statistical analysis

Categorical outcomes were summarized as counts and percentages for each group at pretest and posttest. Absolute change was expressed in percentage points (posttest percentage minus pretest percentage), and the difference in change was calculated descriptively as the intervention-group change minus the comparison-group change. The original manuscript reported paired and independent t-tests after representing adequate/inadequate categories numerically. Inspection of the aggregate tables showed that the reported means were consistent with 1/2 coding of these binary categories. Because a t-test of such category codes does not provide an appropriate analysis of paired binary outcomes, and because individual-level paired transition data were not available in the submitted files, those p-values were not retained in this revision. Before submission, the individual-level dataset should be reanalyzed using methods appropriate to the outcome scale and repeated measurements. For dichotomous outcomes, within-group paired change can be assessed with McNemar's test, while the principal between-group comparison is better estimated with a repeated-measures binary model that includes group, time, and a group-by-time interaction (for example, generalized estimating equations or a mixed-effects logistic model). The final report should provide effect estimates with 95% confidence intervals, exact p-values where applicable, the statistical software and version, assumption or model checks, and the approach to missing data.

2.6 Ethical considerations

The source manuscript reports ethical approval from the Health Research Ethics Committee of Universitas Islam Negeri Alauddin Makassar under approval number 070/004/KR/V/2024. The final manuscript should state the informed-consent procedure exactly as approved by the ethics committee and should distinguish ethical approval from any separate local-government research permission. No personally identifying participant information is reported in this manuscript.

3 Results

3.1 Participant characteristics

All 68 participants were male. Educational attainment and age distributions differed descriptively between groups. In the intervention group, 18 farmers (52.9%) had junior high school education and 16 (47.1%) had senior high school education; none had a bachelor's degree. In the comparison group, 12 (35.3%) had junior high school education, 20 (58.8%) had senior high school education, and 2 (5.9%) had a bachelor's degree. The most common age category in the intervention group was 21-24 years (14/34; 41.2%), whereas the comparison group was more evenly distributed and the largest single category was 25-28 years (7/34; 20.6%).

Table 1. Baseline characteristics of vegetable farmers by study group

Characteristic	Intervention (n=34)	Comparison (n=34)
Sex: male	34 (100.0)	34 (100.0)
Education: junior high school	18 (52.9)	12 (35.3)
Education: senior high school	16 (47.1)	20 (58.8)
Education: bachelor's degree	0 (0.0)	2 (5.9)
Age 19-20 years	8 (23.5)	6 (17.6)
Age 21-24 years	14 (41.2)	6 (17.6)
Age 25-28 years	5 (14.7)	7 (20.6)
Age 29-32 years	5 (14.7)	6 (17.6)
Age 33-36 years	1 (2.9)	6 (17.6)
Age 37-39 years	1 (2.9)	3 (8.8)

Values are n (%). Percentages were calculated from the reported frequencies.

3.2 Changes in knowledge, attitudes, and practices

At pretest, the intervention group had higher proportions of adequate knowledge and attitudes than the comparison group, while the proportion with adequate practices was similar. After the intervention period, all three adequate categories increased in the intervention group. Knowledge increased from 19 of 34 farmers (55.9%) to 33 of 34 (97.1%); adequate attitudes increased from 10 (29.4%) to 30 (88.2%); and adequate practices increased from 5 (14.7%) to 14 (41.2%).

In the comparison group, adequate knowledge increased from 6 of 34 farmers (17.6%) to 14 (41.2%) and adequate attitudes increased from 3 (8.8%) to 9 (26.5%). Adequate practices decreased slightly from 6 (17.6%) to 5 (14.7%). Thus, the observed percentage-point changes in the intervention group were +41.2 for knowledge, +58.8 for attitudes, and +26.5 for practices, compared with +23.6, +17.7, and -2.9 percentage points, respectively, in the comparison group. The descriptive between-group differences in change were therefore +17.6 percentage points for knowledge, +41.1 for attitudes, and +29.4 for practices. These differences are descriptive and should not be interpreted as adjusted or causal effect estimates.

Table 2. Pretest and posttest pesticide-safety outcomes by study group

Outcome	Category	Intervention pre	Intervention post	Comparison pre	Comparison post
Knowledge	Adequate	19 (55.9)	33 (97.1)	6 (17.6)	14 (41.2)
	Inadequate	15 (44.1)	1 (2.9)	28 (82.4)	20 (58.8)
Attitude	Adequate	10 (29.4)	30 (88.2)	3 (8.8)	9 (26.5)
	Inadequate	24 (70.6)	4 (11.8)	31 (91.2)	25 (73.5)
Practice	Adequate	5 (14.7)	14 (41.2)	6 (17.6)	5 (14.7)
	Inadequate	29 (85.3)	20 (58.8)	28 (82.4)	29 (85.3)

Values are n (%).

4 Discussion

The principal descriptive finding was a larger improvement in the intervention group across all three pesticide-safety domains, with the greatest observed increase in adequate attitudes, followed by knowledge and practices. Knowledge reached a high posttest level in the intervention group, while the increase in adequate practice was more modest. The comparison group also improved in knowledge and attitudes, whereas adequate practice changed little. These patterns suggest that exposure to the digital literacy intervention coincided with favorable changes, but the available data do not support a definitive causal estimate because the original inferential analysis was not appropriate for the reported binary coding and individual-level paired data were not available for reanalysis.

The observed improvement in knowledge is plausible because digital delivery can increase opportunities to access, revisit, and share safety information. Digital agricultural extension has been promoted as a means of expanding access to advisory services and technical information, particularly where conventional extension contact is limited [6]. In the context of pesticide management, information that is available at the time of decision making may help farmers interpret labels, recognize exposure routes, select protective measures, and remember safe handling and storage practices. However, the content and delivery characteristics of the intervention in this study were not adequately documented, so it is not possible to identify which digital components may have contributed to the observed change.

The distinction between knowledge and practice is important. Indonesian evidence has shown that farmers may understand pesticide hazards and recognize recommended protective equipment while still not consistently applying the recommended behavior [3,4]. This knowledge-practice gap can arise from factors that information alone does not remove, including cost and availability of personal protective equipment, thermal discomfort, time pressure, habitual spraying routines, perceived pest pressure, access to safer products, and local norms. Consequently, a strong increase in knowledge should not be interpreted as evidence that exposure has been adequately controlled.

The intervention group's larger descriptive increase in adequate attitudes may reflect greater acceptance of safety norms or greater perceived relevance of pesticide risk information. Behavioral change interventions often seek to alter not only knowledge but also beliefs about susceptibility, severity, benefits, social norms, and confidence in performing protective actions. A recent cluster-randomized trial among Ugandan smallholder farmers found that pesticide-safety education improved knowledge and that adding text messages improved attitudes, while broad practice scores did not significantly change [8]. That pattern is consistent with the general observation that cognitive and attitudinal outcomes may respond sooner than routine work practices.

The practice result in this study deserves particularly cautious interpretation. Adequate practice increased from 14.7% to 41.2% in the intervention group but remained below half of participants at posttest. This suggests that even if digital education contributed to behavior change, a substantial proportion of farmers still did not meet the study's adequacy criterion. Training studies in vegetable production have likewise emphasized that practical pesticide management requires repeated reinforcement, demonstration, and enabling conditions rather than information transfer alone [7]. Multi-channel behavior-change campaigns have also combined peer learning, mass communication, demonstrations, and access to practical services to strengthen adoption of safer pesticide behaviors [9].

The local public-health relevance is supported by prior evidence from Gowa Regency. Habibi et al. documented pesticide-intoxication symptoms among vegetable farmers and reported associations with spraying methods, personal hygiene, and personal protective equipment [5]. These factors are directly linked to behaviors that an educational program may attempt to influence. An effective pesticide-safety strategy in Kanreapia should therefore connect digital literacy with concrete exposure-control measures: correct product selection and label use, calibrated application, consistent personal protection, hygienic practices after spraying, safe storage, container management, and access to agricultural extension or health services when symptoms occur.

The comparison group improved in knowledge and attitudes despite not receiving the reported digital intervention. Several explanations are possible and should be explored in the study records. Participants may have been exposed to information from extension workers, peers, pesticide retailers, media, or routine community activities during the study period. Baseline testing itself may also sensitize participants to the topics being measured. In addition, the groups were not equivalent at baseline: the intervention group already had higher proportions of adequate knowledge and attitudes. These features make simple comparison of within-group p-values an inadequate basis for estimating an intervention effect and strengthen the need for a formal group-by-time analysis of the individual-level data.

From a methodological perspective, the source manuscript illustrates why outcome scale must guide statistical analysis. The reported means in the original Table 3 were generated from numeric coding of adequate/inadequate categories rather than from the original knowledge, attitude, or practice scores. Applying t-tests to those category codes obscures the binary nature and paired structure of the data. Reanalysis should use the original individual-level score data if the validated continuous scores are available; otherwise, binary repeated-measures methods should be used. The primary result should be an effect estimate with a 95% confidence interval for the difference in change or group-by-time interaction, not a comparison of whether separate within-group p-values cross the 0.05 threshold.

Several strengths are evident. The study addressed an occupational and environmental health problem in a vegetable-farming community with documented pesticide-related concerns, included a comparison group, and measured outcomes before and after the intervention. The KAP domains also provide a useful progression from information to attitudes and reported behavior. At the same time, important limitations constrain inference. Purposive sampling may limit representativeness; group allocation was not described; baseline outcome differences were substantial; the sample was small and exclusively male; instrument validity, reliability, and adequacy cut-points were not reported; practice assessment combined observation and self-report without sufficient procedural detail; intervention dose and fidelity were not documented; and potential contamination or concurrent educational exposure was not assessed.

An additional limitation is that only aggregate marginal pretest and posttest frequencies were available in the submitted manuscript. Without the individual-level paired transitions, it is not possible to reconstruct valid McNemar statistics, repeated-measures models, or confidence intervals. Therefore, the revised results intentionally present descriptive changes and avoid the original t-test p-values. This limitation is remediable if the original dataset is available. Reanalysis, completion of the intervention description, documentation of instrument properties and consent procedures, and transparent reporting of participant flow would materially strengthen the manuscript and allow a more defensible estimate of the intervention's association with pesticide-safety outcomes.

For practice and policy, digital literacy should be viewed as one component of a broader pesticide-risk-reduction system. Digital messages can extend reach and repetition, but they should be integrated with extension support, availability of suitable protective equipment, safer pest-management options, label literacy, and mechanisms for monitoring adoption. The FAO/WHO pesticide-management framework emphasizes coordinated responsibility across the pesticide life cycle rather than placing the entire burden of safety on individual farmers [2]. Future evaluations in similar communities would benefit from prespecified sample-size calculations, clearer allocation procedures, validated outcome instruments, longer follow-up, objective indicators of protective behavior where feasible, and an analysis plan centered on group-by-time effects.

Environmental-health implications extend beyond the individual applicator. Inappropriate pesticide handling can contribute to contamination of clothing, household surfaces, soil, water, and food, creating opportunities for secondary exposure among family members and nearby communities. For this reason, pesticide-safety education should not focus exclusively on personal protective equipment. It should also reinforce correct dose and product selection, avoidance of unnecessary pesticide use, equipment maintenance, prevention of spills, hand and body washing after application, separation of work clothing, safe storage away from children and food, and appropriate management of empty containers. Digital materials may be useful for reinforcing these steps through short visual demonstrations and reminders, but their content should be aligned with product labels, agricultural extension recommendations, and national pesticide-management requirements. Future intervention development should therefore include farmers and extension personnel in formative work to identify local barriers, preferred communication channels, language needs, and feasible protective behaviors. Such co-design would improve the likelihood that digital literacy translates into practical exposure reduction rather than remaining an improvement in knowledge alone.

5 Conclusion

Among 68 vegetable farmers in Kanreapia Village, the group receiving the reported digital literacy intervention showed larger descriptive pretest-to-posttest improvements in adequate pesticide-safety knowledge, attitudes, and practices than the comparison group. The largest difference in change was observed for attitudes, followed by practices and knowledge. These findings are consistent with the potential value of digital risk communication but do not, in their current form, establish a causal intervention effect. Before submission, the original individual-level paired data should be reanalyzed using methods appropriate to the outcome scale and repeated measurements, and the intervention, measurement, sample-size, allocation, and consent procedures should be fully documented. A strengthened digital intervention should be combined with practical exposure-control support to translate improved knowledge and attitudes into sustained safe pesticide practices.

6 Declarations

Ethics approval and consent to participate

The source manuscript reports approval by the Health Research Ethics Committee of Universitas Islam Negeri Alauddin Makassar (No. 070/004/KR/V/2024). The authors should verify and insert the exact informed-consent procedure approved by the committee before final submission.

Consent for publication

Not applicable; the manuscript does not report identifiable participant information.

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Competing interests

The authors declare no competing interests.

Author contributions (CRediT)

Conceptualization: Asril, Andi Susilawaty. Methodology: Andi Susilawaty, Sitti Raodhah. Investigation: Habibi. Formal analysis: Asril, Andi Susilawaty. Writing - original draft: Asril. Writing - review & editing: Andi Susilawaty, Sitti Raodhah, Habibi.

Data availability

The de-identified individual-level dataset should be made available from the corresponding author on reasonable request, subject to applicable ethical and privacy requirements. Availability conditions should be verified by the authors before submission.

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Generative AI statement

The authors used OpenAI ChatGPT (GPT-5.6 Sol) to support language editing, structural alignment with the HIGIENE template, and consistency checking during manuscript revision. All outputs were critically reviewed and edited by the authors, who retain full responsibility for the accuracy and integrity of the manuscript.

7 References

1. World Health Organization. Pesticide residues in food [Internet]. Geneva: World Health Organization; 2022 [cited 2026 Aug 19]. Available from: https://www.who.int/news-room/fact-sheets/detail/pesticide-residues-in-food.
2. Food and Agriculture Organization of the United Nations, World Health Organization. International Code of Conduct on Pesticide Management. Rome: FAO; 2014.
3. Yuantari MGC, van Gestel CAM, van Straalen NM, Widianarko B, Sunoko HR, Shobib MN. Knowledge, attitude, and practice of Indonesian farmers regarding the use of personal protective equipment against pesticide exposure. Environ Monit Assess. 2015;187:142. https://doi.org/10.1007/s10661-015-4371-3.
4. Istriningsih, Dewi YA, Yulianti A, Hanifah VW, Jamal E, Dadang, et al. Farmers' knowledge and practice regarding good agricultural practices (GAP) on safe pesticide usage in Indonesia. Heliyon. 2022;8(1):e08708. https://doi.org/10.1016/j.heliyon.2021.e08708.
5. Habibi H, Bukhari A, Naiem MF. Symptoms of pesticide intoxication among vegetable farmers in Gowa Regency, Indonesia. Al-Sihah Public Health Sci J. 2022;14(2):172-182. https://doi.org/10.24252/al-sihah.v14i2.32276.

6. Trendov NM, Varas S, Zeng M. Digital technologies in agriculture and rural areas: status report. Rome: Food and Agriculture Organization of the United Nations; 2019.
7. Manuben JJP, Sarmiento JA, Cruz EJD, Galao AAB, Bajet CM. Role of farmers' training on improving pesticide management and food safety in conventional cabbage and eggplant production. Philipp J Sci. 2023;152(5):1851-1860. https://doi.org/10.56899/152.05.26.
8. Ssekkadde P, Tomberge VMJ, Brugger C, Atuhaire A, Dalvie MA, Rother HA, et al. Educational intervention effects on pesticide-related knowledge, attitudes, practices, exposure, and health among Ugandan smallholder farmers: a cluster randomized controlled trial. Int J Public Health. 2025;70:1608952. https://doi.org/10.3389/ijph.2025.1608952.
9. Njenga MW, Kansiime MK, Davis T, Rugaita G, Njunge R, Mchana A, et al. Reducing pesticide risks through social and behavior change communication: a case study of the Ukulima True campaign in Kenya. Front Sustain Food Syst. 2025;9:1627249. https://doi.org/10.3389/fsufs.2025.1627249.