Bull. Environ. Contam. Toxicol. (2003) 70:1136–1142

DOI: 10.1007/s00128-003-0100-7

Bulletin of Environmental Contamination and Toxicology

Evaluation of Beta-Cyfluthrin: Protection of Cole Crops, Dietary Intake, and Consumer Risk Assessment

S. Borah,[1] A. K. Dikshit,[1] O. P. Lal,[2] R. Singh,[3] S. R. Sinha,[2] Y. N. Srivastava[2]

[1] Division of Agricultural Chemicals, Indian Agricultural Research Institute, New Delhi 110012, India
[2] Division of Entomology, Indian Agricultural Research Institute, New Delhi 110012, India
[3] Division of Vegetable Crops, Indian Agricultural Research Institute, New Delhi 110012, India

Received: 20 November 2002/Accepted: 12 March 2003

Crop protection products (CPPs) are highly regulated chemicals, their testing and regulation being equivalent to that of pharmaceuticals. The benefits of CPPs use on crops are well documented and public is aware about their development and subsequent proliferation. These have a profound beneficial impact in a number of ways. Today's consumer expects an affordable constant year-round supply of clean, fresh ,healthy and, above all, safe food. To be effective, CPPs need to exhibit some persistence and the consequence is that the residues of the original materials may remain on food and thus there is a potential for the intake of such residues from contaminated food (Atreya 2001). Such residues in food are not permitted unless they are proven to be safe (below Maximum Residue Limit, MRL) at the highest levels of exposure anticipated based on Good Agricultural Practices (GAP). Therefore environmentally benign chemicals with highest output and economic return will always be referred for practice.

The use of beta-cyfluthrin, a recently introduced synthetic pyrethroid, has been permitted by the Government of India for cotton crop against different pests but no information is available on dietary intake exposure and its residues on cole crops. Therefore residue field trials were carried out to determine (i) rate of decline of beta-cyfluthrin deposits (ii) highest levels of residues at harvest to estimate the potential exposure from the proposed use of beta-cyfluthrin on cole crops and (iii) to predict its total dietary intake, consumer risk assessment and to propose MRL.

MATERIALS AND METHODS

The cabbage (*Brassica oleracea* **L.** var *capitata*) local variety 'Golden Acre' and cauliflower (*Brassica oleracea* **L.** var *botrytis*) local variety 'Pusa Snowball' crops were transplanted at the experimental farm of Indian Agricultural Research Institute, New Delhi, India. Beta-cyfluthrin (Bulldock 025 SC) was sprayed @ 12.50, 18.75, 25.00, 37.50 and 50.00 g ai ha^{-1} on both the crops during the first two years (1999-2000) while @ 18.75 and 37.50 g ai ha^{-1} during the third year (2001). A high dose of 4X i.e. 75 g ai ha^{-1} was also taken during third year to see phytotoxicity and plant compatibility. The insectcide was sprayed at the head and curd formation stages of cabbage and cauliflower crops, respectively in all the

Correspondence to: A. K. Dikshit

trials. A second spray was given after 15 days. The fluid rate was 500 L ha^{-1}. Each treatment was taken in three replicates including untreated control. For assessing rate of decline of beta-cyfluthrin quantity from these crops and to know the total dietary intake to assess consumer risk, the cabbage and cauliflower (and its leaves) samples were collected on 0 d (1 hr after insecticide spray), 1, 3, 5, 7, 10 and 15 d from both the sprays. The samples were cut into small pieces and thoroughly mixed and a sub sample of 50 g was taken for further processing. Soil samples (0-15, 15-30 cm) were taken after final harvest of the crops. Based on the results and performance of the recovery experiments, the optimum conditions suited were adopted for analysis of the field samples as per the methods of Blass (1987); Borah (2002); Dikshit and Singh (2000).

To overview the pesticide tolerance process (MRL), the enforcement agencies should sample food produce for the purpose of tolerance enforcement soon after a farmer markets the treated commodity, so that any tolerance violations may be traced to their source. Thus tolerances are intended to apply to treated raw commodities as soon as they enter into commerce, starting when the produce leaves 'the farm gate'. The 'MRL' or tolerance of beta-cyfluthrin is not available in India, therefore based on residue field data (food chemical concentration), an effort has been made to derive in most approximation the 'MRL' of beta-cyfluthrin on cabbage and cauliflower. The residue data has also been interpreted for processing factor (PF), pre-harvest intervals, Theoretical Maximum Daily Intake (TMDI) and comparison with Maximum Permissible Intake (MPI) based on reference dose to arrive at consumer risk assessment and increase in margin of safety (MOS).

RESULTS AND DISCUSSION

The data on the concentration of beta-cyfluthrin detected on cabbage at varied intervals resulting from three crop years is presented in Table 1. The initial deposits of beta-cyfluthrin ranged from 0.47 to 0.54 mg kg^{-1}, 0.65 to 0.84 $mgkg^{-1}$, 0.97 to 1.18 mg kg^{-1}, 1.10 to 1.45 mg kg^{-1} and 2.15 to 2.51 mg kg^{-1} from 12.50, 18.75, 25.00, 37.50 and 50.00 g ai ha^{-1} treatments, respectively. The initial deposits declined with time. The residence time of the insecticide was 7-10 d and thereafter the amount was not detectable. Thus beta-cyfluthrin was found to be short lived and dissipated faster. The initial deposits observed on cabbage were recorded little higher than aubergine (Dikshit et al. 2001) and okra (Dikshit et al. 2002) due to morphologic and phenotypic character of the crop i.e. natural exposure of the plant having more surface area during spray and hence more retention of insecticide. Also due to loosely packed leaves the insecticide fluid is retained temporarily. Bates (1991; 2002) also reported the influence of rate of application, ratio of surface area to weight of the crop, the nature of the crop surface, application equipment and prevailing meteorological conditions on the initial deposit of the insecticides on the crop. Beta-cyfluthrin concentration dissipated/declined with first order rate kinetics and the half-life was 2.01-2.79 d. The observed initial deposits were well comparable with the theoretical values calculated from dissipation models. However, in the case of second spray of the second year trial, a drastic decline in the residues of beta-cyfluthrin was noticed on the third day onwards. It may be attributed to a sudden heavy rainfall during the period, where residues became non-detectable after 5-7 d and therefore a lower half-life of 0.86-1.03 d was recorded.

Table 1. Amount of beta-cyfluthrin on cabbage from spray treatments

Days	Treatment ($g\ ai\ ha^{-1}$)	Amount of beta-cyfluthrin ($mg\ kg^{-1}$)					
		1999		2000		2001	
		A	B	A	B	A	B
0	12.50	0.47	0.50	0.54	0.50	-	-
	18.75	0.65	0.70	0.80	0.76	0.84	0.65
	25.00	1.09	1.15	0.97	1.18	-	-
	37.50	1.10	1.20	1.45	1.25	1.45	1.15
	50.00	2.38	2.51	2.15	2.30	-	-
1	12.50	0.29	0.31	0.31	0.32	-	-
	18.75	0.34	0.40	0.38	0.30	0.40	0.44
	25.00	0.68	0.74	0.56	0.75	-	-
	37.50	0.80	0.84	0.90	1.00	1.12	0.76
	50.00	1.45	1.58	1.19	1.43	-	-
3	12.50	0.16	0.17	0.20	0.10	-	-
	18.75	0.20	0.24	0.24	0.14	0.22	0.19
	25.00	0.41	0.41	0.34	0.22	-	-
	37.50	0.60	0.72	0.54	0.30	0.70	0.48
	50.00	0.94	0.87	0.72	0.33	-	-
5	12.50	0.11	0.11	0.13	0.05	-	-
	18.75	0.12	0.10	0.14	0.06	0.13	0.10
	25.00	0.25	0.24	0.20	0.12	-	-
	37.50	0.32	0.35	0.28	0.10	0.38	0.26
	50.00	0.58	0.50	0.41	0.16	-	-
7	12.50	0.07	0.07	0.08	ND	-	-
	18.75	0.07	0.05	0.06	ND	0.06	ND
	25.00	0.18	0.11	0.10	0.03	-	-
	37.50	0.20	0.13	0.14	ND	0.10	
	50.00	0.30	0.26	0.20	0.09	-	0.09
10	12.50	ND	ND	ND	ND	-	-
	18.75	ND	ND	ND	ND	ND	ND
	25.00	0.08	0.05	0.04	ND	-	-
	37.50	0.07	0.06	0.05	ND	ND	ND
	50.00	0.10	0.09	0.06	ND	-	-
15	12.50	ND	ND	ND	ND	-	-
	18.75	ND	ND	ND	ND	ND	ND
	25.00	ND	ND	ND	ND	-	-
	37.50	ND	ND	ND	ND	ND	ND
	50.00	ND	ND	ND	ND	-	-

A, first spray; B, second spray; ND, not detectable

Table 2. Decline in the amount of beta-cyfluthrin from cauliflower and its leaves

DAYS	DOSE	Amount of beta-cyfluthrin (mg kg^{-1})											
		1999				2000				2001			
		Curd		Leaves		Curd		Leaves		Curd		Leaves	
		A	B	A	B	A	B	A	B	A	B	A	B
0	T_1	0.73	1.09	0.54	0.59	0.81	0.82	0.44	0.50	-	-	-	-
	T_2	1.00	1.25	0.78	0.80	1.00	1.14	0.70	0.74	0.90	1.20	0.84	0.95
	T_3	1.34	1.83	1.39	1.08	1.25	1.34	1.00	1.01	-	-	-	-
	T_4	1.82	2.10	1.65	1.40	1.68	1.90	1.62	1.45	1.65	1.90	1.80	2.00
	T_5	2.80	3.12	2.54	2.27	2.60	2.61	2.02	2.11	-	-	-	-
1	T_1	0.52	0.78	0.32	0.37	0.56	0.57	0.28	0.32	-	-	-	-
	T_2	0.76	0.84	0.60	0.58	0.70	0.74	0.50	0.52	0.72	0.82	0.68	0.60
	T_3	0.95	1.27	0.85	0.70	0.87	0.92	0.62	0.64	-	-	-	-
	T_4	1.06	1.24	1.00	0.95	1.12	1.30	1.00	1.20	1.14	1.40	1.20	1.60
	T_5	2.00	2.08	1.64	1.40	1.71	1.72	1.23	1.30	-	-	-	-
3	T_1	0.31	0.50	0.17	0.20	0.33	0.34	0.12	0.18	-	-	-	-
	T_2	0.40	0.42	0.39	0.42	0.36	0.40	0.22	0.34	0.42	0.40	0.38	0.30
	T_3	0.64	0.76	0.48	0.36	0.50	0.50	0.29	0.35	-	-	-	-
	T_4	0.76	1.00	0.68	0.72	0.80	0.78	0.48	0.50	0.48	0.43	0.50	0.70
	T_5	1.39	1.31	0.89	0.72	1.03	0.94	0.57	0.60	-	-	-	-
5	T_1	0.17	0.23	0.10	0.12	0.20	0.22	0.06	0.09	-	-	-	-
	T_2	0.24	0.30	0.18	0.15	0.18	0.24	0.06	0.16	0.18	0.22	0.20	0.15
	T_3	0.37	0.39	0.26	0.20	0.30	0.34	0.10	0.21	-	-	-	-
	T_4	0.48	0.52	0.38	0.34	0.50	0.45	0.18	0.24	0.30	0.24	0.36	0.44
	T_5	0.77	0.66	0.54	0.41	0.54	0.65	0.22	0.38	-	-	-	-
7	T_1	0.08	0.07	0.03	0.03	0.09	0.07	ND	ND	-	-	-	-
	T_2	0.12	0.10	0.06	0.05	0.09	0.14	ND	0.10	0.06	0.07	0.05	ND
	T_3	0.20	0.18	0.08	0.06	0.12	0.15	0.04	0.06	-	-	-	-
	T_4	0.25	0.20	0.14	0.09	0.18	0.16	0.07	0.10	0.14	0.09	0.18	0.16
	T_5	0.39	0.21	0.20	0.13	0.28	0.22	0.10	0.20	-	-	-	-
10	T_1	ND	ND	ND	ND	0.02	ND	ND	ND	-	-	-	-
	T_2	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.06	0.07
	T_3	0.10	0.06	ND	0.03	0.04	0.05	ND	0.03	-	-	-	-
	T_4	0.12	0.07	ND	ND	0.05	0.06	ND	ND	0.05	ND	0.05	0.06
	T_5	0.18	0.10	0.04	0.06	0.07	0.08	0.03	0.03	-	-	-	-
15	T_1	ND	ND	ND	ND	ND	ND	ND	ND	-	-	-	-
	T_2	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	T_3	ND	ND	ND	ND	ND	ND	ND	ND	-	-	-	-
	T_4	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	T_5	0.08	ND	ND	ND	ND	ND	ND	ND	-	-	-	-

T_1, T_2, T_3, T_4, T_5 are the treatments @ 12.50, 18.75, 25.00, 37.50, 50.00 g ai ha^{-1}; A, first spray; B, second spray; ND, not detectable

Beta-cyfluthrin deposits on cauliflower curds (Table 2) in all the cases were somewhat higher than that of cabbage. This could be due to higher surface area and therefore quantity of insecticide spray per unit area is likely to be more and also due to small troughs on the surface of curd of cauliflower which retained the pesticide solution. Although, curd is the main consumable portion of the cauliflower plant yet a major portion of its leaves are used as leafy vegetables and also as livestock feed as well. Therefore residues determination in leaves became necessary. The beta-cyfluthrin concentration on curd/leaves was non-detectable on the 10th day from the recommended dose (18.75 g ai ha^{-1}) except 0.06 to 0.07

mg kg^{-1} residues in case of leaves on the 10^{th} day from third year. The theoretical initial deposition of beta-cyfluthrin extrapolated from the first order dissipation models did not differ substantially from the actual observed deposits and hence these models can represent the actual situation and prediction of residues at different periods can be made with the help of these models. The half-life of beta-cyfluthrin was recorded 1.91-2.66 and 1.47-1.91 d from curd and leaves, respectively.

The data (Table 1 and 2) revealed that the insecticide dissipated faster in earlier days compared to later period presumably due to loose association of insecticide residues with the crop substrates and also due to faster growth during initial days and consequently quick loss of insecticide by natural elements. This effect was also noticed on *Brassica campestris* (Kumar et al. 2000).

The data on the availability of beta-cyfluthrin on cabbage and cauliflower (Table 1 and 2) was viewed for different guiding parameters to find the safety assurance and risk assessment *vis-a-vis* treatments by comparing the dietary intake exposure. All human health risk situations are a function of hazard and exposure to that hazard. If the hazard is small and fixed, then the risk will be proportional to the exposure, which can be reduced to low and occasional (Bates 2002). The actual exposure of any consumer to pesticide residues can theoretically be determined by the analysis of the consumer's total diet. Beta-cyfluthrin has been assigned a reference dose of 0.02 mg kg^{-1} body weight (Tomlin 2000) and considering an average Indian of 50 kg, therefore the maximum allowable concentration i.e. MPI is 1mg $person^{-1}day^{-1}$ without involving any appreciable risk or at no-observed-adverse-effect-level (NOAEL). WHO/ FAO in their reports (Anonymous 1962; 1982; 1990) and Bates (1990) have emphasized the need for harmonization on pesticide residues in evaluation in food and related requirements for consumer safety. Based on residue field trial data reflecting maximum residues that may occur under 'worst case' conditions as a result of use of beta-cyfluthrin from recommended dose (18.75 g ai ha^{-1}), the TMDI values on 0 d are found as 0.084, 0.125 and 0.095 mg $person^{-1}$ $day^{-1}$from cabbage, cauliflower curd and its leaves, respectively. These values are much less than the MPI (1mg $person^{-1}$ day^{-1}). The TMDI has been arrived at considering recommended consumption of vegetables as 100 g for leafy or fruit vegetables other than roots and tubers (Anonymous 1999) and total diet as 1.5 kg. The TMDI values would also be less than MPI even if the worst and non-recommended highest dose (50 g ai ha^{-1}) is considered but practising non recommended doses is not permissible and will lead intentional undue residues in edible portion and transfer in environment. A social as well as mandatory requirement is to harvest the produce after giving some allowance after spray of the insecticide and most appropriate would be third day for cole crops, therefore the TMDI would be 0.024 mg $person^{-1}$ day^{-1} for cabbage and 0.042 mg $person^{-1}$ day^{-1} for cauliflower curd and its leaves. If this practice/schedule is followed, the dietary intake exposure due to consumption of these crops will be far less as compared to MPI and the MOS is further increased (considering 3 days residues). Therefore application of beta-cyfluthrin appears safe on these crops and probably involves no risk to consumers and free from health hazards.

A minimum of 3 days pre-harvest interval is suggested and on the basis of extrapolation as above and the facts known at that time MRL of 0.3 mg kg^{-1} for cabbage and 0.5 mg kg^{-1} for cauliflower (rounded to significantly higher values) is proposed in Indian conditions. Besides, PF from 3rd day contaminated samples, if washed and cooked, would lead to further increase in MOS and consumption of processed/cooked vegetables (cabbage, cauliflower) will probably not pose health hazard.

Soil samples (0-15, 15-30 cm), collected at final harvest of the crop, did not show the presence of insecticide residues and therefore no build up and downward movement is expected. The four times recommended dose (75 g ai ha^{-1}) did not exhibit any phytotoxic effect during the growth of the crop. The intended doses (recommended, 18.75 g ai ha^{-1} and double the recommended, 37.50 g ai ha^{-1}) did not cause any appreciable effect on beneficials like *coccinella*.

To conclude, the insecticide beta-cyfluthrin was effective in managing pests and found to be short lived on these crops. Based on experimental evaluations the consumer health risks are minimal at the recommended doses.

REFERENCES

Anonymous (1962) Principles governing consumer safety in relation to pesticide residues. WHO Technical Report, WHO/FAO, Geneva

Anonymous (1982) Report of the second Government consultation on international harmonization of pesticide registration requirements, FAO, Rome

Anonymous (1990) WHO environmental health criteria, Principles for the toxicological assessment of pesticide residues in food. WHO, Geneva

Anonymous (1999) Dietary guidelines for Indians. Indian Council of Medical Research, New Delhi, India

Atreya NC (2001) Inappropriate anxieties about crop protection residues in foods. Internat Conf Pestic Environ Food Security, Society of Pesticide Science, Extended Abstracts, Session-1: pp. 17, November 19-23, 2001, New Delhi, India

Bates JAR (1990) The prediction of pesticide residues in crops by the optimum use of existing data. IUPAC Report on Pesticides No. 26 Pure Appl Chem 62:337-350

Bates JAR (1991) Perspective on pesticide residues in food. In: Pesticide Chemistry- Advances in International Research, Development and Legislation. Ed.Helmet Frehse. ISBN 3-527-28111(VCH, Weinheim)

Bates R (2002) Pesticide residues and risk assessments. Pestic Outlook 13:142-147

Blass (1987) Method on the gas chromatographic determination of cyfluthrin residues in plant material, beer and sugar with ECD, Bayer AG, Germany

Borah S (2002) Dissipation of beta-cyfluthrin on cabbage (*Brassica oleracea* **L.** var *capitata*) and cauliflower (*Brassica oleracea* **L.** var *botrytis*). Ph.D. thesis, P.G. School, IARI, New Delhi, India

Dikshit AK, Singh SP (2000) Persistence and bioefficacy of beta-cyfluthrin against gram pod borer. Indian J Entomol 62:227-230

Dikshit AK, Srivastava YN, Lal OP (2001) Residue studies and bioefficacy of beta-cyfluthrin and lambda-cyhalothrin in brinjal (*Solanum melongena* **L.**) fruits. Pestology 25:27-32

Dikshit AK, Lal OP, Sinha SR, Srivastava YN (2002) Safety evaluation, persistence and bioefficacy of imidacloprid and beta-cyfluthrin on okra:Part II. Pestology 26:30-37

Kumar R, Dikshit AK, Prasad SK (2000) Persistence and safety evaluation of alphamethrin on mustard (*Brassica campestris* **L.**). Bull Environ Contam Toxicol 65:200-206

Tomlin CDS (2000) The pesticide manual, XIIth edition, A world compendium, British Crop Protection Council, UK