The Canadian Society for Bioengineering
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La Société Canadienne de Génie Agroalimentaire et de Bioingénierie
La société canadienne de génie agroalimentaire, de la bioingénierie et de l'environnement

CSBE | SCGAB

Paper No. 06-211

The Degradation Pattern of Soil Applied Insecticides

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Written for presentation at the
CSBE/SCGAB 2006 Annual Conference
Edmonton Alberta
July 16 - 19, 2006

Abstract

The degradation pattern of soil applied insecticides was studied in the field during main (April - June) and autumn (July – September) seasons. Samples were collected from potato field treated with carbofuran (1.0 kg a.i./ha), quinalphos (1.25 kg a.i./ha) and phorate (2.5 kg a.i./ha),the commonly used insecticides to combat the major soil pests like cutworms *Agrotis ipsilon* (Hfn), white grubs *Holotrichia sp*., tuber moth *Pthorimaea operculella*(Zeller) and golden cyst nematode *Globodera rostochinensis* (Wollenweber). The rate of initial dissipation in carbofuran was 32.0 per cent in first 15 days of application in main season and up to 51.4 per cent at 30 days of application in autumn. A 70.0 per cent reduction in the initial deposit was observed for quinalphos residues up to 30 days in both seasons. The initial loss is more in phorate which declined to an extent of >80.0 per cent on day 15 in both seasons. For all the three insecticides studied the residues reached below detectable limit on 90 days after application. The respective half life values for carbofuran, quinalphos and phorate were 15.06, 14.14 and 6.99 during main season and 15.97, 12.67 and 14.17 days during autumn seasons. The degradation pattern followed first order kinetics for all three insecticides applied during both season.

Introduction:

Potato is one of the major vegetable crops in The Nilgiris district of Tamil Nadu. The crop is endangered by the outbreak of pests and diseases like late blight, virus diseases like leaf roll, mosaic and streak and cyst nematode with drastic reduction in yield. Golden nematode *Globodera rostochinensis* (Wollenweber), cutworms *Agrotis ipsilon* (Hfn), white grubs *Holotrichia* sp., and tuber moth *Pthorimaea operculella* (Zeller) are the important pests of potato resulting in serious damage and crop loss. The white grubs alone were found to be responsible for damage level ranging from 40 to 100 per cent (Chandramohan and Nanjan, 1992).

All these pests warrant the application of pesticides to reduce the economic loss. The pesticides that are applied to the target find its way into surrounding environment and undergo various dynamic processes that determine their fate. Soil acts as the ultimate sink for the directly applied soil insecticides as well as unintentional deposits like drift from foliar insecticides. Of the total pesticide applied, less than 0.1 per cent reaches the target pest and the remaining goes to the environment (Pimental and Levitan, 1986). Pesticides reaching soil when applied on plant canopy or applied to the soil generally remain in top 6" of soil (Lichtenstein *et al.,* 1962).

The degradation of soil applied insecticides is influenced by soil characteristics like clay content, organic matter, moisture, pH and microbial population in soil and pesticide properties like solubility and persistence (Sonon and Schwab, 1995).

Materials and methods:

Soil samples were collected from farmer's field at regular intervals. The selected potato fields received the soil application of recommended insecticides like carbofuran (1.0 kg a.i. /ha), quinalphos (1.25 kg a.i./ha) and phorate (2.5 kg a.i./ha). The degradation pattern was studied by analysing the samples collected from the day of application up to 90 days at an interval of 15 days.

The soil samples were collected from treated field at random during cropping period of main and autumn seasons. A bulk sample of two kilograms was collected from each sampling site and by employing quartering technique a representative sample of 500 g was collected. The soil sample was dried at room temperature and sieved to remove plant debris and stones. A sub-sample of twenty-five gram was taken for analysis. The soil samples were analysed for the residues of carbofuran, phorate and quinalphos.

Residue analysis

The procedure described by Leppert *et al.* (1983) was followed for extracting carbofuran residues. The residues were subjected to derivatisation as per Cook *et al.* (1977) using 1 per cent 1fluoro 2,4-dinitrobenzene (FDNB) reactant solution for final determination. Quinalphos and phorate residues were extracted from twenty gram of soil mixed with 10% acetone in distilled water using a mechanical shaker. The aqueous extract was partitioned with dichloromethane and eluted using 1:1 mixture of hexane: dichloromethane for quinalphos residues and 2:1 mixture of acetone: dichloromethane for phorate residues. The residues were dissolved in hexane for final determination. Fenvalerate residues were extracted by adopting the one step extraction cum cleanup method detailed by Agnihotri *et al.* (1986).

Statistical analysis:

The insecticide degradation pattern was analysed by applying seven different functions as suggested by Hoskins (1961) and Timme *et al.* (1986). The pesticide decay curves were fixed based on the procedure described by Regupathy and Dhamu (2001) and half-lives and best-fit degradation models were arrived at.

Results :

Level of Residues

Soil application of carbofuran @ 1.0 kg a.i. /ha during main season (March to June) has resulted in 0.465 µg/g residues as initial deposit which dissipated to an extent of 32.0 per cent in first 15 days of application (Table 1). More than 90 per cent of the applied insecticide dissipated after 60 days and further decline was slow.

The initial deposit of 0.407 µg/g was observed in the field sample collected during autumn season. A similar trend of slow degradation was observed from 60 days as in main season trial (Fig.1).

The quinalphos residues detected on '0' day of application was 0.432 and 0.414 µg/g during main and autumn seasons, respectively. The initial rate of dissipation was more and 70 per cent reduction was observed up to 30 days in both seasons(Table1). The phorate applied @ 2.5 kg a.i. /ha has resulted in 0.939 and 0.885 µg/g of residues as initial deposit. The residues declined to an extent of 81.4 and 84.6 per cent on day 15 of application.

For all the three insecticides studied the residues reached below detectable limit 90 days after application. The rate of initial dissipation was comparatively slow in carbofuran and quinalphos (< 50%) than in phorate(> 80%).

Linearisation of data

The degradation behaviour was studied by linearisation of data using seven types of functions and the decay curve with best fit was selected based on values of modified r^2 (Table 2).

The 'r' values were significant at 5 per cent level for all seven transformations tested for the residue data of carbofuran. Based on modified r^2 value (0.8595), inverse power law function was found to be the best fit during main season trial (Table 2). Since the half-life value was low (1.5 days) the first order function was selected as the next best fit. The degradation pattern followed was first order function in autumn season (Fig.1). The best fit obtained for this season was first order with modified r^2 value of 0.7813 (Table 3). The half-life was 15.06 days during main season and 15.97 days during autumn season (Table 4).

The degradation behaviour of quinalphos followed first order function during both seasons (Fig.1). The correlation co-efficient (r) was significant at 5 per cent level for all the transformations during autumn season trial. The 'r' values close to unity in first order function indicates its relative fitness (Tables 2 and 3).The calculated half lives were 14.14 and 12.67 days for quinalphos residues during main and autumn season, respectively (Table 4).

The dissipation pattern of phorate followed first order function during main season. The 'r' values were significant for all the functions during both seasons studied. Root function first order was the best fit obtained for the residue data of autumn season trial with a half life of 1.72 days. An outlier test was applied and first order function was found to be the best fit. The half-life values ($T_{0.5}$) for main and autumn season were 6.9 and 14.17 days, respectively (Table 4).

Discussion:

In the field, respective per cent dissipation observed for carbofuran, quinalphos and phorate was >50, >70 and >80 during first 30 days of application during main and autumn seasons. The residues of all insecticides reached below detectable level on day 90 of application. Similar declining trend of low level of residues on days 40 to 70 days of treatment for carbofuran and phorate residues was reported by Panda *et al*., (1988) and Singh and Singh (1997).

Chandrasekaran and Regupathy, (1993) reported that the first order kinetic degradation pattern of carbosulfan in various types of soil with the half-life from 8.8 to 17.5 days. In consistency with the persistence studies conducted by Rajukannu *et al.* (1989) degradation in case of carbofuran was slow when compared to phorate. The half-life value of phorate applied

@ 1.0, 2.0 and 4.0 kg a.i/ha in groundnut field was found to vary between 10-12 days (Singh and Singh, 1997).

Among the chemicals studied phorate is classified as systemic in nature while others are contact insecticide (EPA, 1984). This systemic activity of phorate favour high initial absorption by plants and translocation from soil to plant. This might also be a reason for decreased half-life of phorate as reported by Singh and Singh (1997). Depending upon the dose applied also influence the persistence of phorate and carbofuran residues (Rajukannu *et al.,* 1989; Balwinder Singh and Kalra, 1989).

In the present study, no discussable seasonal variation in $T_{0.5}$ of carbofuran was observed. There was some marginal difference in $T_{0.5}$ of quinalphos. However the $T_{0.5}$ of phorate varied significantly with seasons. The $T_{0.5}$ was low during main season and variation in half-life is attributed to temperature and rainfall during cropping period. The main season in the Nilgiris is characterized by high mean maximum temperature ranging from 24.8 to 26.4°C while that of autumn is 21.92 to 23.1°C. In the autumn season dominant climatic factor is rainfall. The mean rainfall is 566 mm during autumn and the main season receives about 354 mm (SSLOU, 1998). In case of phorate increased degradation was observed under high temperature (Grant *et al*., 1969).

The results of the study showed pronounced degradation of insecticides in the early period, up to 15 days in both the seasons. Initial loss by volatilisation upto 25% within one hour was observed in earlier study when labeled thimet was applied to soil (Getzin and Shanks, 1970). In addition, soil applied phorate undergoes oxidation and hydrolytic degradation (Getzin and Shanks, 1970) and the decomposition is favoured by temperature (Grant *et al*., 1969).

The general pattern of initial phase dominated by fast dissipation has been attributed to surface loss (run off, volatilisation and photo degradation). The initial disappearance from the site, though not actual dissipation but is by runoff and leaching. Fast dissipation was reported in many of soil applied insecticides like monocrotophos and chlorpyriphos (Laabs *et al.,* 2002), carbofuran (Lalitha Anand and Awasthi,1987;Gangwar *et al.,*2000). In quinalphos type of formulation was found to contribute to initial loss (Gajbhiye *et al*., 1995).

The other factors favouring insecticide degradation are soil micro flora, pH and the organic matter content of the soil. Pesticide tolerant strains of *Bacillus* sp., *Streptomyces* sp. and *Pseudomonas* sp. were isolated from the soil samples collected in the Nilgiris district and were found to tolerate high level of carbofuran and phorate (Karthikeyan, 1992).The bacterial and actinomycete populations were favoured by the pH (6.2) and high organic carbon content (4.04%) of the soil in the field where the experiment was conducted (Oblisami *et al.,* 1979; Mathur *et al.,* 1980; Karthikeyan, 1992).

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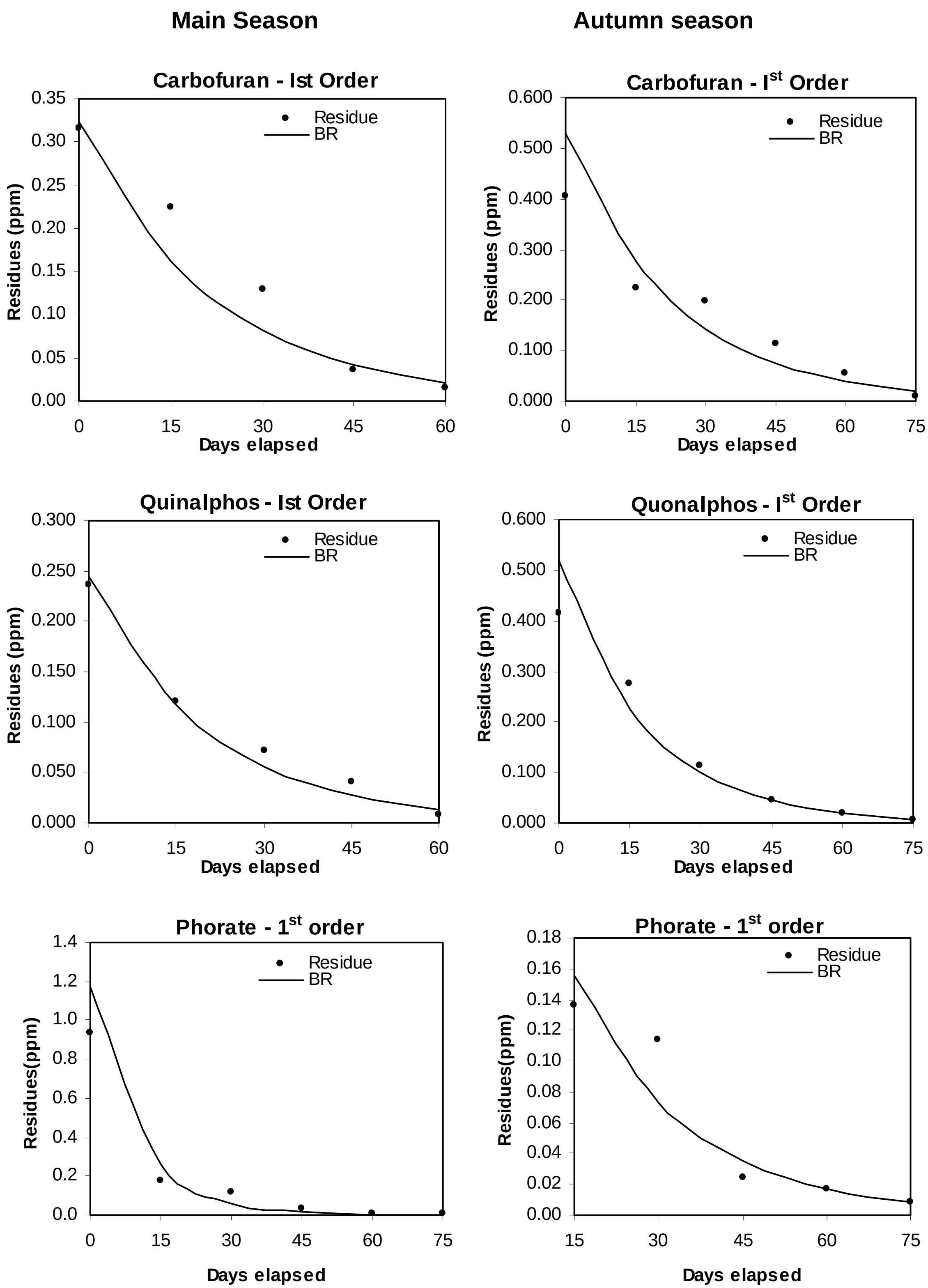

Fig. 1. Back transformed decline curve Main and Autumn seasons

TABLES

Table 1. Degradation of insecticides applied in soil

Days after application	Main season (February - March)			Autumn season (July - September)		
	Carbofuran	Quinalphos	Phorate	Carbofuran	Quinalphos	Phorate
	Residues (μg/g)			Residues (μg/g)		
0	0.465	0.432	0.939	0.407	0.414	0.885
15	0.316 (32.00)	0.237 (45.14)	0.175 (81.36)	0.224 (44.96)	0.275 (33.57)	0.136 (84.63)
30	0.224 (51.83)	0.120 (72.22)	0.115 (87.75)	0.198 (51.35)	0.115 (72.22)	0.114 (87.12)
45	0.129 (72.26)	0.071 (83.56)	0.036 (96.17)	0.113 (72.24)	0.044 (89.37)	0.025 (97.17)
60	0.037 (92.04)	0.041 (90.51)	0.01 (98.93)	0.056 (86.24)	0.019 (95.41)	0.017 (98.08)
75	0.015 (96.77)	0.008 (98.15)	0.008 (99.15)	0.011 (97.30)	0.008 (98.07)	0.009 (98.98)
90	BDL	BDL	BDL	BDL	BDL	BDL

numbers in parenthesis indicate per cent degradation

Table 2. Correlation coefficients of insecticide residues in soil for different methods of transformation (Main season).

Functions	Carbofuran		Quinalphos		Phorate	
	r	Modified r^2	r	Modified r^2	r	Modified r^2
First order	-0.9696*	0.7368	-0.9751*	0.9476	-0.9647*	0.9000
1.5th order	0.9087*	-196.84	0.8723*	-1646.58	0.8799*	-0.2819
Second order	0.8388*	-2.1450	0.7673*	-17.4847	0.8509*	-0.4597
Root function first order	-0.8696*	-0.1687	-0.9011*	0.2425	-0.9003*	-2.6672
Root function 1.5th order	0.7737*	-60553.70	0.7464*	-10313.15	0.7471*	-0.3417
Root function - second order	0.6877*	-1.5938	0.6225	-1.1362	0.7036*	-0.4105
Inverse power law	0.9055*	0.85951	0.9043*	0.9270	0.8864*	0.8073

*Significant at 5% level

Table 3. Correlation coefficients of insecticide residues in soil for different methods of transformation (Autumn season).

Functions	Carbofuran		Quinalphos		Phorate**	
	r	Modified r^2	r	Modified r^2	r	Modified r^2
First order	-0.9447*	0.7813	-0.9954*	0.9020	-0.9703*	0.8577
1.5^{th} order	0.8453*	-253.49	0.9499*	-2946.03	0.9759*	-0.2239
Second order	0.7557*	-13.3293	0.8704*	-0.7211	0.9522*	-5.3186
Root function first order	-0.8477*	0.1142	-0.9244*	-0.1368	-0.9629*	-0.7209
Root function 1.5^{th} order	0.7111*	-22422.92	0.8282*	-383.28	0.9529*	-2.6950
Root function - second order	0.6086	-1.7216	0.7240*	-0.9728	0.9148*	-3.5477
Inverse power law	0.8381*	0.7101	0.9754*	0.8241	0.9395*	-0.7779

*Significant at 5% level ** - Outlier test applied

Table 4. Intercept, slope, half-life and their confidence limit values for insecticides in soil

Treatments	Main season			Autumn season		
	Carbofuran	Quinalphos	Phorate	Carbofuran	Quinalphos	Phorate
	Ist order	Ist order	Ist order	Ist order	Ist order	Ist order
UCL	-0.0299	-0.0056	-0.0615	-0.0225	-0.0474	-0.0265
K_1 (b)	-0.0461	-0.0490	-0.0990	-0.0434	-0.0547	-0.0489
LCL	-0.0621	-0.0335	-0.1366	-0.0643	-0.0619	-0.0713
UCL	7.2049	6.9375	8.7699	7.2188	6.5816	6.8940
K_2 (a)	6.4735	6.2347	7.0664	6.2699	6.2499	5.7797
LCL	5.7421	5.5318	5.3630	5.3211	5.9183	4.6656
Modified r^2	0.7368	0.9476	0.9000	0.7813	0.9020	0.8577
UCL	20.3350	18.6065	9.6493	23.6743	14.3678	20.6713
$T_{0.5}$	15.0645	14.1414	6.9987	15.9786	12.6752	14.1778
LCL	9.7915	9.6762	4.3482	8.2829	10.9825	7.6827