PLANT SCIENCE TODAY
Vol 13(sp1): 1-10
https://doi.org/10.14719/pst.12321

eISSN 2348-1900

RESEARCH ARTICLE

Deltamethrin residue dissipation dynamics, consumer safety evaluation and dietary risk assessment in cowpea and soil

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Received: 17 October 2025; Accepted: 27 February 2026; Available online: Version 1.0: 08 April 2026

Cite this article: Sujan M, Vinay P, Abhinay, Sharad S, Kuldeep S, Pratap AD. Deltamethrin residue dissipation dynamics, consumer safety evaluation and dietary risk assessment in cowpea and soil. Plant Science Today. 2026; 13(sp1): 1-10. https://doi.org/10.14719/pst.12321

Abstract

Deltamethrin is a widely used synthetic pyrethroid insecticide for controlling cowpea pod borers; however, its persistence in crops and soil may raise environmental and food safety concerns. In this study, deltamethrin residues in cowpea pods, leaves and soil were quantified using gas chromatography to evaluate their persistence under field conditions. The half-life of deltamethrin in cowpea pods ranged from 1.73 days at the recommended dose (RD) to 3.15 days at the double dose (DD). Similarly, the half-life ranged from 1.65–1.51 days in leaves and 1.86–1.71 days in soil for RD and DD, respectively. Dietary risk assessment indicated that residue levels in pods exceeded the maximum permissible intake (MPI) of 0.60 mg person^{-1} day^{-1} on some sampling days. However, due to rapid degradation and short persistence, deltamethrin can be considered relatively safe when applied at RDs in the cowpea ecosystem.

Keywords: cowpea pod; deltamethrin residue; dissipation dynamics; leaf; safety; soil

Introduction

A popular vegetable, cowpea (*Vigna unguiculata* L.), is rich in protein and carbohydrates and has an amino acid pattern that complements cereal grains, making it a vital part of the human diet (1–2). It belongs to the family Fabaceae. It is grown on 58,000 hectares in India, where it produces 4.8 million tons annually and yields around 8.44 tons per hectare (3). Although the crop is important, its yield is threatened by various biotic and abiotic factors. The decline in crop yield can be attributed to a various insect pests, including the spotted pod borer, *Maruca vitrata* and other cowpea (legume) pod-borers (4).

There could be a more than 30 % reduction in yield if there is a serious borer infestation (5). Therefore, managing this pest is crucial for the sustainable production of cowpeas. Even with the availability of sustainable and environmentally friendly pest management techniques, such as host plant resistance (HPR), plant secondary metabolites, bio-control agents, botanicals and defence proteins, farmers still choose synthetic pesticides (6–11). Farmers indiscriminately apply a range of insecticides to increase yield and reduce the negative effects of the spotted pod borer on different pulse crops. Efforts are being made to use microbial pesticides, plant products and insecticides because they are typically safer, more environmentally friendly and less likely to develop resistance (12, 13).

In such situations, new generation insecticides have been developed to provide improved selectivity, reduced environmental risk and lower toxicity to pollinators (14–17). To protect leguminous crops such as cowpea, soybean and pigeon pea against the pod borer *M. vitrata*, modern-generation pesticides such as deltamethrin have been found to work fairly well (18, 19). Similarly, farmers frequently use it on cowpeas, even though the Central Insecticide Board and Registration Committee, the pesticide governing body, advises against it (20). Therefore, it is important to assess the dissipation patterns of deltamethrin in cowpea. Deltamethrin [(S)-α-cyano-3-phenoxybenzyl (1R,3R)] is an insecticide. The pyrethroid family includes -3-(2,2-dibromovinyl)-2,2-dimethylcyclopropanecarboxylate. The chemical structure of deltamethrin is shown in Fig. 1. Pyrethroids are synthetic variations of pyrethrins, which are naturally occurring insecticides generated from chrysanthemum flowers (21). Additionally, excessive and careless pesticide use contaminates farmed soils and groundwater (22, 23).

Materials and Methods

Chemicals and reagents

Deltamethrin (purity 95 %) was procured from Sigma-Aldrich Pvt. Ltd. (Bangalore, India). An analytical-grade supply of acetone, n-hexane, sodium sulphate (Na_2SO_4), magnesium sulphate ($MgSO_4$) and sodium acetate (CH_3COONa) was obtained from Thomas Baker in Mumbai, India. Activated $MgSO_4$ was stored in desiccators for 5 hr at 600 °C in a muffle furnace before use. The supplier of primary secondary amine (PSA) with a 40 µm mesh size was Agilent Technologies, based in Bangalore, India. A Millipore Water Purification System (Sartorius AG, Goettingen, Germany) generated deionised water for the mobile phase, which was then filtered through Millipore GV filter paper (pore size 0.22 µm).

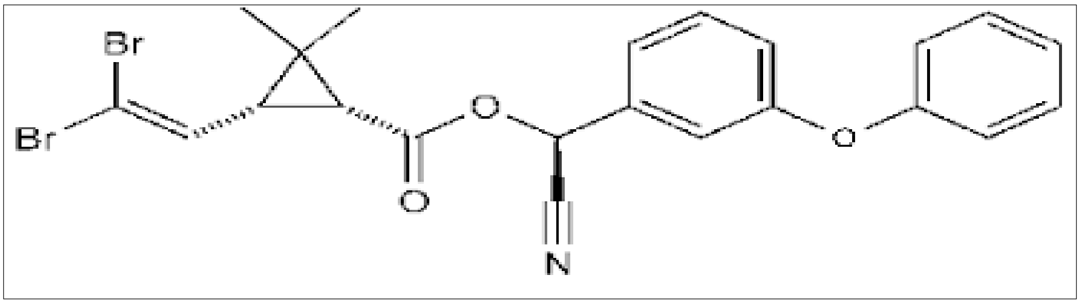


Fig. 1. Chemical structure of deltamethrin.

Apparatus

In the experimental setup, the equipment employed included a centrifuge from Kubota, Germany; a Microfuge Pico microcentrifuge by Kendro, D-37,520, Osterode, Germany; a mixer and grinder from Bajaj India Pvt. Ltd., Mumbai; a precision balance by Vibra, Adair Dutt, Mumbai, India; a Geni 2 T vortex mixer from Imperials Biomedicals, Mumbai, India; and an ultrasonic bath by Oscar electronics, Mumbai, India.

Reference Standard

Deltamethrin reference standards, certified at 95 % purity, were sourced from Sigma-Aldrich Pvt. Ltd., Bangalore, India. The standard stock solutions were prepared by precisely measuring 10 (±0.1) mg of each standard and dissolving it in 10 mL of ethyl acetate, yielding a concentration of 1000 µg mL^{-1}.

By thoroughly mixing and further diluting this stock solution, a working standard mixture with a concentration of 10 µg mL^{-1} was created. From this mixture, calibration standard solutions with concentrations of 0.01, 0.02, 0.04, 0.06, 0.08 and 0.1 µg mL^{-1} were prepared. Standards matched to the matrix at the given concentration were formulated using cowpea extract prepared by the sample preparation and analysis technique described in the section on sample preparation and analysis (24).

Field experiment

In accordance with Food and Agricultural Organisation (FAO) guidelines, field experiments on the cowpea variety Kashi Kanchan were conducted for two consecutive kharif seasons at the Indian Institute of Vegetable Research (IIVR) experimental farm near Varanasi, Uttar Pradesh, India (82°52' E longitude and 25°12' N latitude) (25). The soil of the experimental field was sandy loam. The soil had a pH of 7.7 and the electrical conductivity (EC) was 0.13 dS m^{-1}, indicating low salinity levels. The organic carbon (OC) content was 0.46 %, which represents a moderate amount of soil organic matter. Irrigation was provided as per crop requirements to maintain optimum soil moisture during the crop growth period. In the field, deltamethrin 11 % EC at 12.5 g active ingredient (ai) ha^{-1} was sprayed on the crop at the recommended dosage (RD) and 25 g ai ha^{-1} in double dosage (DD), using a randomised block design (RBD) with eight treatments and three replications. The average maximum and minimum temperatures for cowpea cultivation during the trial period were 20 °C and 30 °C, respectively. The cowpea crop was cultivated using standard agronomic practices in raised beds measuring 4 m × 5 m. The insecticide was applied using a hollow-cone nozzle on a high-volume backpack sprayer. During insecticide application, the weather was warm, sunny and with minimal wind; 500 L of water was sprayed per ha. Six to nine days passed between the distribution of the first round of applications.

Sampling

Samples of cowpea pods were taken from each replication at 0 (2 hr after spraying), 1, 2, 5, 7 and 10 days after the last spray, using a zigzag pattern determined by the deltamethrin application. The samples were placed in sampling bags and stored at -20 °C to prevent pesticide degradation before analysis. The same procedure was used to collect leaf samples for up to ten days. In the experimental field, soil samples were collected at of 0–15 cm for each replication. To determine the dispersion pattern and ultimate residual amount of deltamethrin in the soil, soil samples were collected at 0, 1, 2, 5, 7 and 10 days after the most recent spray (26, 27).

Extracting and cleaning samples

The samples were extracted using the modified QuEChERS technique. In accordance with established guidelines from previous publications, the samples were collected, analysed and cleaned up with slight adjustments tailored to the specific crop and pesticide employed (24). After being finely chopped, the entire laboratory subsample was ground up in a mixer grinder. A blend of 10 g of pods and 10 g of leaves from each category was extracted with 10 mL of ethyl acetate containing 1 % acetic acid. The mixture was vortexed for 2 min, then centrifuged at 6000 rpm for 5 min. The dispersive solid-phase extraction (DSPE) method, using 225 mg MgSO4, 75 mg PSA and 15 mg GCB, was used to purify the ethyl acetate layer (1.5 mL) in the supernatant. After subjecting the extract to centrifugation at 10,000 rpm for 5 min, it underwent filtration via a 0.22 µm Nylon 6 membrane filter before being analysed using GC-µECD (Fig. 2). The extraction process for leaf and soil samples mirrored that of cowpea pods: 10 g of soil samples were combined with 10 mL of water, left to stand for 20 min and then extracted using an ethyl acetate solvent (Fig. 2) (27, 28).

GC- µECD Analysis

Instrumental analysis was done using gas chromatography with a microelectron capture detector (µECD, 63Ni) and an autosampler (model 7890 B). Deltamethrin was detected using an HP-5 inert capillary column 30 m long, 320 µm id and 0.25 µm film thick. The temperature program for the oven was set as follows: 1500 °C for 4 min, 1900 °C ramped at 100 °C min^{-1} and held for 4 min, 2900 °C ramped at 180 °C min^{-1} and kept for 4 min. The temperatures of the injector and detector were kept at 2800 °C and 3000 °C, respectively. In these experimental circumstances, deltamethrin demonstrated a retention time (RT) of 15.65 min (Fig. 3a, b, c, d). About 18 min were needed to run the program. Nitrogen gas flowed at a rate of 1 mL min^{-1}. For the split injection mode analysis, the standard and sample injection volumes were 1 µL, with a split ratio of 10:1. By comparing the peak regions of the matrix-matched standards with those of unknown or spiked samples under the same experimental conditions, the residues were computed.

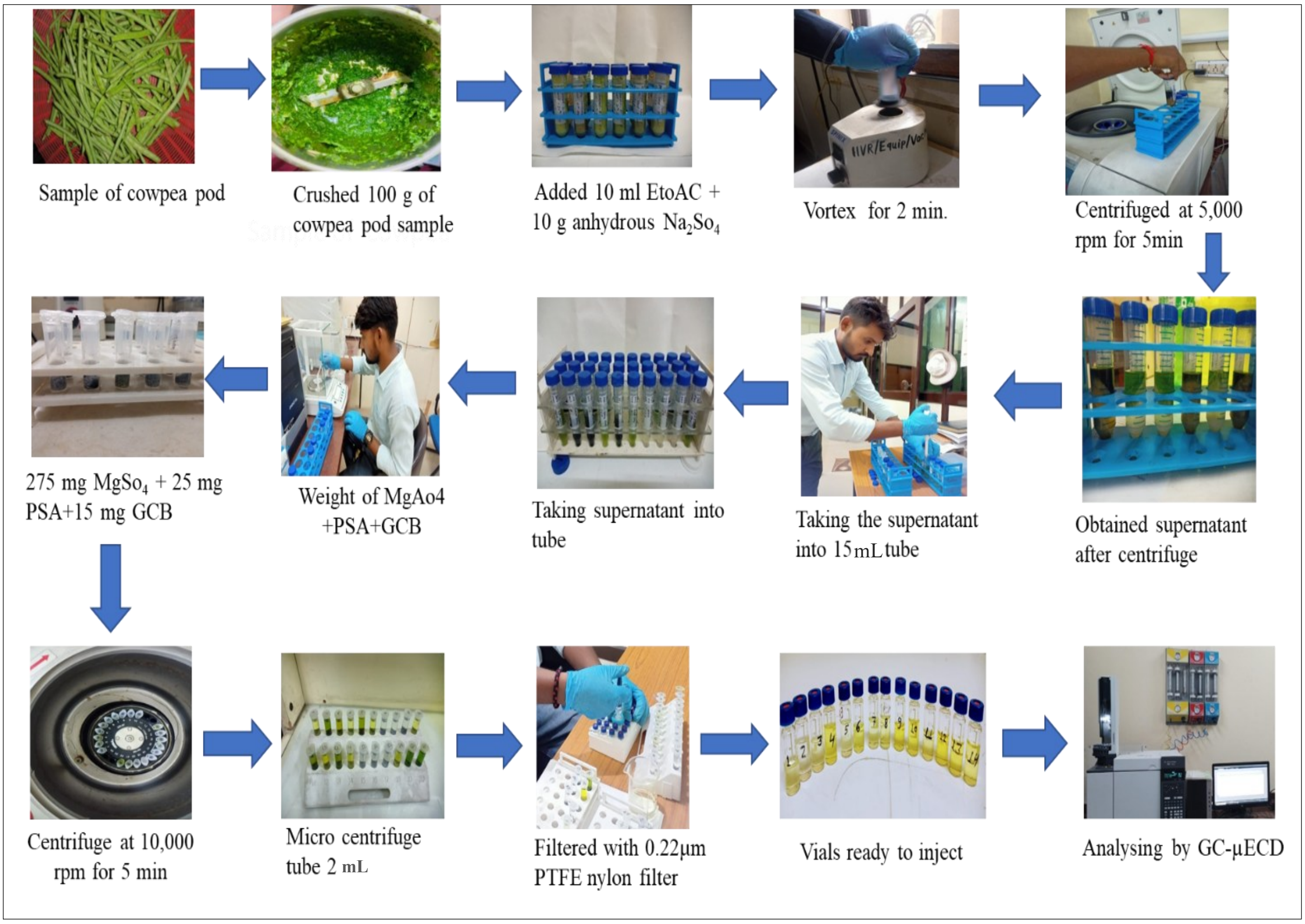
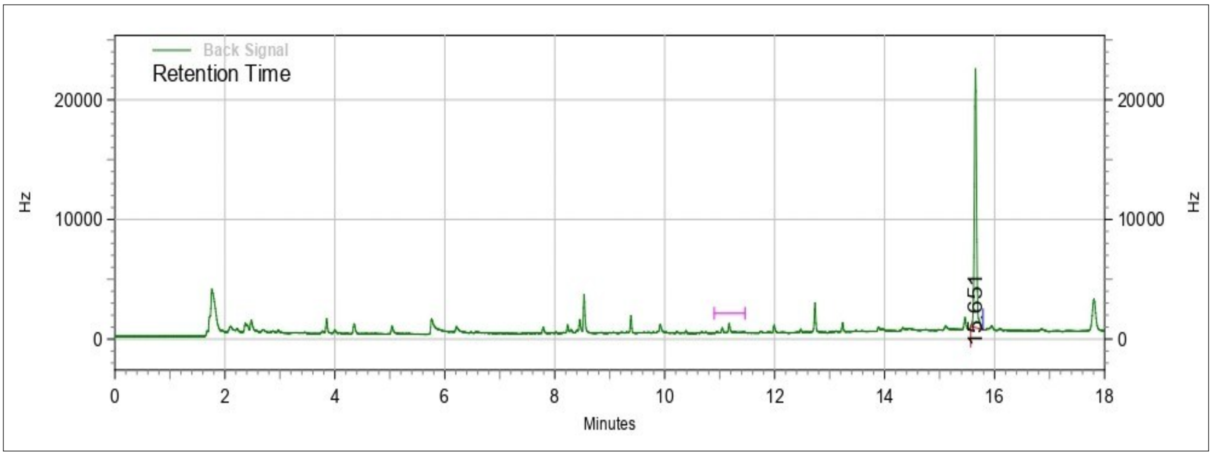
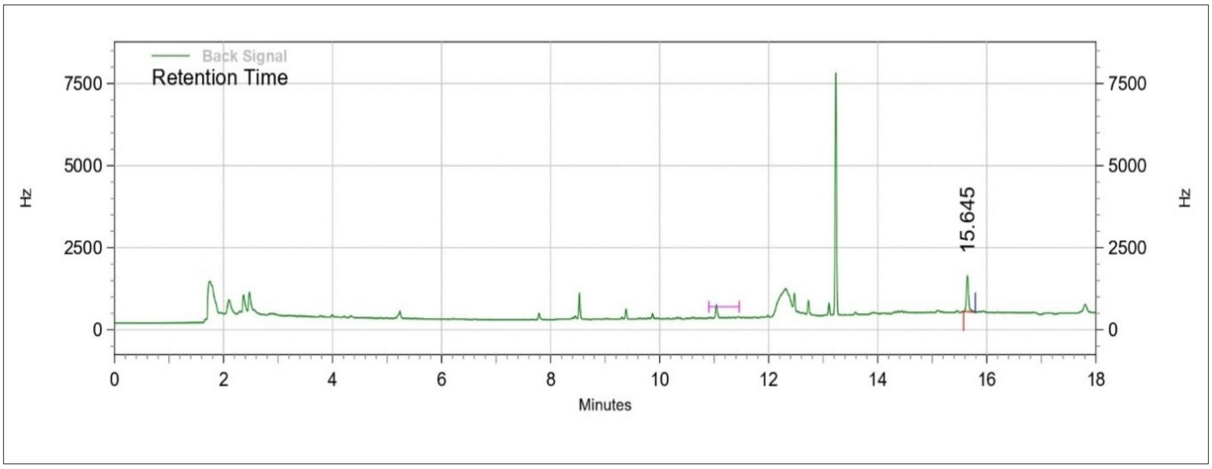


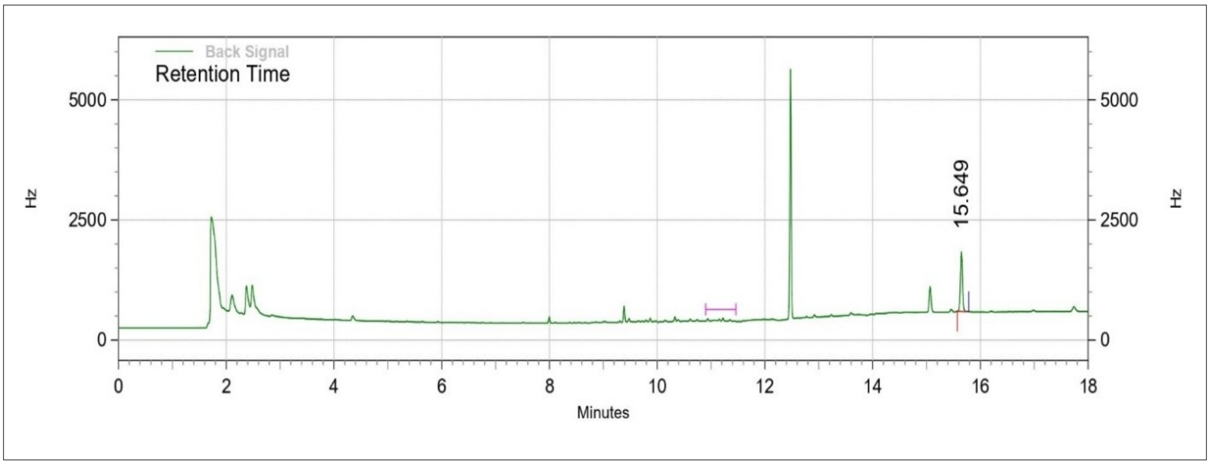
Fig. 2. Extraction and cleanup of deltamethrin from cowpea pod, leaf and the soil.



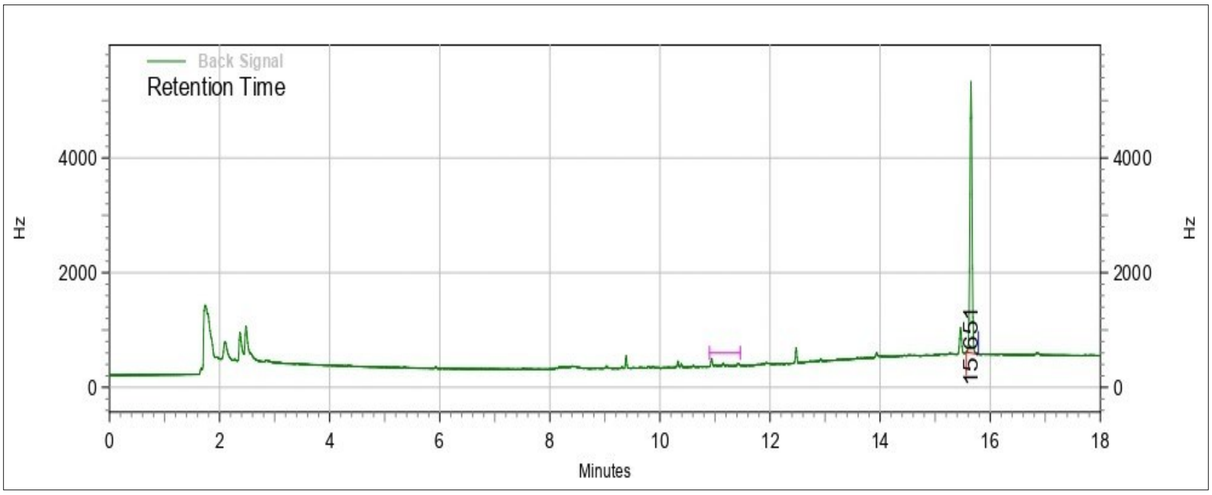
(a) Standard



(b) Cowpea pod



(c) Cowpea leaf



(d) Soil

Fig. 3. Chromatogram of a) standard b) cowpea pod c) cowpea leaf d) the soil.

Pesticide residue in mg kg^{-1} was calculated as follows:

$$\text{Residue in ppm} = \frac{\mathbf{A1 \times C \times V1}}{\mathbf{A2 \times W}} \times R_f \qquad \text{(Eqn. 1)}$$

Where,

Where A1 represents the area corresponding to the field sample in the chromatogram, while A2 denotes the peak area associated with the analytical standard. V1 is the total volume of the sample measured in mL, C is the analytical standard's concentration in ppm, W = Sample weight in g and Rf is the Recovery Factor.

Analytical method validation

Five calibration levels of deltamethrin in pure solvent and in matrix (pod, leaf and soil) at concentrations of 0.01-0.10 mg kg^{-1} were prepared to construct a linearity graph (Fig. 4). The limit of detection (LOD) and limit of quantification (LOQ), which identify the lowest measurable quantity in the cowpea, leaf and soil matrices at signal-to-noise ratios (S/N) of 3:1 and 10:1, respectively, were used to assess the method's sensitivity. Fresh, untreated (control) cowpea pods, leaves and soil were used for the recovery study. There were six replications for each of the five concentrations (0.01, 0.02, 0.05, 0.1 and 0.5 mg kg^{-1}) used (Table 1).

Dissipation kinetics

The data were analysed using a first-order kinetic equation to examine the dissipation of deltamethrin (28).

$$C_t = C_0 e^{-kt} \qquad \text{(Eqn. 2)}$$

where Ct is the concentration at time t, C_0 is the starting concentration, t is the time and k is the insecticide dissipation rate constant.

Using the following formula, the residue data were statistically analysed to determine the half-life ($t_{1/2}$) of the parent compounds (28).

$$t_{1/2} = \ln 2/k \qquad \text{(Eqn. 3)}$$

Assessment of consumer risk

Deltamethrin's food safety was assessed by examining its theoretical maximum daily intake (TMDI) and dietary exposure to determine whether it fell within the maximum permissible intake (MPI). The acceptable daily intake (ADI) was multiplied by the average adult body weight (60 kg) to calculate MPIs. The ADI for the insecticide deltamethrin is 0.01 mg kg^{-1} of body weight per day. The estimated MPI of deltamethrin was 0.60 mg $person^{-1}$ day^{-1}. The average daily consumption for the urban and rural populations was 0.005 and 0.003 kg day^{-1}, respectively and the residue levels in each sample were used to compute dietary exposure.

Results and Discussion

Standardisation of the process for extracting residues

When cowpea pods are crushed and water is added, a homogenous material is created that facilitates extraction but results in an inadequate recovery of residues. When the analysis was performed with 50, 75 and 100 mg of PSA, or without any cleaning, the ethyl acetate extract of cowpea pods and leaves generated a greater

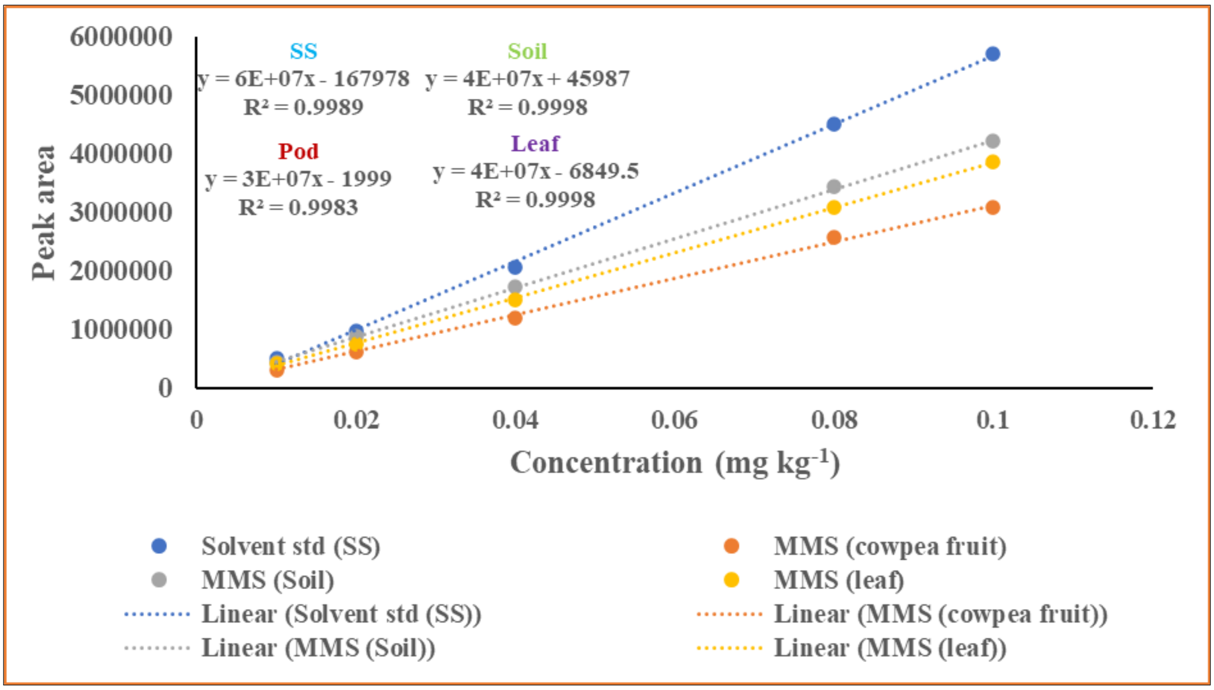


Fig. 4 Linearity graph for solvent standard and matrix-matched standard (MMS) for all the matrices.

Table 1. Percentage recovery of deltamethrin in cowpea pod, leaf and soil

Level of fortification (mg kg^{-1})	% Recovery	% RSD
Pod		
0.01	80.00	1.250
0.02	86.67	8.813
0.05	85.33	7.160
0.1	85.00	9.189
0.5	84.67	3.608
Leaf		
0.01	82.67	3.044
0.02	88.33	8.646
0.05	83.33	3.666
0.1	87.67	7.764
0.5	83.33	3.666
Soil		
0.01	83.33	2.498
0.02	78.33	9.750
0.05	85.33	4.879
0.1	92.33	1.654
0.5	84.00	2.81

matrix-induced signal amplification. The d-SPE cleanup of 1.5 mL of ethyl acetate extracts from cowpea pod and leaf matrices was optimised using only 75 mg PSA, 225 mg $MgSO_4$ and 15 mg GCB. However, cleaning was used to analyse soil samples using only 75 mg PSA and 225 mg $MgSO_4$ for the 1.5 mL extract. For cleanup purposes, only PSA and $MgSO_4$ were used rather than GCB because the soil sample's ethyl acetate extract showed no colour.

Method validation

The SANTE guidelines for estimating deltamethrin residues in cowpea pods, leaves and soil were followed to validate the analytical method (29). Five levels were used to estimate the percentage recovery for each soil matrix and for complete cowpea pod and leaf samples. All matrices had percentage recoveries of 0.01, 0.02, 0.05, 0.1 and 0.5 mg kg^{-1}, which ranged from 80.00 to 92.33 % (Table 1) and those with relative standard deviations (RSD) below 20 % met the SANTE criteria (29). Deltamethrin was found at an RT of 15.651 min under typical chromatographic conditions. The linearity of the method was demonstrated by calibration curves with coefficients of determination (R2) of 0.9989 for the solvent standard, 0.9983 for the matrix-matched standard (cowpea pods), 0.9998 for the leaves and 0.9998 for the soil. The calibration range was 0.01-0.50 mg kg^{-1}, depicted in Fig. 4. The LOD and LOQ for each matrix were determined to be 0.005 mg kg^{-1} and 0.01 mg kg^{-1}, respectively. The average matrix effect (ME) was less than 20 %. The paddy matrix measurements of acetamiprid and buprofezin pesticide residues showed up to 93.67 % recovery, meeting international standards. However, the matrix-matched calibration method significantly reduced the need to consider matrix-induced false detections (30).

Residue dissipation kinetics in cowpea pod, leaf and soil

Microbial decay, volatilisation and breakdown, as well as other environmental elements such as weathering, heat and sunlight, can cause pesticide residues to break down rapidly. Additionally, plant metabolism linked to different stages of development, such as fruit maturity, may be responsible for the decrease in pesticide residue levels (23). After a period of faster behaviour, the dissipation slowed down. The degradation pattern was exponential, indicating that residue dissipation followed simple first-order kinetics. The R2 values for the RD and DD were 0.927 and 0.988, respectively (Fig. 5). Table 2 illustrates that the half-lives of the particular residue in cowpea pods were 3.15 days for DD and 1.73 days for RD. Two hr after the final spray, the initial deltamethrin residue deposition in cowpea pods decreased to 0.71 and 0.98 mg kg^{-1} for RD and DD, respectively. This is because pesticide residues can degrade rapidly due to microbial breakdown, volatilisation and initial microbial deposition at the same doses, as mentioned in Table 3. At practically all doses, degradation was rapid for up to 5 days after application (DAA). Deltamethrin residues in leaves exhibited good linearity of exponential simple first-order dissipation kinetics in their dissipation behaviour, with R2 values of 0.909 for DD and 0.910 for RD (Fig. 6). Table 4 demonstrates that the initial residue deposition in the leaf was 1.10 mg kg^{-1} for DD and 0.83 mg kg^{-1} for RD. In leaf samples, RD and DD had half-lives of 1.65 and 1.51, respectively (Table 2). Deltamethrin residues in soil exhibited similar dissipation behaviour and the exponential first-order dissipation kinetics showed strong

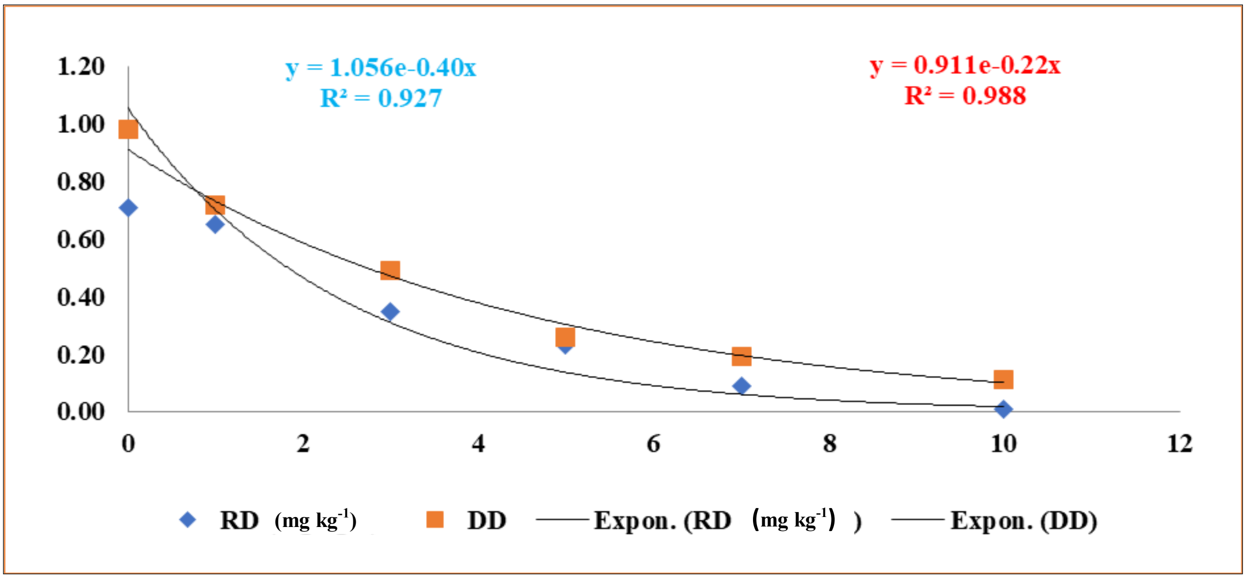


Fig. 5. Degradation pattern of deltamethrin in cowpea pods under field conditions.

Table 2. Coefficient of determination and half-life of deltamethrin in different matrices of the cowpea

Doses	Regression equation	Coefficient of determination (R^2)	Half-lives ($t_{1/2}$) days
	Pod		
RD	$y = 1.056e^{-0.40x}$	0.927	1.73
DD	$y = 0.911e^{-0.22x}$	0.988	3.15
	Leaf		
RD	$y = 1.276e^{-0.42x}$	0.910	1.65
DD	$y = 1.807e^{-0.46x}$	0.909	1.51
	Soil		
RD	$y = 0.744e^{-0.37x}$	0.918	1.86
DD	$y = 1.065e^{-0.40x}$	0.925	1.71

Table 3. Percentage reduction of deltamethrin residue on different days of sampling in cowpea pods

Days after spray	Recommended dose		Double dose	
	Residues (mg kg^{-1})	% decrease residue	Residues (mg kg^{-1})	% decrease residue
0	0.71	0.00	0.98	0.00
1	065	8.45	0.72	26.53
3	0.35	50.70	0.49	50.00
5	0.23	67.61	0.26	73.47
7	0.09	87.32	0.19	80.61
10	0.01	98.59	0.11	88.78

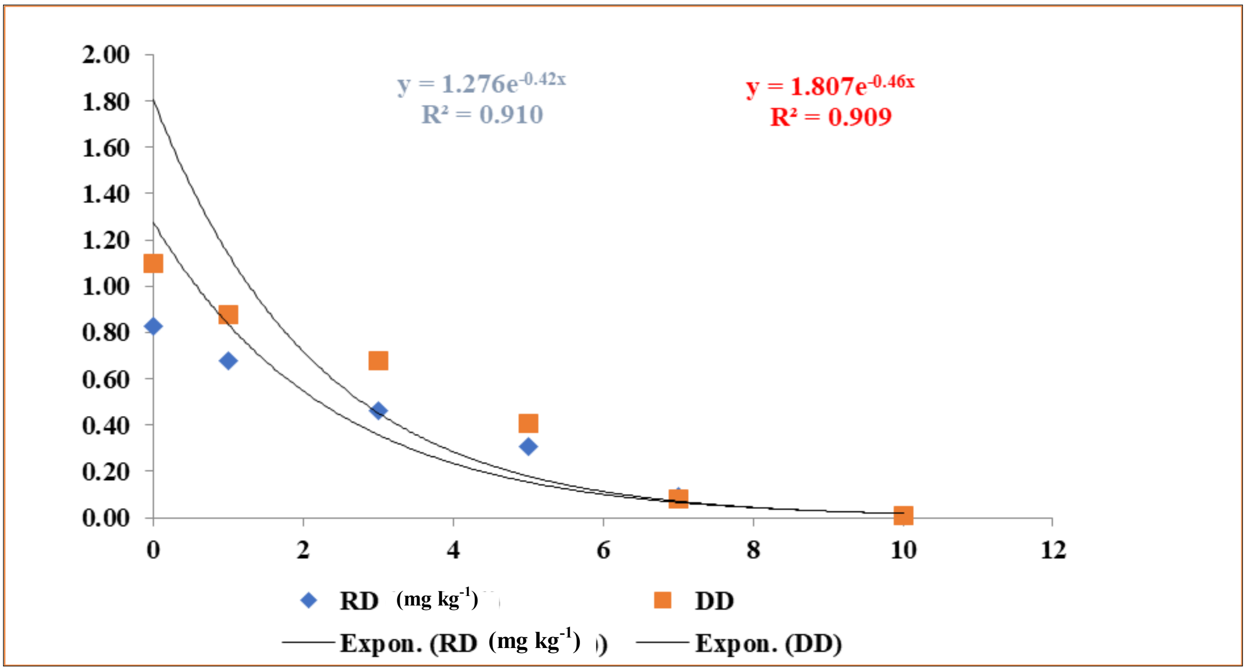


Fig. 6. Degradation pattern of deltamethrin in leaf under field conditions.

Table 4. Percentage reduction of deltamethrin residue on different days of sampling in cowpea leaf

Days after spray	Recommended dose		Double dose	
	Residues (mg kg^{-1})	% decrease residue	Residues (mg kg^{-1})	% decrease residue
0	0.83	0.00	1.10	0.00
1	0.68	18.07	0.88	20.00
3	0.46	44.58	0.68	38.18
5	0.31	62.65	0.41	62.73
7	0.09	89.16	0.08	92.73
10	0.01	98.80	0.01	99.09

linearity, with R2 values of 0.960 and 0.961 for DD and RD, respectively (Fig. 7). According to Table 5, the initial soil residue depositions for RD and DD were 0.57 and 0.77 mg kg^{-1}, respectively. According to Table 2, the half-lives of deltamethrin residue in soil samples are 1.86 days for RD and 1.71 days for DD. A preliminary investigation found that the half-lives of buprofezin in cauliflower for RD and DD were 2.36 and 2.1 days, respectively, whereas in cabbage were 1.73 and 1.85 days (31). In earlier studies, acetamiprid half-lives for plant matrices, such as rice, okra, mustard and tea (35), were reported to be between one and two days (32–35). However, some studies on watermelon have reported much higher half-lives (2–5 days), cowpea and chilli (36–38). Half-lives of soil matrices were typically observed to range from 5 to 10 days and half-lives longer than ten days were also noted in certain instances (36, 37, 39). These findings corroborate our findings. Beyond individual crop comparisons, pesticide dissipation behaviour in legumes is influenced by unique physiological and rhizosphere-driven processes. Leguminous crops are known to support dense and metabolically active rhizosphere microbial communities through root exudates such as organic acids, amino acids and phenolic compounds, which can enhance microbial-mediated degradation of xenobiotics, including pesticides. These plant–microbe interactions may accelerate pesticide transformation and reduce persistence compared to some non-leguminous cropping systems (40). Legumes also modify soil physicochemical properties and microbial ecology through nitrogen fixation and rhizodeposition, creating conditions that enhance pollutant bioavailability and microbial degradation potential. Such rhizosphere-mediated processes are considered important contributors to pesticide dissipation through mechanisms such as rhizodegradation and phytoremediation (41). Field studies on legumes such as chickpea have demonstrated first-order pesticide dissipation kinetics in soil, with measurable half-lives, confirming that pesticide persistence in legume ecosystems is governed by complex interactions among crop physiology, soil properties and environmental conditions (42). Additionally, residue occurrence and persistence in legume grains are strongly influenced by application timing, environmental conditions and crop metabolic characteristics, further supporting the need to interpret half-life data within the broader context of legume production systems (43). As half-life values can be helpful in lowering the pesticide residue burden in the cowpea ecosystem, the current study may help build a complete approach to the dynamics of deltamethrin residue in cowpea.

Overall, the relatively rapid dissipation observed in the present study supports the growing evidence that pesticide persistence in legume-based agroecosystems is shaped not only by pesticide chemistry but also by legume-specific rhizosphere activity, microbial diversity and plant metabolic processes. Therefore, integrating crop-specific ecological and biochemical characteristics is essential for accurately predicting pesticide behaviour and optimising residue management strategies in legume cultivation systems.

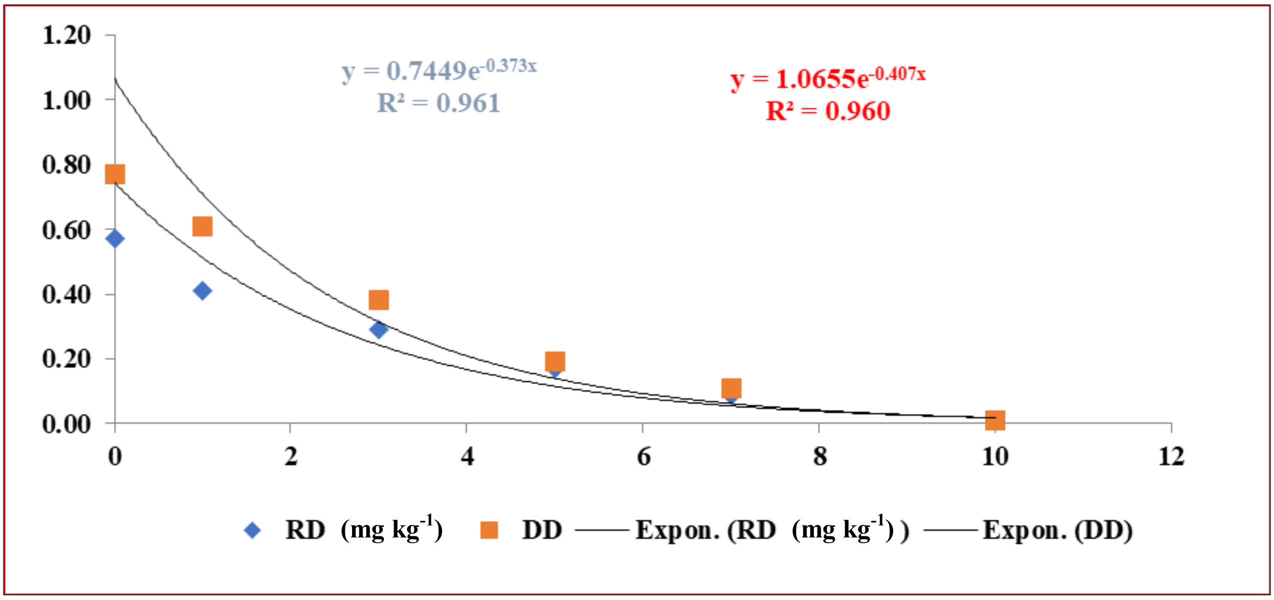


Fig. 7. Degradation pattern of deltamethrin in the soil under field conditions.

Table 5. Percentage reduction of deltamethrin residue on different days of sampling in the soil

Days after spray	Recommended dose		Double dose	
	Residues (mg kg^{-1})	% decrease residue	Residues (mg kg^{-1})	% decrease residue
0	0.57	0.00	0.77	0.00
1	0.41	29.31	0.61	20.78
3	0.29	50.00	0.38	50.65
5	0.17	70.69	0.19	75.32
7	0.09	84.48	0.11	85.71
10	0.01	98.28	0.01	98.70

Consumer risk assessment

The usage of deltamethrin in vegetables is poorly documented, so it is necessary to evaluate the safety of this pesticide residue. Deltamethrin has an ADI of 0.01 mg kg^{-1} of body weight. Deltamethrin's MPI was determined by multiplying the ADI by the average body weight (60 kg), which came out to be 0.60 mg person^{-1} day^{-1}. At both the recommended dose (RD) and a double dose (DD), the average daily consumption of cowpeas by rural and urban people was 0.003 and 0.005 kg day^{-1}, respectively, on all sample days. Furthermore, the residues' dietary exposures were below the MPI of 0.60 mg person^{-1} day^{-1} (Table 6). Therefore, there is little risk of acute toxicity when using deltamethrin to control pests in cowpeas.

Soil risk assessment

The risk quotients (RQs) for earthworms (*Eisenia foetida*) and another arthropod (*Aphidius rhopalosiphi*) were calculated in compliance with European guidelines (44). The acute 14-day LC50 and LR50 values for arthropods and earthworms were 750 mg ha^{-1} and >1000 mg kg^{-1} when determining the RQ (41). Risk quotient was used to estimate the environmental danger to earthworms and other arthropods. For earthworm (*E. foetida*) RQ values ranged from 0.57 to 0.01 (RD) and 0.77 to 0.01 (DD) from 0 (2 h) to 10 days following deltamethrin application in the field soil. In the case of arthropods (*A. rhopalosiphi*), the RQ values were in the range of 0.76-0.01 (RD) and 1.03 - 0.01 (DD) (Table 7i &7 ii). Earthworms may be at negligible risks (RQ < 0.01) or low risk (0.01 ≤ RQ < 0.1) when deltamethrin residues are present, according to the RQ values. Arthropods may also be at negligible or low risk (until 0 days after the last DD spray). Thus, the application of deltamethrin to cowpeas at specific dosages is safe for the soil ecosystem.

Conclusion

The optimised GC-ECD analytical method showed satisfactory performance for the determination of deltamethrin residues in cowpea pods, leaves and soil. Per cent recovery ranged from 80.00 to 86.77 (RSD: 1.25–8.81 %) in pods, 82.67 to 88.33 (RSD: 3.04–8.65 %) in leaves and 83.33 to 92.33 (RSD: 1.65–2.50 %) in soil. The LOQ was 0.01 mg kg^{-1}. The half-life of deltamethrin residues in cowpea plant matrices ranged from 1.71 to 1.86 days, while in soil it was less than two days. Dietary exposure assessment indicated that the intake of deltamethrin residues remained below the MPI. Risk assessment based on RQ values indicated negligible (RQ < 0.01) to low risk (0.01 ≤ RQ < 0.1) to arthropods and earthworms, except on the day of the final double-dose application.

Acknowledgements

This research received support from the Indian Council of Agricultural Research, Department of Agricultural Research and Education, Government of India. The authors gratefully acknowledge the Head, Division of Crop Protection and the Director, ICAR-Indian Institute of Vegetable Research, Varanasi, for providing essential research facilities.

Authors' contributions

SM conceptualised the study, supervised the work, curated data, wrote the original draft and handled writing tasks overall. VP, A and SS contributed to the methodology and investigation. KS performed review and editing, formal analysis and data curation. PAD handled conceptualisation, performed formal analysis and carried out writing, review and editing. All authors read and approved the final manuscript.

Table 6. Safety evaluation of day-wise residues of deltamethrin in cowpea pods

Days after spray	Recommended dose			Double the recommended dose		
	Residues (mg kg^{-1})	Dietary exposure (mg person^{-1} day^{-1})		Residues (mg kg^{-1})	Dietary exposure (mg person^{-1} day^{-1})	
		Rural	Urban		Rural	Urban
0	0.71	0.0021	0.0036	0.98	0.0029	0.0049
1	0.65	0.0020	0.0033	0.72	0.0022	0.0036
3	0.35	0.0011	0.0018	0.49	0.0015	0.0025
5	0.23	0.0007	0.0012	0.26	0.0008	0.0013
7	0.09	0.0003	0.0005	0.19	0.0006	0.0010
10	0.01	0.0000	0.0001	0.11	0.0003	0.0003

Table 7. Soil ecological risk assessment (i) For earthworms; (ii) for arthropods

i.

Days	RD	LC 50	PNCE (mg kg^{-1})	RQs	DD	LC50	PNCE (mg kg^{-1})	RQs
0	0.57	>1000	1.00	0.57	0.77	>1000	1.00	0.77
1	0.41	>1000	1.00	0.41	0.61	>1000	1.00	0.61
3	0.29	>1000	1.00	0.29	0.38	>1000	1.00	0.38
5	0.17	>1000	1.00	0.17	0.19	>1000	1.00	0.19
7	0.09	>1000	1.00	0.9	0.11	>1000	1.00	0.11
10	0.01	>1000	1.00	0.01	0.01	>1000	1.00	0.10

ii.

Days	RD	LC 50	PNCE (mg/kg)	RQs	DD	LC50	PNCE (mg/kg)	RQs
0	0.57	>750	0.75	0.76	0.76	>750	0.75	1.03
1	0.41	>750	0.75	0.55	0.61	>750	0.75	0.81
3	0.29	>750	0.75	0.39	0.38	>750	0.75	0.51
5	0.17	>750	0.75	0.23	0.19	>750	0.75	0.25
7	0.09	>750	0.75	0.12	0.11	>750	0.75	0.15
10	0.01	>750	0.75	0.01	0.01	>750	0.75	0.01

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interest to declare.

Ethical issues: None

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Peer review: Publisher thanks Sectional Editor and the other anonymous reviewers for their contribution to the peer review of this work.

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