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Fate of Benfuracarb Insecticide in Mollisols and Brinjal Crop

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Abstract The fate of benfuracarb was studied under field conditions in brinjal fruits and soil following foliar spray application at 0.25 and 0.50 μg g^{-1} by HPLC. At 0.25 μg g^{-1}, benfuracarb persisted up to 7 days both in soil and brinjal but at 0.50 μg g^{-1}, benfuracarb residues persisted up to 10 and 12 days in soil and brinjal fruits, respectively. The persistence of benfuracarb residues, both in soil and brinjal, followed first-order kinetics. The half-life values of benfuracarb in soil and brinjal fruit were found to be 3.54 and 3.90 days at 0.25 μg g^{-1} and 3.75 and 4.73 days at 0.50 μg g^{-1}, respectively.

Keywords Benfuracarb · Persistence · Dissipation · Brinjal fruit · Soil

The indiscriminate use of broad-spectrum chemicals has resulted in reduction of natural enemies, contamination of food and fodder, ecosystem and hazards to environment including human beings through food chain and ground water (Arora 2006). Brinjal (*Solanum melongena* L. var. *Pant rituraj*) is an important staple vegetable crop of India which is often attacked by a number of insect pests during its growing period. In order to overcome the losses caused due to pests, tactics based on the use of newer insecticides is used. Benfuracarb (Ethyl *N*-[(2,3-dihidro-2,2-dimethylbenzofuran-7-yl) oxycarbonyl(methyl)-aminothio]-*N*-isopropyl-*β*-alalinate) is one such new carbamate insecticide which shows outstanding insecticidal activity against several pests like stem and fruit borers, jassids, aphids, leaf caterpillar, mites, etc. (Goto et al. 1983). It is being applied in this region for the control of pests in brinjal in the form of soil and foliar insecticide. Benfuracarb is an acetyl-cholinesterase inhibitor and acts via, first forming the enzyme inhibitor complex and then the carbamylation of the enzyme (Terry and David 1999). Since the thrust of vegetable growers is to apply several sprays for increasing the yield, there is often a problem of residue above maximum residue limits (MRLs) in the crops, besides environmental hazards and ecological imbalances (Muthukumar and Kalyanasundaram 2003). The present investigation was therefore undertaken to study the persistence behavior of benfuracarb and determine its residues in soil and brinjal at different time intervals with a view to ensure environmental and human safety.

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Materials and Methods

The field experiment on brinjal (cv. *Pant rituraj)* was laid out in randomized block design with three replications (two for treated and one for untreated control) at vegetable research centre, Pantnagar during summer season 2007 in a plot size of 5 × 5 sq mt. Seedlings were planted in a spacing of 60 × 45 cm^2 as interplant and inter row distances, respectively. Insecticide benfuracarb 40% EC was sprayed, by dissolving 15.6 and 31.2 mL of the formulation in 10 L of water so as to give the rate of application at 0.25 and 0.50 μg g^{-1} of soil, using a hand sprayer after 20 days of transplanting without providing any covering to the plants. Two more spray applications were applied at 20 days interval each. For control treatment (0 μg g^{-1}

Table 1 Metereological data during the experimental period

Week	Temperature (°C)		Relative humidity (%)		Rainfall in (cm)	Sunshine (h)	Wind speed (km/h)
	Maximum	Minimum	Morning	Evening			
14–20 May 07	35.2	21.3	70	40	09.2	08.6	20.3
21–27 May 07	38.5	22.9	63	24	07.2	09.6	21.6
28–03 Jun 07	39.1	21.5	63	21	00.0	10.8	18.9
04–10 Jun 07	38.8	26.6	60	34	124.0	09.3	15.7
11–17 Jun 07	29.3	24.9	87	75	57.2	01.3	8.3
18–24 Jun 07	32.0	24.9	87	64	101.0	06.1	5.4
25–01 July 07	33.4	26.1	84	63	89.8	06.7	3.1
02–08 July 07	31.8	26.4	84	72	79.8	05.4	3.1
09–15 July 07	32.8	26.3	85	66	13.6	07.8	2.4
16–22 July 07	33.1	26.0	84	62	82.0	05.4	2.8
23–29 July 07	28.2	23.4	95	80	233.2	01.2	2.5

benfuracarb), an equivalent volume of water was sprayed on the same dates.

About 500 g of brinjal fruit and soil (0–15 cm) were sampled randomly from each plot at 0 (1 h after application), 1, 3, 5, 7, 10, 12 and 15 days after the third spray application. The samples were kept in air plastic bags and stored in deep freeze (−20°C) until extraction. The metereological data from the first spray to the final sampling date (14.05.2007 to 25.07.2007) is presented in Table 1.

The representative brinjal sample (50 g) from the stored replication was extracted twice with pH 8.0 phosphate buffer solution, silver nitrate and methanol (10 + 0.5 + 25 by volume; 100 mL). The contents were transferred to a conical flask and subjected to shaking for an hour on a mechanical shaker at room temperature (30°C). Soil samples (50 g) were then extracted twice in 100 mL solution consisting of pH 8.0 phosphate buffer solution (0.2 M Na_2HPO_4 + 0.2 M NaH_2PO_4), silver nitrate and methanol (10 + 0.5 + 25 by volume, respectively) for 30 min on a mechanical shaker. The contents were filtered and the combined filtrate obtained was evaporated to dryness on the rotovapor at 40°C. The residue was taken in dichloromethane and water (1:1, v/v) in a separating funnel, shaken and allowed to stand for few minutes. After the layers separated, the lower organic fraction was collected and the process was repeated thrice to extract maximum amount of benfuracarb. The combined extracts of organic layer thus collected were also evaporated to dryness at 40°C and the residue obtained was dissolved in 5 mL carbon tetrachloride. The carbon tetrachloride extract was cleaned up by passing through the column packed with florisil and eluting the benfuracarb with *n*-hexane-ethyl acetate (9:1, v/v) mixture. The collected eluate was evaporated to dryness at 35°C and redissolved in 5 mL of carbon tetrachloride. This was again loaded on another column packed with silica gel (100–200 mesh) and re-eluted with *n*-hexane-ethyl acetate mixture. The collected eluate was evaporated to dryness and taken up in 2 mL methanol for HPLC analysis.

The residue of benfuracarb was determined using a HPLC (Beckman model-322) equipped with a UV detector at 280 nm (λ_{max} of benfuracarb).The column used was C_{18} (25 cm length × 4.0 mm i.d.). The mobile phase was methanol–water (75:25, v/v) at a flow rate of 1.0 mL/min. A 10 µL aliquot of the sample was injected each time for residue analysis. The retention time of benfuracarb under the above conditions was found to be 8.0 min. A calibration curve was plotted between different concentrations of benfuracarb and peak area. The concentrations of benfuracarb in replicates of different samples were calculated with the help of the calibration curve. The mean values of the three replicates were computed. The recoveries of benfuracarb from brinjal and soil sample were carried out 1 and 0.05 µg g^{-1}. The samples were extracted, cleaned up and analyzed as per the procedure mentioned above.

Results and Discussion

The percentage recovery values of benfuracarb from soil and brinjal samples were found to be in a range of 85%–90.2% and 88.2%–92.1%, respectively, at the two levels of fortification.

As evident from Table 2, benfuracarb residues declined consistently with time in soil as well as in brinjal. At the lower application rate (0.25 µg g^{-1}), benfuracarb residues persisted up to 7 days both in soil and brinjal samples, respectively, whereas at higher rate of application, i.e. 0.50 µg g^{-1}, the residues could be detected up 10 and 12 days in soil and brinjal. The half-lives of carbofuran a similar carbamate insecticide have been reported to vary with the rate of application, that is, with lower persistence at the lower application rates and higher persistence at higher application rates (Singh and Kalra 1990).

Table 2 Persistence of benfuracarb from brinjal fruits and soil

Days of application	Residues of benfuracarb (µg g^{-1})			
	Soil		Brinjal	
	0.25	0.50	0.25	0.50
0 (1 h)	0.225 (0)	0.461 (0)	0.236 (0)	0.476 (0)
1	0.138 (38.28)	0.405 (12.04)	0.152 (35.76)	0.410 (12)
3	0.083 (62.98)	0.204 (55.56)	0.097 (58.89)	0.256 (46)
5	0.069 (69.14)	0.187 (59.26)	0.083 (64.81)	0.212 (55.2)
7	0.052 (76.55)	0.136 (70.38)	0.062 (73.75)	0.148 (64.08)
10	ND	0.068 (85.19)	ND	0.116 (72.23)
12	ND	ND	ND	0.076 (81.49)
15	ND	ND	ND	ND

Values in the parenthesis show % dissipation

ND < 0.05 µg g^{-1}

Rate of application, µg g^{-1}

The data on the amount of benfuracarb recovered from soil and brinjal samples for both application rates were fitted to first-order kinetic equation.

$$C = C_0 e^{-\lambda t}$$

where C is the amount of benfuracarb recovered from the samples at time t, C_0 is the amount of benfuracarb recovered at $t = 0$, λ is the degradation constant and t is time in days. For both the rates of benfuracarb application (0.25 and 0.50 µg g^{-1}), the natural logarithm of benfuracarb residues were plotted against time (Fig. 1). The distribution of points for soil and brinjal at both the levels of treatment suggested that persistence of benfuracarb could occur through a single distinct phase conforming to first-order

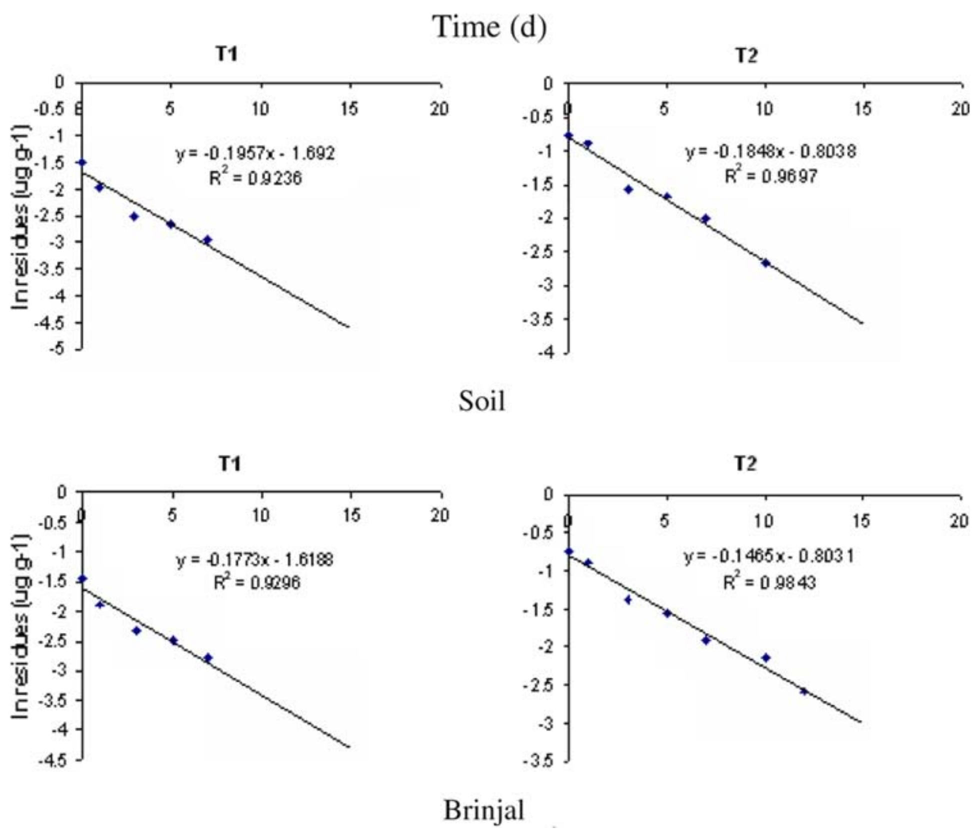

Fig. 1 Plots of natural logarithm of benfuracarb concentration in soil and brinjal versus time at two rates of application (T1 = 0.25 µg g^{-1} and T2 = 0.50 µg g^{-1})

kinetics. The computed values of the coefficient of determination (R^2) between log residues in soil and brinjal time varied from 0.9236 to 0.9697 and 0.9296 to 0.9843 (all significant at $p = 0.05$), indicating that persistence of benfuracarb could be accounted for by first-order kinetics. The half-life values of benfuracarb in different samples were calculated from the slope of the regression equation.

The half-life values of benfuracarb in soil and brinjal were 3.54 and 3.90 days at the lower rate of application, i.e. 0.25 μg g^{-1}. However, at the higher rate of application, i.e. at 0.50 μg g^{-1} the half-life values in soils of this region, i.e. mollisols and brinjal fruit were found to be 3.75 and 4.73 days, respectively. A relatively higher half-life value of benfuracarb in soil at 0.50 μg g^{-1} as compared to 0.25 μg g^{-1} in the present study could be attributed to possible slow conversion of benfuracarb into carbofuran and 3-hydroxy carbofuran. Studies pertaining to degradation of benfuracarb under sterilized conditions were found to be slower ($t_{1/2} = 6.3$–8.8 days) as compared with the normal condition ($t_{1/2} = 6.8$–10.4 days) (Xue et al. 2006).

A combination of both degradation and dissipative mechanisms control overall persistence of a chemical in the natural environments. The fate of residues in the soil compartments is controlled principally by the primary mechanisms of degradation as well as adsorption–desorption characteristics (Cheng 1990). These aspects are influenced both by the physico-chemical characteristics of the chemical compound and of the environmental matrix. Therefore, the fate of a compound in the environment is often predictable, if adequate knowledge of key properties of the chemical and matrix with which it is interacting are known (Mackay and Stiver 1991). The possible routes of benfuracarb dissipation and transformation in the environment include hydrolysis, oxidation in flooded conditions and transformation in plant (Fukuto 1990).

Thus, it can be concluded, that benfuracarb does not persist for a longer duration both in mollisols which are rich in organic carbon and brinjal under sub-humid and sub-tropical climatic conditions. It can thus, be considered as a safe insecticide from the environmental aspect.

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