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Construction and Validation of a Knowledge Test on Pesticide Safety for Vegetable Growers

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HIGHLIGHTS

- Eighty-two items were initially developed using extensive literature review and multidisciplinary expert inputs.
- Sixty experts evaluated item relevancy, refining the pool to 45 high-quality, validated items.
- Thirty-eight items met all psychometric criteria, including acceptable difficulty, discrimination, and point biserial values.
- The final knowledge test showed excellent reliability with Cronbach's alpha of 0.90.

ARTICLE INFO

Keywords: Knowledge test, Safety measures, Difficulty index, Discrimination index, Point biserial correlation, Cronbach's alpha.

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ABSTRACT

Vegetable farmers frequently utilize a diverse array of pesticides at varying doses to mitigate yield losses arising from insect pests, pathogens, and other biotic stresses. Although pesticide use has substantially contributed to enhanced crop productivity, a growing body of scientific evidence highlights that indiscriminate, excessive, or unsafe pesticide use can impose serious health hazards on applicators and consumers, while also generating adverse ecological consequences. In this context, the present study was conducted in 2025, developed and standardized a comprehensive knowledge test to assess vegetable growers' understanding of safety measures in pesticide application. An initial pool of 82 items was generated ensuring coverage of all critical dimensions of pesticide safety. Based on relevancy scores obtained from 60 experts, 45 items were shortlisted for further evaluation. Item analysis was performed using three statistical indices: difficulty index, discrimination index, and point biserial correlation. Following established psychometric criteria, 38 items were retained with difficulty values between 30–70, discrimination indices ranging from 0.30–0.80, and a minimum point biserial correlation of 0.15. The finalized test comprised 38 items and demonstrated high internal consistency, with a Cronbach's alpha coefficient of 0.90, confirming its reliability for assessing knowledge on pesticide safety.

INTRODUCTION

Pesticides have played a crucial role in enhancing crop productivity and strengthening India's food security (Arora, 2018; Kumar et al., 2025). In vegetable cultivation, insect pests and diseases continue to pose major constraints, often resulting in yield losses of 10–30 per cent (Roy et al., 2017). To mitigate these losses, most vegetable growers depend extensively on chemical pesticides. As a result, vegetable production has become one of the most pesticide-intensive agricultural activities, owing to the high vulnerability of vegetable crops to pest and disease infestations (Meenakshi & Saini, 2022; Singh et al., 2025; Singh et al., 2023a, Singh 2023b). Despite the availability of scientific recommendations, a considerable gap persists between recommended pesticide-use practices and those actually followed by vegetable growers. Indiscriminate, excessive, and unsafe pesticide application

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practices pose serious threats to human health, environmental integrity, and the sustainability of agricultural ecosystems (Nain & Singh, 2015; Mishra et al., 2021; Pathak et al., 2022). Although vegetable growers acknowledge the importance of pesticides for crop protection, their adherence to essential safety measures such as using personal protective equipment (PPE), ensuring safe storage, following correct disposal procedures for empty containers, and complying with label instructions remains inadequate (Hossain et al., 2024). Even trace levels of pesticide residues in vegetables have been linked to long-term health risks among consumers (Gupta et al., 2010). Studies across India highlight this paradox: while vegetable growers are aware of the potential hazards associated with pesticides, they often continue to engage in unsafe practices. For example, in Haryana, more than 77 percent of vegetable growers reported awareness of the harmful effects of pesticides, yet the majority could not interpret toxicity colour codes or follow label guidelines, leading to frequent incidents of acute poisoning (Meenakshi & Saini, 2022). These patterns underline the urgent need for interventions that address not only growers' knowledge but also their attitudes toward safe and responsible pesticide use. Integrated Pest Management (IPM) has been promoted as a sustainable alternative to indiscriminate pesticide reliance (Lal et al., 2024; Lal et al., 2025). Through national programs, Krishi Vigyan Kendra's (KVKs), and state extension agencies, IPM advocates the use of biological control agents, cultural practices, and judicious chemical application (Meenakshi & Saini, 2022). However, the effective adoption of IPM hinges largely on farmers' attitudes toward safety, precautionary measures, and long-term sustainability. Although awareness about IPM is gradually increasing, actual adoption remains limited, primarily due to entrenched attitudes favouring chemical pesticides (Gupta et al., 2020). Given these challenges, systematically assessing vegetable growers' knowledge level toward pesticide safety particularly in relation to IPM practices is essential for designing behaviour-oriented interventions. While several Knowledge, Attitude, and Practice (KAP) studies have examined pesticide use among Indian farmers, there remains a notable lack of standardized tools tailored specifically to measure knowledge level toward pesticide safety in vegetable cultivation. A rigorously developed and validated knowledge test is needed to capture the multidimensional aspects of pesticide safety, including handling, storage, application methods, post-application precautions, container disposal practices, health and environmental safeguards, and compliance with regulatory norms.

METHODOLOGY

Items related to safety measures in pesticide application were systematically developed, refined, and standardized through sequential stages comprising item generation, expert validation, and statistical screening. Initially, a pool of 82 statements was generated from secondary sources, including scientific journals, extension manuals, research reports, and other relevant literature. Expert consultations from the disciplines of Plant Pathology, Entomology, and Agricultural Extension were further utilized to enhance comprehensiveness and conceptual clarity. The preliminary items were subjected to relevancy judgment by 60 experts. Each statement was rated on a three-point continuum Most Relevant (3), Relevant (2), and Not Relevant (1). Relevancy Weightage (RW) and Mean Relevancy Score (MRS) were computed using:

$$RW = \frac{MR + R + LR}{MPS}, MRS = \frac{MR + R + LR}{n}$$

Where, MR = Most Relevant, R = Relevant, LR = Least Relevant, MPS = Maximum Possible Score (60 × 3 = 180), and n = number of judges. The Overall Mean Relevancy Score (OMRS) was 2.35. Items with RW > 0.80 and MRS ≥ OMRS were retained, resulting in 45 qualified statements.

Item analysis

These 45 items were administered to 30 non-sample respondents. Total scores were arranged in descending order and classified into six equal groups: G1 to G6. For item analysis, only the extreme groups G1, G2, G5, and G6 were considered. Difficulty Index (P) was computed as:

$$P = \frac{\text{Number of correct responses}}{\text{Total respondents}} \times 100$$

Items with P between 30 and 70 were retained to avoid extremely easy or difficult questions.

Discrimination Index (E1/3), reflecting the item's ability to differentiate between high and low scorers, was calculated using:

$$E1/3 = \frac{(S1 + S2) - (S5 + S6)}{N/3}$$

Where, S1, S2, S5, and S6 denote frequencies of correct responses in respective groups. Items with discrimination values ranging from 0.20 to 0.80 were selected. Internal validity of each item was further examined using point biserial correlation:

$$r_{pbis} = \frac{(M_P - M_Q)}{SD} \sqrt{PQ}$$

Where, MP and MQ represent mean scores of respondents answering correctly and incorrectly; P and Q denote proportions of correct and incorrect responses. Items significant at 1% and 5% levels were retained.

After applying all screening criteria, 38 items were selected for the final knowledge test. Reliability was assessed using Cronbach's alpha in SPSS (Version 27), yielding a coefficient of 0.90, confirming excellent internal consistency and robustness of the instrument.

RESULTS

Reliability analysis

The internal consistency of the knowledge test was assessed using Cronbach's alpha. The computed reliability coefficient was 0.90, which falls within the "excellent" category. This indicates that the items function cohesively to measure a single underlying construct knowledge on safety measures in pesticide application. Such a high level of internal consistency suggests that the instrument is stable, dependable, and suitable for use in further empirical assessments.

Validity analysis

Content validity

The content validity of the test was ensured through a rigorous multi-stage development process. A comprehensive pool of 82 items was derived from scientific literature, extension manuals, expert consultation, and field-level experience. Sixty experts evaluated each item on relevancy, and items with RW > 0.80 and MRS ≥ OMRS (2.35) were retained. This ensured that the retained items represented the full conceptual domain of pesticide safety, establishing strong content adequacy.

Construct validity

Construct validity was examined using Point Biserial Correlation (rpbis). Items with significant correlations at the 1% and 5% levels were retained, indicating that each of these items was appropriately aligned with the underlying construct and effectively discriminated between knowledgeable and less-knowledgeable respondents. The majority of retained items had rpbis > 0.25, which is considered satisfactory for educational and psychometric testing.

Relevancy assessment

Table 1 presents the results of relevancy analysis. Out of 82 initially generated items, 45 items met the requisites of RW and MRS for inclusion in the preliminary test. These items demonstrated strong content representation of pesticide safety knowledge.

Item analysis

The 45 selected items were administered to 30 non-sample vegetable growers for statistical screening. Difficulty Index (DI), Discrimination Power (DP), and Point Biserial Correlation (PBS/ rpbis) were computed. The item analysis revealed that the retained statements met all standard psychometric criteria. Most items fell within the acceptable difficulty range (0.30–0.70), indicating neither excessive ease nor undue difficulty. The discrimination indices (0.20–0.80) confirmed strong ability of the items to differentiate between high- and low-knowledge respondents. Additionally, all selected items achieved the minimum point biserial correlation (≥0.15, preferably >0.20), demonstrating satisfactory internal consistency and strong item total relationships. Analysis revealed

Table 1. Relevancy test scores of item selection

Item No	Items	RW	MRS	OMRS
1.	Are you able to recognize the symptoms of disease infestation, Insect attack, nematode attack or nutritional deficiency?	0.96	2.88	2.35
2.	A face mask is not required while mixing pesticides	0.69	2.08	
3.	Do you apply pesticides based on the specific pest identified?	0.91	2.72	
4.	Can you distinguish/identify the beneficial insects?	0.82	2.45	
5.	It is safe to use the same gloves for pesticide application and other farm activities.	0.64	1.93	
6.	Do you know the color code of pesticide?	0.84	2.53	
7.	I think written materials are the best way to educate farmers about pesticide safety.	0.64	1.93	
8.	Pesticide safety training continuous process, not a one-time event.	0.63	1.90	
9.	Do you identify symptoms of little leaf of brinjal?	0.81	2.42	
10.	Do you have know bio-pesticides (eg. *Trichoderma,* NSKE etc.)	0.82	2.47	
11.	Do you know the best time of pesticide spray? (Yes/No)	0.84	2.52	
12.	It is legal to apply pesticides in a manner specified on the label.	0.72	2.15	
13.	Do you identify symptoms of fruit borer, late blight of tomato?	0.90	2.70	
14.	I think pesticides applied by certified applicators	0.73	2.18	
15.	I think record-keeping of pesticide application is not necessary.	0.77	2.30	
16.	Do you know Diamond Back Moth of cabbage can be managed by growing Chinese cabbage or Indian mustard?	0.81	2.43	
17.	It is legal to use pesticides that have not been approved by the government.	0.74	2.22	
18.	I monitor the health of myself and workers regularly for symptoms of pesticide exposure	0.74	2.23	
19.	Do you know the best time of pesticide spray?	0.81	2.43	
20.	Do you know about pheromone trap (yellow, blue sticky trap etc.)	0.85	2.55	
21.	Do you know upward curling of chilly is due to?	0.80	2.40	
22.	I know drinking milk can neutralize ingested pesticides.	0.77	2.32	
23.	Do you know downward curling of chilly is due to?	0.69	2.08	
24.	I know pesticides can cause allergic reactions in some individuals.	0.74	2.22	
25.	Inhalation is the route of exposure to pesticides.	0.75	2.25	
26.	Do you know marigold is good trap crop in tomato for the control of tomato fruit borer?	0.84	2.52	
27.	It is safe to spray pesticides during rainy weather.	0.73	2.18	
28.	Do you know Cueleue is good trap for fruit fly of cucurbits?	0.85	2.55	
29.	Buffer zones around water bodies help prevent pesticide contamination	0.67	2.02	
30.	Do you know about universal antidote? (eg. charcoal, tannic acid, magnesium oxide etc.?	0.80	2.40	
31.	Do you know the waiting period of any pesticides?	0.91	2.72	
32.	Applying more pesticide than recommended will increase its effectiveness	0.68	2.03	
33.	Do you know the mode of action of pesticides?	0.84	2.52	

Table 1 contd...

Item No	Items	RW	MRS	OMRS
34.	Using pesticides does not affect non-target species.	0.63	1.90	
35.	Crop rotation can reduce the need for pesticide use.	0.79	2.38	
36.	Do you know at which stage paraquat herbicide is typically applied?	0.87	2.62	
37.	The application rate of pesticides is same for all types of crops.	0.71	2.13	
38.	It is important to calibrate spraying equipment before each use.	0.68	2.05	
39.	Do you know the most serious disease of brinjal?	0.87	2.62	
40.	Do you know the, which fungicide is the most effective for the control of Phomopsis blight of brinjal?	0.81	2.42	
41.	Are you aware of banned pesticides?	0.82	2.47	
42.	Pesticide spills should be cleaned immediately using any available cloth.	0.67	2.00	
43.	Whitefly is a serious pest of which vegetable?	0.85	2.55	
44.	Do you know the Critical weed-free period in tomato?	0.82	2.47	
45.	Do you know which type of nozzle is used for managing insect and disease in agriculture?	0.83	2.50	
46.	Eye exposure to pesticides, rinse the eyes with clean water for at least 15 minutes.	0.74	2.22	
47.	I take regular training on safe use of pesticide	0.76	2.27	
48.	Do you know Metribuzin 70% WP (Bayer sensor) is used in potato for? A. Insect pests such as cutworms; B. Fungal diseases such as late blight C. Broad-leaf weeds and some grasses; D. Nematode infestation	0.89	2.68	
49.	Do you know the Critical Weed free period in cabbage?	0.90	2.70	
50.	Pesticide safety training continuous process, not a one-time event.	0.67	2.00	
51.	Do you know the which one of the following-coloured pesticide has least toxicity? A. Green; B. Blue; C. Yellow; D. Red	0.80	2.40	
52.	Knowledge of local pest species and their biology is crucial for effective pesticide use.	0.74	2.22	
53.	Do you know the which one of the following-coloured pesticide has maximum toxicity? A. Green; B. Blue; C. Yellow; D. Red	0.89	2.68	
54.	Do you know *Trichoderma viride* used as? A. Seed treatment; B. Soil treatment	0.86	2.57	
55.	It is unnecessary to seek medical attention if the symptoms of pesticide exposure are mild.	0.73	2.20	
56.	Pesticide exposure incidents should be documented and reported.	0.68	2.05	
57.	Do you know the recommended dose of *Trichoderma viride* 1.0% WP for Seed Treatment in cauliflower?	0.87	2.60	
58.	Do you know that incorrect pesticide use can contaminate water sources?	0.69	2.07	
59.	Do you know that pesticides can cause both acute and chronic health effects?	0.69	2.08	
60.	Do you know that Pheromone trap can control insect-pest?	0.85	2.55	
61.	Do you know Coragen® MaX pesticide is used for the control of which pests?	0.91	2.73	
62.	Do you know that emergency contact numbers should be available during pesticide use?	0.69	2.07	
63.	Do you know that label instructions must be strictly followed when mixing pesticides?	0.84	2.52	
64.	Do you know that immediate medical help is needed if pesticide poisoning is suspected?	0.79	2.37	
65.	Do you know the trade name of Halosulfuron Methyl 75% WG is?	0.79	2.38	
66.	Do you know that wearing gloves is necessary when handling pesticides?	0.68	2.05	
67.	Do you know the trade name of Emamectin Benzoate 5% SG is?	0.78	2.35	
68.	Do you know that pesticides must be kept out of reach of children and pets?	0.74	2.23	
69.	Do you know which insecticide is used in control of Whitefly, Thrips, Aphids, Caterpillar and Leaf miner in bitter gourd and watermelon?	0.64	1.93	
70.	Do you know the recommended dose of Cyantraniliprole 10.26% OD in bitter gourd for insects' control?	0.79	2.38	
71.	Do you know that spraying equipment must be cleaned after each use?	0.81	2.43	
72.	Do you know that children and pregnant women are more vulnerable to pesticide poisoning?	0.80	2.40	
73.	Do you know the trade name of Mandipropamid 23.4% SC is?	0.77	2.30	
74.	Do you know the recommended dose of *Ampelomyces quisqualis* 2.0% WP for powdery mildew disease of cucumber?	0.75	2.25	
75.	Do you know that long-term pesticide exposure may lead to cancer?	0.84	2.52	
76.	Do you know the recommended dose of *Trichoderma viride* 1.0% WP for Seedling Root dip Treatment in cabbage?	0.68	2.05	
77.	Do you know the trade name of Imidacloprid 17.8 SL	0.76	2.27	
78.	Do you know that symptoms like headache, dizziness, and nausea indicate pesticide poisoning?	0.83	2.50	
79.	Do you know that Integrated Pest Management (IPM) helps reduce dependency on pesticides?	0.90	2.70	
80.	Do you know that leftover pesticides should not be disposed of in rivers or streams?	0.87	2.62	
81.	Did you know that pesticides should always be stored in a cool, dry place and kept strictly out of the reach of children and pets for safety?	0.88	2.65	
82.	Do you know the mode of action of Imidacloprid 17.8 SL or Thiamethoxam 25% WG?	0.77	2.32	

Table 2. Item difficulty, discrimination and point biserial correlation scores of items for item analysis

S.No.	Items	P	E1/3	rpbis
1	Can pesticides cause both acute (short-term) and chronic (long-term) health effects? (Yes/No)	0.70	-0.13	-0.13
2	Should pesticides always be stored in their original containers with the labels intact? (Yes/No)	0.63	0.13	0.01
3	Do you keep records of pesticide use, including the date, type, and quantity applied? (Yes/No)	0.60	0	0.02
4	Is reading the pesticide label alone sufficient to fully understand proper pesticide application and safety measures? (Yes/No)	0.60	0.25	0.13
5	Should an emergency contact number be kept readily available in case of pesticide exposure? (Yes/No)	0.60	0.13	0.10
6	Are you able to recognize the symptoms of disease infestation, Insect attack, nematode attack or nutritional deficiency? (Yes/No)	0.60	0.50	0.47*
7	Can you distinguish/identify the beneficial insects? (Yes/No)	0.50	0.38	0.27*
8	Do you know the color code of pesticide? (Yes/No)	0.63	0.50	0.38*
9	Do you know the which one of the following-coloured pesticide has least toxicity? A. Green B. Blue C. Yellow D. Red	0.60	0.38	0.35*
10	Do you know the which one of the following-coloured pesticide has maximum toxicity? A. Green B. Blue C. Yellow D. Red	0.60	0.63	0.53*
11	Do you identify symptoms of fruit borer, late blight of tomato? (Yes/No)	0.63	0.25	0.27*
12	Do you know that long-term pesticide exposure may lead to cancer? (Yes/No)	0.57	0.50	0.48*
13	Do you know Diamond Back Moth of cabbage can be managed by growing Chinese cabbage or Indian mustard? (Yes/No)	0.63	0.75	0.50*
14	Do you know the best time of pesticide spray? (Yes/No)	0.57	0.75	0.52*
15	Do you know about pheromone trap (yellow, blue sticky trap etc.) (Yes/No)	0.50	0.63	0.37*
16	Do you know upward curling of chilly is due to? A. Thrips B. Yellow mites C. Whitefly D. Caterpillars	0.57	0.75	0.55*
17	Do you know downward curling of chilly is due to? A. Thrips B. Yellow mites C. Whitefly D. Caterpillars	0.57	0.75	0.58*
18	Do you know marigold is good trap crop in tomato for the control of tomato fruit borer? (Yes/No)	0.60	0.63	0.47*
19	Do you know Cueleue is good trap for fruit fly of cucurbits? (Yes/No)	0.63	0.50	0.38*
20	Do you know about universal antidote? (eg. charcoal, tannic acid, magnesium oxide etc.? (Yes/No)	0.60	0.38	0.35*
21	Do you know the waiting period of any pesticides? (Yes/No)	0.60	0.63	0.53
22	Do you know the mode of action of any pesticides (like-systematic, contact? (Yes/No)	0.63	0.25	0.27*
23	Do you know at which stage paraquat herbicide is typically applied? A. Post-emergence of weeds; B. Pre-plant application before crop emergence C. After crop emergence; D. Both a and b	0.57	0.50	0.48*
24	Do you know the most serious disease of brinjal? A. Leaf spot; B. Phomopsis Blight; C. Alternaria Leaf Spots; D. Fruit Rot	0.63	0.75	0.50*
25	Do you know the, which fungicide is the most effective for the control of Phomopsis blight of brinjal? (Yes/No)	0.57	0.75	0.52*
26	Do you know which of the following insecticide are banned now? A. Endosulfan; B. Benomyl; C. Carbendazim; D. Delegate	0.50	0.63	0.37*
27	Do you know Metribuzin 70% WP (Bayer sensor) is used in potato for? A. Insect pests such as cutworms; B. Fungal diseases such as late blight C. Broad-leaf weeds and some grasses; D. Nematode infestation	0.57	0.75	0.55*
28	Do you know the Critical Weed free period in cabbage?	0.57	0.75	0.58*
29	Do you identify symptoms of little leaf of brinjal? (Yes/No)	0.60	0.63	0.47*
30	Do you have know bio-pesticides (eg. *Trichoderma,* NSKE etc.) (Yes/No)	0.60	0.38	0.35*
31	Do you know *Trichoderma viride* used for? A. Seed treatment B. Soil treatment	0.60	0.63	0.53*
32	Do you know the recommended dose of *Trichoderma viride* 1.0% WP for Seed Treatment in cauliflower? A. 3 g/kg seed; B. 2 g/kg seed; C. 4 g/kg seed; D. 5 g/kg seed	0.63	0.25	0.27*
33	Do you know that Pheromone trap can control insect-pest? A. Brinjal shoot & fruit borer; B. Tomato fruit borer; C. Bhindi shoot & fruit borer; D. All of these	0.57	0.50	0.48*
34	DO you know which type of nozzle is used for managing insect and disease in agriculture? A. Hollow cone B. Flat fan C. Solid cone nozzle D. All can be used	0.63	0.75	0.50*
35	Did you know that pesticides should always be stored in a cool, dry place and kept strictly out of the reach of children and pets for safety? (Yes/No)	0.57	0.75	0.52*
36	Do you know that label instructions must be strictly followed when mixing pesticides? (Yes/No)	0.50	0.63	0.37*
37	Do you know that spraying equipment must be cleaned after each use? (Yes/No)	0.57	0.75	0.55*
38	Do you know that children and pregnant women are more vulnerable to pesticide poisoning? (Yes/No)	0.57	0.75	0.58*
39	Do you know that symptoms like headache, dizziness, and nausea indicate pesticide poisoning? (Yes/No)	0.60	0.63	0.47*

Table 2 contd...

S.No.	Items	P	E1/3	rpbis
40	Do you know that Integrated Pest Management (IPM) helps reduce dependency on pesticides? (Yes/No)	0.60	0.13	0.02
41	Do you know that leftover pesticides should not be disposed of in rivers or streams? (Yes/No)	0.60	0.88	0.59*
42	Do you know that leftover pesticides should not be disposed of in rivers or streams? (Yes/No)	0.50	0.63	0.40*
43	Do pesticide safety workshops help in increasing awareness about reducing the risk of pesticide-related accidents? (Yes/No)	0.53	0.13	0.10
44	Do you practice proper handwashing with soap and water immediately after completing pesticide application? (Yes/No)	0.53	0.38	0.26*
45	Is knowledge of basic first aid procedures important for pesticide users to respond quickly and safely in case of pesticide exposure or poisoning? (Yes/No)	0.57	0.75	0.65*

P= Item difficulty index, E1/3= Item discrimination index, rpbis =point biserial correlation, *Selected items

that 38 items met all three criteria. Items exhibiting extremely low discrimination, high difficulty extremes, or negative rpbis were removed. Items with particularly strong rpbis values were marked with "*", indicating high internal validity.Thus, the final standardized knowledge test consisted of 38 items suitable for assessing the knowledge level of vegetable growers on safe pesticide application practices.

DISCUSSION

The present study aimed to develop a statistically sound and content-rich instrument to measure the knowledge of vegetable growers regarding pesticide safety. The results indicate that the methodological rigor employed spanning item construction, expert validation, and psychometric testing was effective in generating a robust and reliable instrument.

The high Cronbach's alpha coefficient (0.90) aligns with the findings of Priyadarshini et al. (2021), who reported similar reliability (0.904), reaffirming that knowledge tests developed through structured multi-stage processes can achieve strong internal consistency. The involvement of experts from multiple disciplines further enhanced content validity, ensuring that the instrument covered all critical dimensions of pesticide safety such as identification of pests, toxicity classification, protective equipment, safe storage, first-aid measures, and environmental precautions.

The discrimination index values observed in this study reflect the instrument's ability to distinguish between well-informed and poorly informed respondents (Loukham & Bandyopadhyay, 2014; Kumar et al., 2016; Muyal et al., 2022; Vijayan et al., 2022; Vijayan et al., 2023). Additionally, the point biserial correlation values (>0.25 for most items) confirm strong construct validity, indicating that individual items contributed meaningfully to the overall knowledge measurement.

The retention of 38 high-quality items from an initial pool of 82 demonstrates the necessity of rigorous filtration in test development. Such refinement minimizes redundancy, enhances precision, and ensures that the final tool is not only comprehensive but also efficient for field administration.

Overall, the study successfully developed a standardized, reliable, and valid knowledge test for assessing safety-related awareness among vegetable growers. The final test can serve as a scientific tool for researchers, extension personnel, policymakers, and training institutions to evaluate and improve pesticide safety literacy, ultimately contributing to safer agricultural practices and reduced pesticide-related health risks.

CONCLUSION

Despite the essential role of pesticides in safeguarding vegetable crops, widespread gaps persist between recommended safety practices and farmers' actual behaviour, posing substantial risks to human health, ecosystems, and food safety. Through a rigorous multi-stage development process including expert validation, difficulty and discrimination testing, and psychometric evaluation the study successfully standardized a 38-item knowledge test with excellent reliability (Cronbach's $\alpha = 0.90$) and strong evidence of content and construct validity (Cronbach, 1951). The instrument effectively captures multidimensional aspects of pesticide safety, ranging from pest identification and toxicity interpretation to storage, handling, application practices, first aid, and environmental safeguards. This validated tool offers significant utility for researchers, extension systems, and policymakers in designing targeted interventions aimed at strengthening safe pesticide use. Ultimately, its application can contribute to reducing pesticide-related hazards and promoting sustainable vegetable production systems.

DECLARATIONS

Ethics approval and informed consent: Informed consent was sought from the judges of the statements/ items regarding the study during the course of the data collection.

Conflict of interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

The authors declare that during the preparation of this work, they thoroughly reviewed, revised, and edited the content as needed. The authors take full responsibility for the final content of this publication.

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