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Istituto di Nematologia Agraria, C.N.R., 70126 Bari, Italy
*Istituto di Chimica Agraria, Università di Bari - 70126 Bari, Italy**

INFLUENCE OF IRRIGATION AND TIME ON LEACHING OF FENAMIPHOS IN SOIL COLUMNS AND ITS UPTAKE AND ACCUMULATION BY TOMATO PLANTS

by
E. Loffredo, N. Senesi*, V.A. Melillo and F. Lamberti

Summary. The effects of three irrigation levels on the leaching of surface incorporated fenamiphos and its metabolites in soil columns and its uptake and accumulation by tomato plants was studied in a greenhouse experiment. Leaching and the disappearance of the nematicide in soil were differently affected by the amount of water added; leaching was highest with higher irrigation levels whilst the highest rate of fenamiphos degradation was found with the lowest water dose used. The irrigation level influenced the amount of fenamiphos residue in plants only in the first stage of growth. The residue concentration in both shoots and roots decreased markedly along an experimental period of 91 days. About 90% of the nematicide absorbed by tomato plants accumulated in the leaves.

Fenamiphos [ethyl 4-(methylthio)-m-tolyl isopropylphosphoramidate] is an organophosporus nematicide used in the protection of a wide variety of crops. The commercial product «Nemacur» is usually applied to the field soil in a granular form. This nematicide is also useful for the collateral action exhibited against sucking insects and mites. Fenamiphos, and its biologically active metabolites, sulfoxide and sulfone, are absorbed by roots and translocated throughout the plant. When applied to leaves, it moves basipetally to the root system (O'Bannon and Taylor, 1967; Homeyer, 1971; Zeck, 1971).

In soil, fenamiphos undergoes a number of physical, chemical and biological processes, including adsorption and desorption on soil colloids (Bilkert and Rao, 1985; Basile *et al.*, 1988), movement in soil water (Bilkert and Rao, 1985; Basile *et al.*, 1988a, b; Loffredo *et al.*, 1991), oxidation to sulfoxide and sulfone and hydrolysis (Wagonner and Khasawinah, 1974; Ou and Rao, 1986; Loffredo *et al.*, 1990). Leaching of fenamiphos has been investigated in the absence of plants, either after a single water application (Bilkert and Rao, 1985; Basile *et al.*, 1988 a, b) or multiple applications within a few days (Loffredo *et al.*, 1991). These experiments do not reflect actual field conditions in which alternate hydrated and dehydrated soil conditions can cause an upward movement of the nematicide and root uptake can influence the movement of the chemical in soil. Thus, the amount of water applied to the soil plays an important role in the behaviour of pesticides by markedly influencing both the movement of the chemical in soil and its availability in the active root zone and uptake by plants.

The metabolism of fenamiphos in the plant has scarcely been studied (Waggoner, 1972; Waggoner and Khasawinah, 1974), and to date no investigations have been on the extent of fenamiphos uptake by plants and on the level of residues accumulated in each plant organ.

The objective of this paper is to present and discuss results obtained in greenhouse experiments on the influence of water dose and time on leaching of fenamiphos in soil columns and on the uptake and accumulation of total residues in the roots, stems and leaves of tomato.

Materials and methods

The experiments were performed in a greenhouse at 25 ± 2°C, using a sandy loam soil (87.2% sand, 0.1% silt, 12,7% clay, 1.2% organic matter, pH 7.4 and 24% moisture content at water-holding capacity) collected between 5 and 30 cm depth and steam-sterilized. Six weeks after sterilization, plastic cylinders (50 × 15.4 cm), lined with polythylene foil, were filled with the soil. Two 30-day old tomato plants were transplanted in each soil column and 28.8 mg of fenamiphos (about 15 Kg/ha) were added in the form of Nemacur (4.8% a.i.) granules to the top of each column and incorporated into the surface layer (1 cm) of the soil. Then, water was applied at the rate of 16, 32 or 48 mm in three applications each week respectively to three groups each comprising twelve soil columns. The interme-

diate irrigation level (32 mm) used is that generally considered as optimal for the growth of tomato plants. About two months after the plants were transplanted, 0.4 g of ammonium nitrate was supplied to each soil column in the water dose applied.

Residues of fenamiphos were determined in the soil and plants in three columns (replicates) for each irrigation level after 28, 49, 70 and 91 days. Tomato plants were cut at soil level. Soil columns were removed from the cylinders and sliced with a knife into 10 cm soil sections. After thoroughly mixing, and removing 10 g subsamples to determine the water content, each soil sample section was air-dried and sieved through a 2-mm sieve. Most of the roots were collected during the handling of the soil, with the exception of the soils sampled after 28 days.

Soil samples (50 g) were extracted with acetone according to the procedure described by Loffredo *et al.*, (1991). The total toxic residue (fenamiphos + sulfoxide + sulfone) was then completely oxidized to sulfone with $KMnO_4$ solution (Thornton, 1971) and finally measured as sulfone by gas chromatography.

Whole fresh plant samples were placed in a blender jar and extracted with acetonitrile (1:2, w/v) by blending at high speed for about 3 min. After filtration on blotting-paper, the mixtures were poured into glass cylinders containing 10 g of NaCl, vigorously shaken and allowed to stand for about 30 min. Then, aliquots (25 ml) of the top phase (acetonitrile fraction) were dried in a rotary evaporator. Finally, the residues were dissolved in acetone and oxidized to obtaine the sulfone (Thornton, 1971), except for the leaf samples where residues were dissolved in chloroform (50 ml) and decoloured with 1 g of active charcoal before oxidation. Recovery efficiencies of the extraction process from plant samples (50 g) fortified in the blender with fenamiphos, fenamiphos sulfoxide and fenamiphos sulfone (250 μg each) were, respectively, 91% (standard deviation sd = 4.1), 92% (sd = 4.7) and 94% (sd = 4.5) (six measurements for each chemical).

Gas chromatographic analyses were performed on a Varian 3400 gas chromatograph equipped with a dual-flame photometric detector with phosphorus-emission filter (530 nm). Column characteristics and operational conditions have been described previously (Loffredo *et al.*, 1991).

Results and discussion

The results presented in Fig. 1 and Tab. II clearly indicate that leaching of fenamiphos along the soil profile was markedly affected by the amount of water added to soil surface. In the lowest water dose treatment, the nem-

TABLE I - *Total fenamiphos residue concentration in soil after soil column leaching with water.*

Days after treatment	Soil depth in the column (cm)	Total fenamiphos residue (μg g^{-1} of dry soil)		
		Water applied weekly (mm)		
		16	32	48
28	0 – 10	7.94 ± 1.01*	5.87 ± 1.52	3.44 ± 0.04
	10 – 20	0.17 ± 0.13	2.30 ± 0.85	3.67 ± 0.93
	20 – 30	< 0.01	0.25 ± 0.02	1.26 ± 0.13
	30 – 40		< 0.01	0.21 ± 0.06
	40 – 50			< 0.01
49	0 – 10	3.67 ± 0.23	3.12 ± 0.72	1.42 ± 0.55
	10 – 20	0.59 ± 0.04	2.66 ± 0.45	1.38 ± 0.11
	20 – 30	< 0.01	1.79 ± 0.07	2.31 ± 0.13
	30 – 40		0.13 ± 0.10	2.23 ± 0.09
	40 – 50		< 0.01	0.15 ± 0.06
70	0 – 10	1.17 ± 0.17	0.74 ± 0.23	0.57 ± 0.12
	10 – 20	0.17 ± 0.13	0.73 ± 0.30	0.54 ± 0.22
	20 – 30	< 0.01	1.09 ± 0.48	0.68 ± 0.34
	30 – 40		0.13 ± 0.06	1.21 ± 0.20
	40 – 50		< 0.01	0.10 ± 0.07
91	0 – 10	0.11 ± 0.02	0.17 ± 0.02	0.12 ± 0.02
	10 – 20	0.15 ± 0.01	0.82 ± 0.15	0.23 ± 0.09
	20 – 30	< 0.01	0.59 ± 0.02	0.24 ± 0.05
	30 – 40		0.12 ± 0.03	0.37 ± 0.11
	40 – 50		< 0.01	0.72 ± 0.17

* Standard deviation (n = 3).

aticide and its metabolites were mostly recovered from the top 10 cm layer within 70 days, and residues became measurable at the 10-20 cm soil depth only after the end of the experimental time (91 days). In the intermediate water dose treatment, fenamiphos appeared to gradually leach to 40 cm depth, whereas in the treatment with the highest water application, residues were already detectable at the lowest soil level (50 cm) 49 days from the start of the experiment, and where they became prevalent at a high level at the end of the experiment.

After 28 days, except at the highest water dose, the residues in the upper 10 cm of soil exceeded 5 $\mu g\ g^{-1}$ (Tab. I), which is considered to be the lowest dose of fenamiphos and metabolites required for 100 percent control of nematodes in the soil (Homeyer, 1971).

Fig. 2 shows that the disappearance of total fenamiphos residue was more rapid in the soil receiving the lowest dose than in those where intermediate or high amounts of water were added. This is not surprising when one considers that most of the fenamiphos and its metabolites remained in the top 10 cm of soil during almost the entire time with the lowest water dose treatment (Fig. 1 and Tab. II). Close to the soil surface, degradation of the nematicide may be accelerated by high soil temperatures and by various photochemical effects. Experiments conducted with the same soil exposed to sunlight have shown, in fact, that the amount of total fenamiphos residue degraded in 15 days was more than three times higher than that degraded in soil incubated in the dark (Loffredo *et al.*, unpublished results).

TABLE II - *Distribution of fenamiphos residue in the various plant organs, expressed as a percentage of the total residue recovered from the whole plant.*

Days after treatment	Plant organ	Water applied weekly (mm) 16	32	48
49	Leaves + Stems	96.7	98.6	99.9
	Roots	3.3	1.4	1.0
70	Leaves	93.4	94.4	95.5
	Stems	4.8	4.3	4.5
	Roots	1 .8	1.3	n.d.
91	Leaves	89.5	80.3	92.5
	Stems	9.0	18.2	6.6
	Roots	1.5	1.5	0.9

n.d.: not determined.

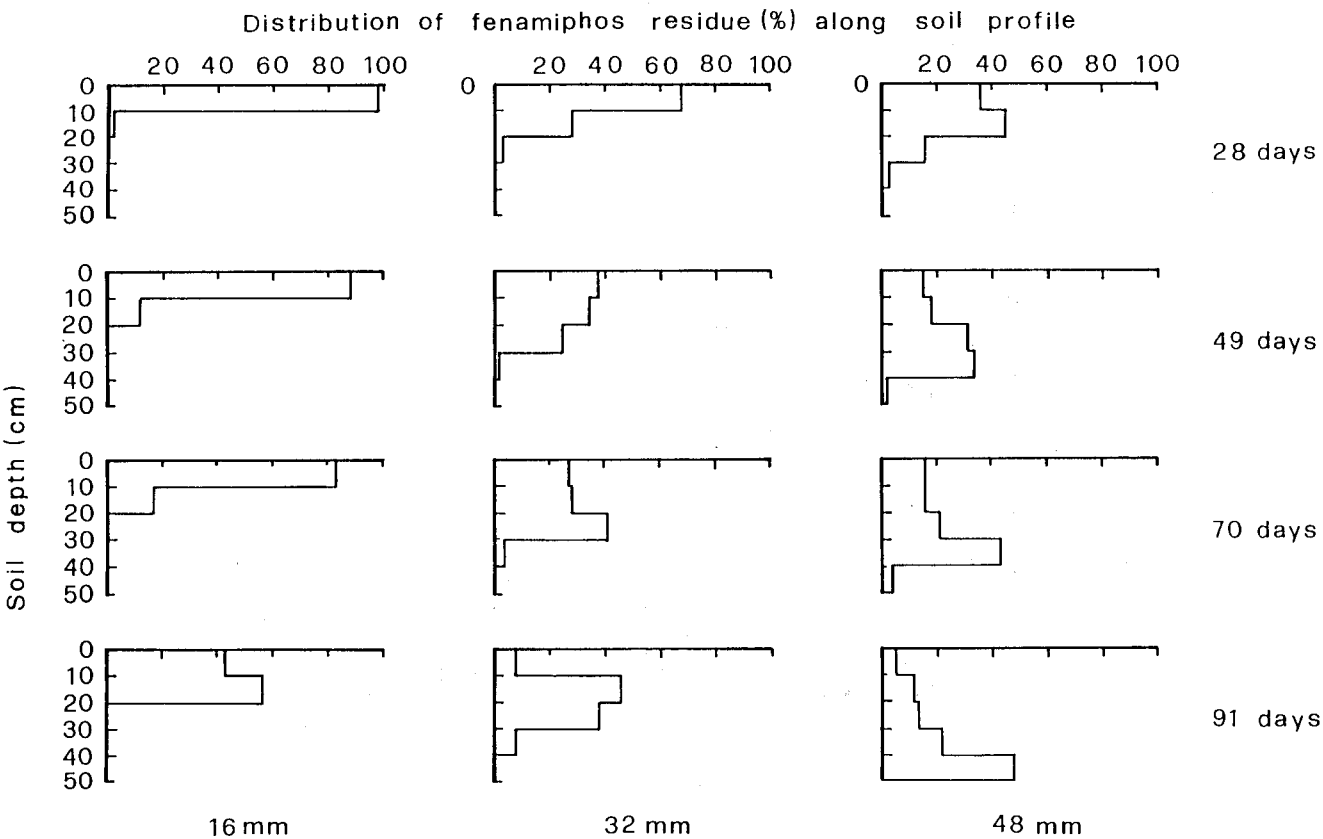

Fig. 1 - Distribution of fenamiphos residue in the various soil sections, expressed as a percentage of the total residue recovered from the whole soil column.

The absolute amount and concentrations of total toxic residue of the nematicide recovered in tomato plants are given respectively in Fig. 3A and 3B as a function of sampling time and water dose used. The highest absolute amount of fenamiphos residue was measured in plant samples collected after 49 days in the experiment conducted with the lowest water dose and corresponds to about 4% of total nematicide initially applied to the soil. This suggests that the progressive decrease with time measured for the total nematicide residue in soil (Fig. 2) can probably be ascribed to degradative processes of fenamiphos and its metabolites rather than to their removal by plant uptake.

In the intermediate or the highest irrigation levels, the highest amount of fenamiphos residue was recovered after 70 days. For any water dose used, however, the highest concentration of the chemical in the plants was found after 28 days, and then it decreased progressively until the end of the experiment (91 days). A similar trend has been shown for vine leaves sampled in a vineyard treated with fenamiphos either by broadcast or band application (Krause *et al.*, 1986).

Further, data presented in Tab. II show that leaves are the preferential organ of tomato plants for the accumulation of the nematicide. Most of fenamiphos residue was recovered in the leaves throughout the duration of the experiment and for all the water doses used.

Both the total fenamiphos residue and its concentration in the plants were influenced by the water dose applied only in the two first samplings made; apparently, with the progression of time and with the decrease of the amount of nematicide present in the soil, water dose did not cause any further alteration of the nematicide uptake by the plant.

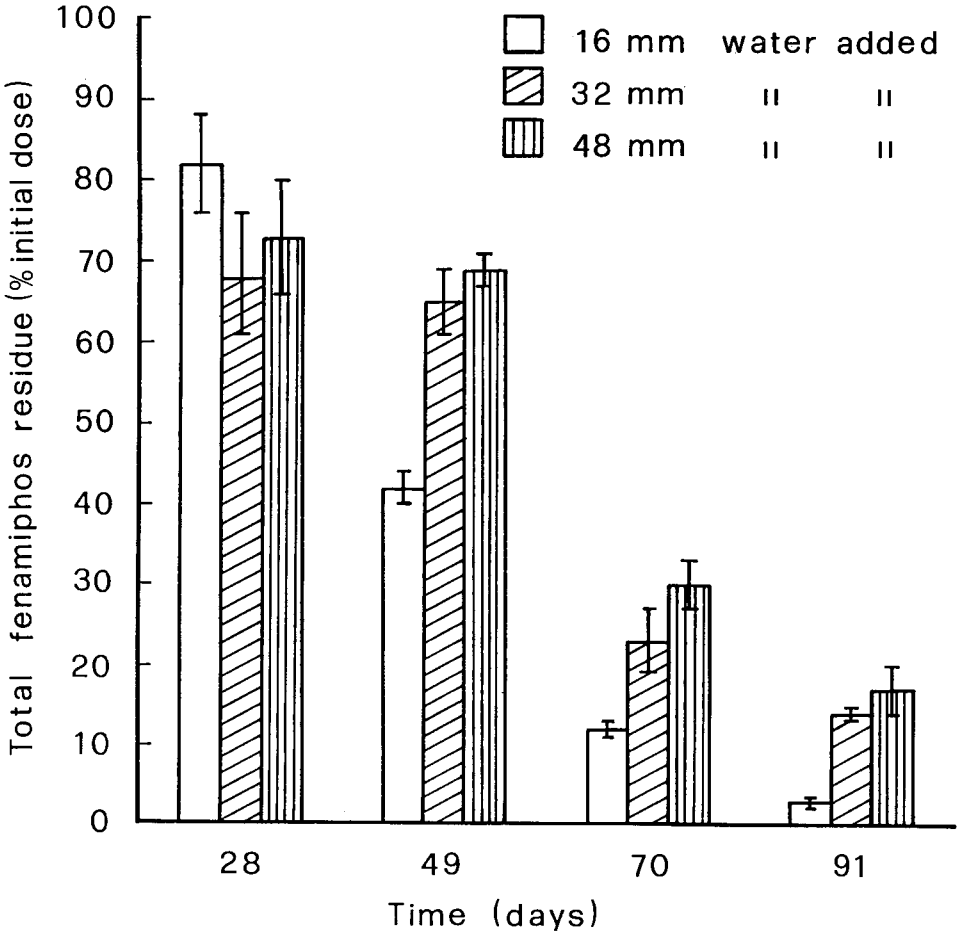

Fig. 2 - Total fenamiphos residue recovered from the whole soil columns, expressed as a percentage of the dose initially applied. Bars represent standard deviation (n = 3).

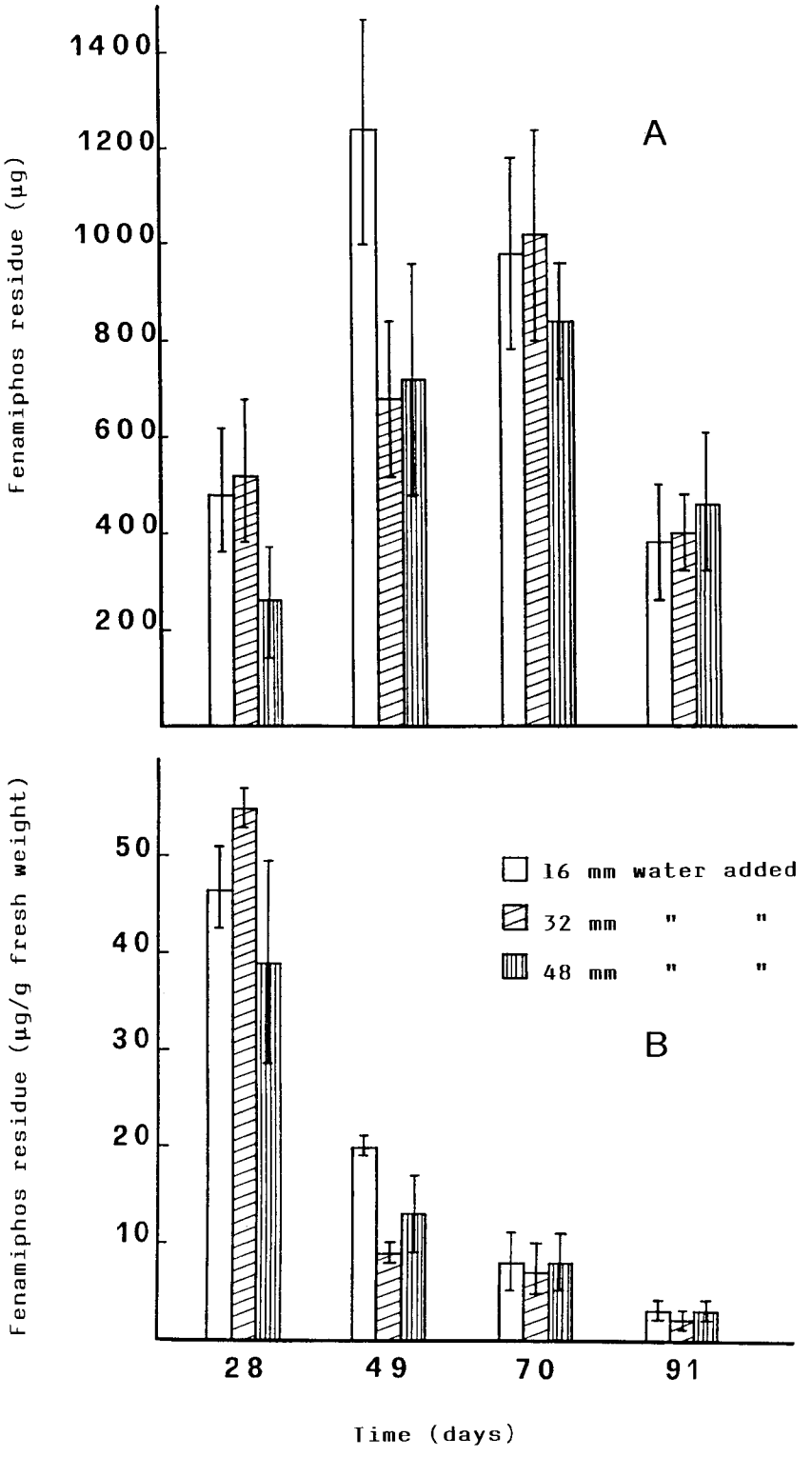

Fig. 3 - Absolute amounts (A) and concentrations (B) of total fenamiphos residue measured in the whole plant. Bars represent standard deviation (n = 3).

Conclusions

The results of this study, carried out in a greenhouse and in conditions simulating those existing in the field, show that both the water dose applied and the time considerably influence leaching and persistance of fenamiphos in the soil. The total residue content measured in tomato plants represents only a small fraction of the nematicide amount recovered from the whole soil-plant system in any experiment. The irrigation level appears to affect both the uptake and accumulation of nematicide by tomato plants and its concentration in the plant at the earlier stages of plant growth. The residue concentrations in the plant organs has been found to decrease considerably along the experimental period. A large percentage of fenamiphos was recovered in the leaves throughout the experiment. In conclusion, it is confirmed that the irrigation level is a relevant factor in the behaviour of fenamiphos and its metabolites in the integrated soil-plant system.

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