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Residue risks in vegetable cultivation: A ground-level analysis of farmers' awareness

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Abstract

Vegetable cultivation is an important component of agriculture, but indiscriminate pesticide use has raised concerns about harmful residue effects on health and the environment. The present study was conducted in Bharuch district of South Gujarat to assess the awareness of vegetable growers regarding hazardous effects of pesticide residues using an ex-post facto design with 120 respondents selected through multistage sampling. Data were analyzed using correlation, regression, and path analysis techniques. The results revealed that a majority (52.50%) of growers had a medium level of awareness. Education, extension contact, mass media exposure, and scientific orientation showed a positive and significant relationship with awareness, while age and farming experience showed a negative significant relationship. The selected variables explained 17.60 per cent variation in awareness, with extension contact emerging as the most influential positive factor and age as the strongest negative factor. Path analysis indicated that extension contact had the highest positive direct effect, whereas social participation showed the highest indirect effect. The study concludes that strengthening extension services, improving information access, and promoting social participation are essential to enhance farmers' awareness regarding pesticide residue hazards.

Keywords: Vegetable growers, pesticide residues, awareness, extension contact, path analysis

1. Introduction

Pesticides play a crucial role in modern agriculture by protecting crops from pests, diseases, and weeds, thereby contributing significantly to enhanced productivity and food security. However, their extensive and often indiscriminate use has given rise to a critical concern in agricultural and public health domains, namely pesticide residues. These residues, defined as traces of chemical substances that remain in or on agricultural produce after application, persist primarily due to improper dosage, non-adherence to recommended waiting periods, and unscientific application practices.

The presence of pesticide residues in food commodities, particularly vegetables, has emerged as a serious issue affecting food safety and human health worldwide. To regulate and control this problem, various international and national agencies have established Maximum Residue Limits (MRLs) to ensure that pesticide levels in food remain within permissible limits. Nevertheless, in developing countries like India, inadequate awareness and poor compliance among farmers frequently result in residue levels exceeding these standards (Singh *et al.*, 2022) ^[9].

India, being the second largest producer of vegetables in the world after China, plays a vital role in ensuring nutritional

security (Statista Research Department, 2026) ^[4]. Vegetables are cultivated across diverse agro-climatic regions under both open field and protected cultivation systems. However, their production is highly vulnerable to a wide range of insect pests and diseases, compelling farmers to rely heavily on pesticide applications. Although the per hectare pesticide consumption in India is comparatively lower than that of many developed nations, the challenge lies in its improper and irrational use, which significantly contributes to residue accumulation in vegetables (Pesticide use and trade, 2023a) ^[2].

The occurrence of pesticide residues is largely associated with excessive and repeated applications, use of banned or restricted chemicals, and neglect of pre-harvest intervals. In certain cases, pesticides are also applied to improve the cosmetic appeal of produce, such as enhancing colour and shine, further aggravating the risk of contamination. Empirical evidence suggests that a substantial proportion of vegetable samples contain detectable levels of pesticide residues, with a notable percentage exceeding the prescribed MRLs. Vegetables such as tomato, brinjal, chilli, and okra are particularly prone to such contamination (FSSAI, 2022) ^[1].

Pesticide residues pose significant health hazards as they enter the human body through the consumption of contaminated food and tend to accumulate over time. Acute

exposure may lead to symptoms such as nausea, skin irritation, and respiratory distress, whereas chronic exposure has been linked to severe conditions including cancer, endocrine disruption, reproductive disorders, and neurological impairments (WHO, 2023b) [3]. The magnitude of the problem is reflected in global estimates reporting millions of cases of pesticide poisoning annually, particularly among farming communities (Boedeker *et al.*, 2020) [5].

Beyond human health, indiscriminate pesticide use also contributes to environmental degradation, including soil contamination, water pollution, biodiversity loss, and ecological imbalance. Since vegetables are often consumed fresh or minimally processed, the risk of pesticide exposure through dietary intake is considerably higher, making this issue more critical from a food safety perspective.

To mitigate these risks, several protection measures have been advocated, including the use of personal protective equipment, adherence to recommended dosages, safe handling and storage of pesticides, and strict observance of pre-harvest intervals. However, the effective adoption of these measures largely depends on the awareness level of farmers. Studies indicate that while a considerable proportion of farmers possess general awareness about pesticide hazards, their specific understanding of residue-related risks and safe practices remains limited (Patel & Chauhan, 2021; Meena *et al.*, 2023; Sharma & Singh, 2020) [6, 7, 8].

Furthermore, awareness is not uniform across farming communities and is significantly influenced by various socio-economic and communication-related factors such as education, farming experience, extension contact, and mass media exposure. These factors shape farmers' knowledge, perceptions, and decision-making behaviour regarding pesticide use. Therefore, a comprehensive analysis of these

associated factors is essential for designing targeted and effective extension interventions.

In this context, a systematic assessment of the awareness level of vegetable growers regarding the hazardous effects of pesticide residues, along with the identification of associated factors, becomes imperative. Such an approach will provide valuable insights for developing need-based extension strategies aimed at enhancing farmers' awareness, promoting safe and judicious pesticide use, and ultimately minimizing pesticide residues in vegetables, thereby ensuring food safety, public health, and environmental sustainability.

2. Methodology

The present study was conducted in Bharuch district of South Gujarat. Two talukas, namely Bharuch and Ankleshwar, were purposively selected based on the highest area under vegetable cultivation. From each selected taluka, four villages were purposively chosen, making a total of eight villages. Further, fifteen vegetable growers were selected from each village through simple random sampling, constituting a total sample size of 120 respondents. The study followed an Ex-Post Facto research design, as the variables under investigation had already occurred and were beyond the control of the researcher. A well-structured and pre-tested interview schedule was developed to collect primary data in line with the objectives of the study. The collected responses were systematically compiled, coded, and tabulated. Appropriate statistical measures such as frequency and percentage, correlation coefficient, multiple regression analysis, step wise regression analysis and path analysis were used to analyse the distribution of responses.

3. Results and Discussion

Table 1: Distribution of the respondents according to their profile characteristics (n=120)

Categories	Frequency	Percent
(1) Age		
Young age (up to 35 years)	28	23.33
Middle age (36 to 50 years)	57	47.50
Old age (above 50 years)	35	29.17
(2) Education		
Illiterate	2	01.67
Functionally literate	5	04.17
Primary level (up to 8 th std)	22	18.33
Secondary level (9 th & 10 th std)	26	21.67
Higher Secondary level (11 th & 12 th std)	31	25.83
Graduate & above	34	28.33
(3) Experience in farming		
Low (up to 10 years)	24	20.00
Medium (11 to 20 years)	59	49.17
High (above 20 years)	37	30.83
(4) Social participation		
No membership in any organization	22	18.33
Membership in one organization	49	40.84
Membership in more than one organization	42	35.00
Holding position in organization	7	05.83
(5) Land holding		
Marginal (0.01 to 1.00 ha)	14	11.67
Small (1.01 to 2.00 ha)	27	22.50
Semi medium (2.01 to 4.00 ha)	41	34.17
Medium (4.01 to 10 ha)	30	25.00
Big (Above 10 ha)	08	6.66
(6) Annual income		

Up to ₹50, 000	02	1.67
₹50, 001 to ₹1, 00, 000	25	20.83
₹1, 00, 001 to ₹1, 50, 000	33	27.50
₹1, 50, 001 to ₹2, 00, 000	37	30.83
Above ₹2, 00, 000	23	19.17
(7) Extension contact		
Never (0 to 4 score)	09	07.50
Rarely (5 to 9 score)	19	15.83
Occasionally (10 to 14 score)	45	37.50
Frequently (15 to 19 score)	26	21.67
Regularly (20 to 24 score)	21	17.50
(8) Mass media exposure		
Never (0 to 6 score)	04	03.33
Rarely (7 to 12 score)	19	15.83
Occasionally (13 to 19 score)	57	47.50
Frequently (20 to 25 score)	26	21.67
Regularly (26 to 32 score)	14	11.67
(9) Training received		
Not received any training	52	43.33
Received training	68	56.67
(10) Economic motivation		
Very low (up to 6 score)	02	01.67
Low (07 to 12 score)	03	02.50
Medium (13 to 18 score)	46	38.33
High (19 to 24 score)	53	44.17
Very high (above 25 score)	16	13.33
(11) Risk orientation		
Very low (up to 10 score)	02	01.67
Low (11 to 20 score)	08	06.66
Medium (21 to 30 score)	50	41.67
High (31 to 40 score)	49	40.83
Very high (above 41 score)	11	09.17
(12) Scientific orientation		
Very low (up to 10 score)	01	00.83
Low (11 to 20 score)	12	10.00
Medium (21 to 30 score)	48	40.00
High (31 to 40 score)	45	37.50
Very high (above 41 score)	14	11.67

In table 1 it was observed that 47.50 percent of farmers belonged to middle age group, 28.33 percent farmers had education up to graduate and above level, 49.17 percent farmers had medium farming experience, majority of farmers had membership in one organization (40.84%), also 34.17 per cent of farmers possessed semi-medium land holding, 30.83 percent farmers had annual income between ₹1, 50, 001 to ₹2, 00, 000, 37.50 percent farmers had occasional level of extension contact, followed by 47.50 percent farmers had occasional level of mass media exposure, majority of farmers had received training (56.67%), also 44.17 percent farmers had high level of economic motivation, 41.67 percent farmers had medium level of risk orientation and 40.00 percent farmers had medium level of scientific orientation towards awareness about hazardous effect of pesticide residue.

Table 2: Distribution of respondents according to their level of awareness (n=120)

Categories	Frequency	Percent
Very low (up to 20 score)	08	06.67
Low (21 to 40 score)	11	09.16
Medium (41 to 60 score)	63	52.50
High (61 to 80 score)	29	24.17
Very high (81 and above score)	09	07.50

The data in table 2 indicated that a more than half (52.50%) of the respondents had a medium level of awareness, followed by 24.17 per cent with a high level and 07.50 per cent with a very high level of awareness, while a smaller proportion of respondents exhibited low (09.16%) and very low (06.67%) levels of awareness, respectively.

Table 3: Relationship between profile of vegetable growers and their awareness regarding hazardous effects caused through pesticide residues in vegetables (n=120)

Independent Variables	Awareness Correlation Coefficient ('r' value)
Age	-0.311**
Education	0.299**
Experience in farming	-0.330**
Social Participation	0.079 ^{NS}
Land Holding	0.031 ^{NS}
Annual Income	-0.017 ^{NS}
Extension Contact	0.315**
Mass Media Exposure	0.257**
Training received	0.064 ^{NS}
Economic Motivation	0.135 ^{NS}
Risk Orientation	0.162 ^{NS}
Scientific Orientation	0.258**

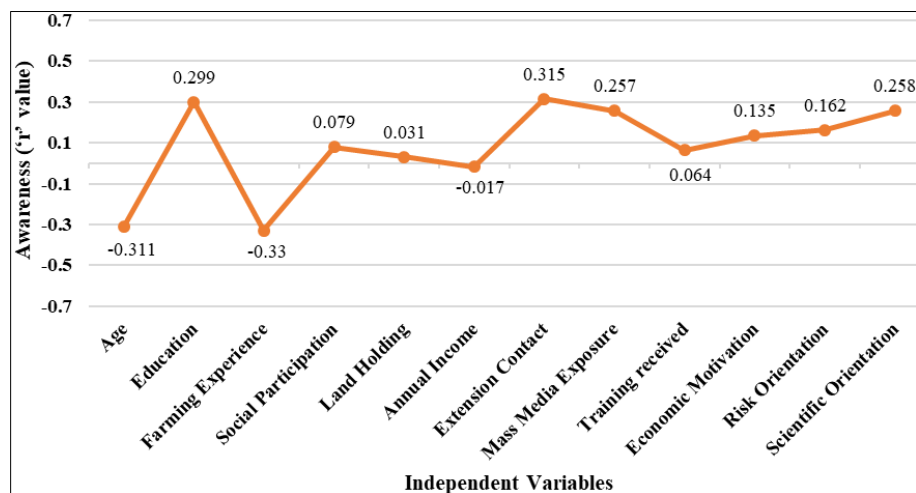


Fig 1: Relationship between profile of vegetable growers and their awareness regarding hazardous effects caused through pesticide residues in vegetables

Data in table 3 showed that independent variables such as extension contact, mass media exposure, education and scientific orientation were positively and significantly correlated with awareness of vegetable growers regarding hazardous effects caused through pesticide residues in vegetables and social participation, land holding, annual income, training received, economic motivation and risk

orientation were positively and non-significantly correlated with the awareness of vegetable growers. Whereas, age and farming experience were negatively and highly significantly correlated with the awareness of vegetable growers regarding hazardous effects caused through pesticide residues in vegetables.

Table 4: Multiple Regression Analysis for awareness regarding hazardous effects caused through pesticide residues in vegetables with other independent variables (n=120)

	Regression coefficient(b)	Std. Error	t value	P- value
Age	-0.221	22.621	-0.637	0.525
Education	0.029	6.394	0.169	0.866
Farm. Experience	-0.037	21.747	-0.115	0.909
Social Participation	-0.185	6.560	-1.606	0.111
Land holding	-0.018	4.072	-0.186	0.852
Annual income	-0.101	4.324	-1.031	0.305
Extension contact	0.221	1.111	1.603	0.112
Mass media exposure	0.071	1.074	0.485	0.629
Training experience	0.066	5.803	0.704	0.483
Economic motivation	0.032	1.029	0.291	0.771
Risk Orientation	0.055	0.610	0.500	0.618
Scientific Orientation	-0.011	0.709	-0.079	0.937
R ² value = 0.176				

Table 4 presents the full model of regression analysis between criterion variable i.e. awareness of vegetable growers regarding hazardous effects caused through pesticide residues in vegetables with respect to selected independent variables. The variables education, extension contact, mass media exposure, training experience, economic motivation and risk orientation had positive contribution, whereas, the variables age, farming experience, social participation, land

holding, annual income and scientific orientation had negative contribution on awareness of vegetable growers regarding hazardous effects caused through pesticide residues in vegetables. It was found that all the independent variables together had contributed 17.60 per cent of variation in awareness of vegetable growers regarding hazardous effects caused through pesticide residues in vegetables.

Table 5: Stepwise Regression Analysis for awareness regarding hazardous effects caused through pesticide residues in vegetables with other independent variables (n=120)

Model		Unstandardized Coefficients(B)	Std error	Standardized coefficient(beta)	t	Sig.
1	(Constant)	102.389	12.372		8.276	0.000
	Age	-21.282	5.672	-0.327	-3.752	0.000
2	(Constant)	67.513	20.193		3.343	0.001
	Age	-15.047	6.283	-0.231	-2.395	0.018
	Extension contact	1.686	0.778	0.209	2.166	0.032

Modal Summary

Model	R-square	Adjusted R ²	Std. error of estimate	R2 change
1	0.107	0.099	44.870	0.107
2	0.141	0.126	44.184	0.034

1. Predictors: (Constant), age
2. Predictors: (Constant), age, Extension contact

In the table 5 stepwise multiple regression analysis was carried out to determine the contribution of selected independent variables towards the awareness of vegetable growers regarding hazardous effects caused through pesticide

residues in vegetables. It was observed that in the first step, the variable age entered into the model and alone contributed 10.70 per cent of variation in awareness of vegetable growers, whereas in the second step, extension contact was included along with age, which increased the explained variation to 14.10 per cent, indicating that extension contact alone contributed an additional 3.40 per cent variation in awareness. Further, it was observed that age had negative and significant contribution, while extension contact had positive and significant contribution towards the awareness of vegetable growers regarding hazardous effects caused through pesticide residues in vegetables.

Table 6: Path coefficient showing the direct, total indirect and substantial indirect effects of independent variables on awareness regarding hazardous effects caused through pesticide residues in vegetables with other independent variables (n=120)

Sr. No.	Independent Variable	Direct Effect	Total Indirect Effect	Substantial Indirect Effect Through	Effect Value
1	X1(Age)	-0.221	-0.105	X7, X4, X3	-0.105
2	X2(Education)	0.029	0.263	X1, X7, X4	0.263
3	X3(Farming experience)	-0.037	-0.286	X1, X7, X4	-0.286
4	X4(Social participation)	-0.185	0.294	X7, X1, X8	0.294
5	X5(Land holding)	-0.018	0.048	X1, X9, X7	0.048
6	X6(Annual income)	-0.101	0.084	X7, X1, X9	0.084
7	X7(Extension contact)	0.221	0.094	X1, X4, X8	0.094
8	X8(Mass media exposure)	0.071	0.186	X7, X4, X1	0.186
9	X9(Training received)	0.066	-0.002	X7, X4, X6	-0.002
10	X10(Economic motivation)	0.032	0.103	X7, X4, X8	0.103
11	X11(Risk orientation)	0.055	0.108	X7, X1, X8	0.108
12	X12(Scientific orientation)	-0.011	0.269	X7, X1, X4	0.269

Note: X1 = Age, X2 = Education, X3 = Farming Experience, X4 = Social Participation, X5 = Land Holding, X6 = Annual Income, X7 = Extension Contact, X8 = Mass Media Exposure, X9 = Training Received, X10 = Economic Motivation, X11 = Risk Orientation and X12 = Scientific Orientation

Direct effect

The data presented in Table 6 reveals that among the independent variables, extension contact (X7) had exerted the maximum direct positive effect (0.221) on awareness regarding hazardous effects caused through pesticide residues in vegetables, followed by mass media exposure (X8) (0.071), training received (X9) (0.066), risk orientation (X11) (0.055), economic motivation (X10) (0.032) and education (X2) (0.029). On the other hand, age (X1) (-0.221) showed the highest direct negative effect, followed by social participation (X4) (-0.185), annual income (X6) (-0.101), farming experience (X3) (-0.037), land holding (X5) (-0.018) and scientific orientation (X12) (-0.011).

From the above results, it can be concluded that the independent variable extension contact exerted the highest positive direct effect on awareness, whereas age exhibited the largest negative direct effect on awareness regarding hazardous effects caused through pesticide residues in vegetables.

Total indirect effect

The data presented in Table 6 indicates that, with respect to total indirect effects, most of the variables showed positive indirect influence on awareness. It was observed that social participation (X4) had the maximum total indirect effect (0.294), followed by scientific orientation (X12) (0.269), education (X2) (0.263), mass media exposure (X8) (0.186), risk orientation (X11) (0.108), economic motivation (X10) (0.103), extension contact (X7) (0.094), annual income (X6) (0.084) and land holding (X5) (0.048). However, farming experience (X3) (-0.286), age (X1) (-0.105) and training

received (X9) (-0.002) exhibited negative total indirect effects on awareness.

From the above results, it can be concluded that social participation exerted the highest positive total indirect effect on awareness, whereas farming experience showed the highest negative total indirect effect on awareness regarding hazardous effects caused through pesticide residues in vegetables.

Substantial indirect effect

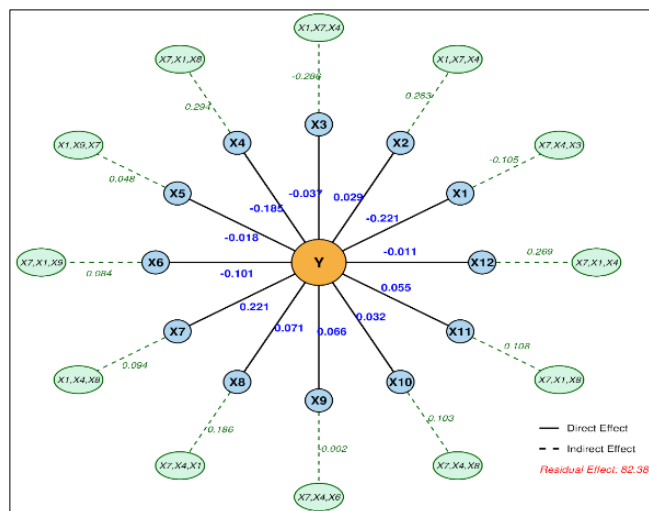
The data presented in Table 6 reveals that substantial indirect effects were mainly routed through key variables such as extension contact (X7), age (X1) and social participation (X4), which appeared repeatedly as important mediating variables influencing awareness.

With regard to substantial indirect effects, the highest positive indirect effect was observed for social participation (X4) (0.294) through extension contact, age and mass media exposure (X7, X1, X8), followed by scientific orientation (X12) (0.269) through extension contact, age and social participation (X7, X1, X4), and education (X2) (0.263) through age, extension contact and social participation (X1, X7, X4). Similarly, mass media exposure (X8) (0.186) through extension contact, social participation and age (X7, X4, X1), and risk orientation (X11) (0.108) through extension contact, age and mass media exposure (X7, X1, X8) also contributed notable positive indirect effects.

In contrast, the highest negative substantial indirect effect was observed for farming experience (X3) (-0.286) through age, extension contact and social participation (X1, X7, X4), followed by age (X1) (-0.105) through extension contact,

social participation and farming experience (X7, X4, X3). A negligible negative indirect effect was also observed for training received (X9) (-0.002) through extension contact, social participation and annual income (X7, X4, X6).

From the above results, it can be concluded that the variables extension contact, age and social participation played a crucial role as major channels through which other independent variables exerted their indirect influence on awareness. This suggests that improvement in extension contact, education, social participation, mass media exposure and scientific orientation would lead to substantial enhancement in awareness regarding hazardous effects caused through pesticide residues in vegetables.



(X1 TO X12: Independent variables & Y: Awareness)

Fig 2: Direct and Indirect effects of independent variables on awareness regarding hazardous effects caused through pesticide residues in vegetables

4. Conclusion

The study revealed that a majority of vegetable growers had a medium level of awareness regarding the hazardous effects of pesticide residues, indicating scope for improvement. Education, extension contact, mass media exposure and scientific orientation showed a positive and highly significant association with awareness, whereas age and farming experience exhibited a significant negative relationship. Regression analysis indicated that education, extension contact and mass media exposure contributed positively, while stepwise regression identified age (negative) and extension contact (positive) as key determinants. Path analysis further confirmed that extension contact exerted the highest positive direct effect, while age had the strongest negative direct effect, and social participation contributed the highest total indirect effect, with extension contact, age and social participation acting as major mediating variables. The findings underscore the critical role of extension systems, communication channels and social participation in enhancing awareness, emphasizing the need for targeted training and communication strategies, particularly for older farmers, to promote safe pesticide use practices.

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