Intern. J. Environmental Studies., 1995 Vol. #, pp. 1–8
Reprints available directly from the Publisher
Photocopying permitted by license only

ASCENDING AND DESCENDING TRANSLOCATION OF ^{14}C-MALATHION IN PLANT-SOIL ECOSYSTEM

MOHAMED A. ABO-EL-SEOUD* and ALI M. SHAMS-EL-DIN†

(Received in Final Form: March 3, 1995)

A glasshouse experiment was carried and to measure the translocation of ^{14}C-malathion applied to cabbage plants. Cabbage seedlings were transplanted in plastic pots containing 1 kg of alluvial or sandy soil. After growth period of 2 months, the radioactive pesticide was applied to leaves or soils of the grown plants. Radioactivity was detected in stems and roots after 4 and 10 days, respectively, of foliar application; however, no ^{14}C-residues could be recovered in either of the used soil. On the other hand, ^{14}C-malathion was detected in cabbage roots after 2 days of soil application; it was then translocated up to stems after 6 and 4 days and to leaves after 10 and 6 days with respect to the alluvial and sandy soil-grown plants, respectively.

KEYWORDS: Malathion, translocation, cabbage plants, radioactivity

INTRODUCTION

The expanding use of pesticides for protecting crops and human health against pest and disease attack is dictated by the needs of a rapidly growing population. Traces or residues of the pesticides inevitably find their way into human food and the environment. Therefore the selection and the safe use of a pesticide depends on a comprehensive study of the persistence, transport and transformation of such toxicant in the environment.

Translocation and distribution of pesticides in a plant-soil eco-system are an important consideration from the view point of habitat pollution as well as non-target organisms. Cultivate soil contains residues of pesticides due to the direct application or fall-out after crop spraying for pest control. A pesticide may remain in the surface soil or may leach down to the subsoil stratum by the action of water. Fate and movement of pesticides in the soil depend on soil type,[1] organic matter,[2] soil moisture,[3] soil pH[4] and temperature.[5]

On the other hand, crop plants growing in such polluted soil absorb some of these chemicals at various rates and, consequently, could be translocated to the upper parts.[6] The extent of penetration of a given pesticide into plant roots and its subsequent transport are functions of a particular plant (root development, transpiration and nutritional status) and physicochemical properties of the pesticide molecule, as discussed by Führ.[7] The penetrated pesticides could be translocated within plant tissues through the symplastic (descending translocation) and apoplastic (scending translocation) systems.[8,9] ascending

Isotope tracer and radioactivation techniques provide a powerful and often unique tool for studying the nature, magnitude and persistence of agrochemical residues since they permit an immediate and accurate measure of the total initial residue. Also, the fate of a labelled pesticide can be followed specifically in the presence of background levels of other pesticides, including the one being studied. However, many of the tracer studies

* Agric. Dept. of Soils and Water Res., Atomic Energy Authority, Inshas, P.O. Box 13759 (Egypt)
† Plant Protection Dept., Fac. of Agriculture, Moshtohor (Egypt)

with radioactive pesticides have been conducted under laboratory conditions[10,11] which would call for more applied and outdoor experiments. Our research aimed investigating the ascending and descending translocation of ^{14}c-malathion added either as foliar or soil application for cabbage plants grown under glasshouse conditions.

14C-

MATERIALS AND METHODS

1. *Radiochemical*

Malathion (*S*-1,2-di(ethoxycarbonyl) ethyl 0,0-dimethyl phosphorodithoate) labelled at the 2,3 position of diethyl maleate (spec. act. 45.5 µCi/mg; 15 mCi/mmol) was purchased from Amersham International, U.K. Radiopurity was 98.5% as checked by TLC.

2. *Plant and Soil*

Cabbage seedlings were transplanted in plastic pots containing 1 kg soil (one plant/pot). Two alternative soils were used in this study; alluvial (organic matter 0.8%, sand 25.1%, silt 36.8%, clay 38.1%, with a pH of 7.16) and sandy soil (organic matter 0.1%, sand 93.5%, silt 3.7%, clay 2.8%, with a pH of 7.1). The used soils were free from pesticides residues. The plants were grown under glasshouse conditions, supplied with the required nutrients and irrigated daily to keep the soil moisture arround the field capacity. After two months, the homogenated plants containing three leaves were chosen for the pesticide treatments.

3. *Application of ^{14}C-malathion*

The radioactive pesticide was applied on the upper surface of plant leaves or dropped and distributed carefully on the soils surface (using a micro-syringe) in two separate experiments. Total radioactivity applied to the individual plant or pot were 300,000 and 500,000 cpm for the leaves or the soil, respectively. Representative samples (4 replicates) were taken at random after 0, 2, 4, 6, 8, 10, 12 and 14 days of application.

4. *Harvesting of Plants and Soils*

After each experimental period, cabbage plants were harvested carefully, separated into leaves, stems or roots, cut into small pieces, and immersed in appropriate extraction solvents at 0°C.

Soils were allowed to dry for 2 days and sieved through a 2-mm screen to remove any root pieces. Then, sand or alluvial soils were thoroughly mixed, and a 100 g aliquot was kept for moisture determination, while a second 100 g aliquot was immersed in 200 mL of extraction solvent.

5. *Extraction and Determination of Radioactivity*

Plant materials were homogensed at 0°C and extracted with methanol/chloroform (2:1, V/V).[12] Soil samples were extracted by blending with a mixture of acetone/methanol/

benzene (1:1:1, V/V/V).[6] Estimation of the extractable radioactivity was achieved using a liquid scintillation counter (Packared model 1000) and the appropriate scintillation cocktail according to the used solvent. Residues of both soil and plant materials were combusted to determine the amount of non-extractable radioactivity.

RESULTS AND DISCUSSION

Data presented in Tables I–IV demonstrate the distribution, fate and movements of ^{14}C-malathion either as foliar or soil application for grown cabbage plants. Such data would be very helpful to obtain a more accurate understanding of important concepts like phytotoxicity, residue half-life, worker re-entry and tolerance limits of pesticides.

1. *Foliar Application*

The degree of penetration of the radioactive pesticide into tissues of cabbage leaves and its subsequent translocation down to stems or roots for plants grown in alluvial or sandy soil could be obtained from results shown in Tables I & II. Leaves of plants grown in both the used soils showed maximum radioactivity in the initial periods after application, afterwards it declined gradually and slightly up to the end of the experiment, i.e. after 14 days of application. For example, 98.95 and 84.64% of the initial applied activity were found in leaves of cabbage grown in alluvial soil after 2 and 14 days of application, respectively. On the other hand, the extractable and bound radiocarbon exhibited a variety effects during different experimental periods. While a decline was observed for the extractable radiocarbon, an increase was found for the non-extractable (bound) ^{14}C-residues. Such a phenomenon is attributed to the metabolic processes and degradation of the pesticide molecule. On the other side, radioactivity was hardly translocated within

TABLE I
Distribution and movement of radioactivity of ^{14}C-malathion applied to leaves of cabbage plants grown in alluvial soil.

Distribution of radioactivity	Sampling dates in days							
	Zero	2	4	6	8	10	12	14
	— Values are % of applied radioactivity—							
1. Leaves:								
Extractable	98.35	96.87	92.83	87.61	82.13	78.18	74.68	71.80
Non-extractable	0.18	2.08	3.95	6.08	8.65	10.85	11.85	12.84
2. Stems:								
Extractable	–	–	0.66	1.88	2.91	3.16	3.97	4.36
Non-extractable	–	–	–	0.37	0.47	0.84	0.91	0.96
3. Roots:								
Extractable	–	–	–	–	–	0.43	1.48	1.92
Non-extractable	–	–	–	–	–	–	0.35	0.53
4. Soils:	–	–	–	–	–	–	–	–
Total recovery of radioactivity	98.53	98.95	97.44	95.94	94.16	93.46	93.24	92.41

TABLE II
Distribution and movement of radioactivity of ^{14}C-malathion applied to leaves of cabbage plants grown in sandy soil.

Distribution of radioactivity	Sampling dates in days							
	Zero	2	4	6	8	10	12	14
	— Values are % of applied radioactivity—							
1. Leaves:								
Extractable	98.38	95.68	91.53	87.62	83.25	79.16	76.45	74.21
Non-extractable	0.12	2.25	4.84	7.77	9.63	11.41	13.16	14.33
2. Stems:								
Extractable	–	–	0.85	1.43	1.98	2.56	2.98	3.08
Non-extractable	–	–	–	0.16	0.25	0.36	0.58	0.79
3. Roots:								
Extractable	–	–	–	–	–	0.53	0.96	1.08
Non-extractable	–	–	–	–	–	–	–	0.28
4. Soils:	–	–	–	–	–	–	–	–
Total recovery of radioactivity	98.50	97.93	97.22	96.98	95.11	94.02	94.13	93.77

plant tissues as it was detected in stems and roots after 4 and 10 days, respectively. At the end of experiment, the total measured activity in cabbage stems were 5.32 and 3.87%; however, those of roots were 2.45 and 1.36% of the applied radioactivity for plants grown in the alluvial and sandy soils, respectively. On the other hand, no radioactivity could be transported or detected in either of the used soils. Thus, it could be concluded that ^{14}C-malathion undergoes a slow release and movement inside the tissues of cabbage plant. This conclusion is, supported by the findings of El-Refai and Hopkins[13] that malathion does not translocate to a great extent in plants, but penetrates from the surface into the interior of the leaves. Malathion is classified on quasi-systemic pesticides[14] which have low solubility in water and might be soaked into leaves, but do not migrate around the plant.

2. *Soil Application*

Data presented in Table III & IV shrew extractable and bound radiocarbon recovered from ^{14}C-malathion-treated soils and cabbage plants which had grown in these soils. As expected, both the alluvial and sandy soil showed a higher initial radioactivity after the pesticide application, then it declined gradually until the end of the experiment. However, the alluvial soil gaw higher ^{14}C-remaining residues rather than the sandy soil. In this consideration, the percent of total remaining ^{14}C-materials detected in the final experimental period was 56.19 and 29.33% of the initial activity for the alluvial and sandy soils, respectively. These results might be interpreted by the fact that the alluvial soil has a greater adsorptive capacity for pesticides than sandy soil.[6] In turn, ^{14}C-residues in sandy soils were more available for volatilization and plant uptake. For both the used soils, the extractable radiocarbon exhibited a higher proportion rather than the bound one during the earlier periods after application; however, it decreased by the end of the experiment. For instance, ratios of extractable/non-extractable ^{14}C-residues were 83.9:1

TABLE III
Distribution and translocation of radioactivity of ^{14}C-malathion applied to alluvial soil of the grown cabbage plants.

Distribution of radioactivity	Sampling dates in days							
	Zero	2	4	6	8	10	12	14
	— Values are % of applied radioactivity—							
1. Leaves:								
Extractable	–	–	–	–	–	0.95	1.41	2.61
Non-extractable	–	–	–	–	–	–	0.58	0.93
2. Stems:								
Extractable	–	–	–	1.07	2.25	3.83	4.21	6.08
Non-extractable	–	–	–	0.34	0.89	1.14	1.88	2.17
3. Roots:								
Extractable	–	4.25	7.14	11.05	14.17	16.18	18.08	20.65
Non-extractable	–	0.33	1.05	2.34	2.95	3.11	5.31	6.93
4. Soils:								
Extractable	98.31	93.09	86.81	78.31	71.31	63.14	65.11	48.11
Non-extractable	0.33	1.11	2.65	3.15	4.16	6.35	7.15	8.08
Total recovery of radioactivity	98.64	98.78	97.65	96.26	95.73	94.70	94.73	95.56

TABLE IV
Distribution and translocation of radioactivity of ^{14}C-malathion applied to sandy soil of the grown cabbage plants

Distribution of radioactivity	Sampling dates in days							
	Zero	2	4	6	8	10	12	14
	— Values are % of applied radioactivity—							
1. Leaves:								
Extractable	–	–	–	0.94	1.89	3.45	4.12	6.11
Non-extractable	–	–	–	–	0.35	0.96	1.05	1.33
2. Stems:								
Extractable	–	–	1.36	3.36	6.48	9.03	11.81	13.06
Non-extractable	–	–	0.47	1.98	2.36	2.88	3.04	3.09
3. Roots:								
Extractable	–	9.63	16.76	20.15	24.11	29.16	31.14	33.40
Non-extractable	–	1.78	3.25	4.28	5.24	5.98	6.77	7.11
4. Soils:								
Extractable	97.83	85.31	74.16	63.18	52.36	40.31	31.16	23.86
Non-extractable	0.28	0.98	1.24	2.56	3.08	4.16	4.95	5.47
Total recovery of radioactivity	98.11	97.70	97.24	96.45	95.87	95.93	94.04	94.23

TABLE V

Comparison between ascending and descending translocation of ^{14}C-malathion in cabbage plant grown in alluvial and sandy soil.

Sampling date in days	Alluvial soil						Sandy soil					
	A- Translocated[a] portion		B- Total activity in plant		% of translocation (A/B × 100)		A- Translocated portion		B- Total activity in plant		% of translocation (A/B × 100)	
	F[b]	S[c]	F	S	F	S	F	S	F	S	F	S
0	–	–	98.53	–	–	–	–	–	98.50	–	–	–
2	–	–	98.95	4.58	–	–	–	–	97.93	11.41	–	–
4	0.66	–	97.44	8.19	0.68	–	0.85	1.83	97.22	21.84	0.87	8.38
6	2.25	1.41	95.94	14.80	2.35	9.53	1.59	6.28	96.98	30.71	1.64	20.45
8	3.38	3.14	94.14	20.62	3.59	15.23	2.23	11.08	95.11	40.43	2.34	27.41
10	4.43	5.92	93.46	25.21	4.74	23.48	3.45	16.32	94.02	51.46	3.67	31.71
12	6.71	8.08	93.24	31.47	7.20	25.68	4.52	20.02	94.13	57.93	4.80	34.56
14	7.77	11.79	92.41	39.37	8.41	29.95	5.23	24.39	93.77	64.90	5.58	37.58

[a] Total activity detected away from site of application.
[b] Foliar application which represent the descending translocation.
[c] Soil application which represent the ascending translocation.

and 87.1:1 after 2 days; however, they became 5.9:1 and 4.4:1 after 14 days of application with respect to the alluvial and sandy soil, respectively.

In time, the radioactive pesticide and/or its metabolites penetrated into the roots of the grown cabbage plants and translocated up to the upper parts. In this regard, radioactivity was detected in roots after 2 days of ^{14}C-malathion application for plants grown in both the alluvial and sandy soil. However, it was initially recovered after 6 and 4 days in stems and, after 10 and 6 days in leaves of the alluvial and sandy soil-grown plants, respectively. The uptake of ^{14}C-residues by the grown cabbage plants increased gradually during the studied experimental period. Total recovered ^{14}C-residues in the whole plant tissues at the final sampling date were 39.37 and 64.9% of the applied radioactivity for the plants grown in alluvial and sandy soil, respectively. Thus, it could be easily noted that cabbage grown in a sandy soil contained more radiocarbon than that grown in an alluvial soil. This is due to the greater availability of ^{14}C-pesticide in the sandy soil, as previously reported. Of course, the distribution of radioactivity was ranked as follows: roots>stems>leaves. The extractable/non-extractable ratio in plant tissues varied according to the sampling date, plant organ and the soil type.

3. *Ascending and Descending Translocation of ^{14}C-malathion*

A comparison between the ascending and descending translocation of ^{14}C-malathion applied the soil or leaves for the grown cabbage plants by given in Table V. With regard to the plants grown either in an alluvial or sandy soil, the translocated portion of the radioactive pesticide and in turn the percent of translocation were comparatively higher in the case of soil application treatment rather than values obtained after foliar application. As demonstrated in Table V, the calculated percent of translocation at the latest sampling date was 5.58 and 8.41% after foliar application; however it reached 37.58 and 29.95% after soil application for plants grown in sandy and alluvial soils, respectively. From the above mentioned results, it many be deduced that rate of translocation (ascending) from root and upwards to leaves was much faster as compared with the translocation (descending) from leaves and down to the roots. A similar trend was obtained for the movement and translocation of ^{14}C-parathion applied to leaves or nutrient solution of grown soybean and wheat plants[15]. Mechanisms and pathways of absorption and translocation of pesticides in plant tissues were discussed in detail elsewhere[16].

to is

REFERENCES

1. B. Yaron and S. Saltzman, "Soil-parathion surface interaction" *Residue Reviews* **69**, pp. 1–28 (1978).
2. G. W. Baily and J. L. White, "Factors influencing the absorption, desorption, and movement of pesticides in soil" *Residue Reviews* **32**, pp. 29–58 (1970).
3. C. R. Harris, Further studies on the influence of soil moisture on the toxicity of insecticides in soil," *J. Econ. Entomol*" **60**, 41–48 (1967).
4. G. J. Konrad, G. Ghesters and D. E. Armstrong, Soil degradation of malathion, a phosphorodithioate insecticide" *Soil Sci. Soc. Amer. Proc.* **33**, 259–267 (1969).
5. W. F. Spencer and M. M. Cliath, "Vaporization of chemicals" In: *Pesticides in Aquatic Environments* (M. A. Q. Khan, Ed.) (Plenum Press, New York and London, 1975) pp. 67–75.
6. T. W. Fuhremann and E. P. Lichtenstein, "A comparative study of the persistence, movement, and metabolism of six carbon-14 insecticides in soils and plants" *J. Agric. Food Chem.* **28**, 446–452 (1980).
7. F. Führ, "Agricultural pesticid residues In: *Isotopes and Radiation in Agricultural Sciences* (M. F. L' Annunziata and J. O. Legg, Eds.) (Academic Press, New York, 1984) **Vol. 2**, pp. 239–270.

8. D. E. Bayer and J. M. Lumb, "Penetration and translocation of herbicides" In: *Pesticides Formulations* (W. V. Valkenburg, Ed.) (Academic Press, New York, 1973) pp. 387–439.
9. A. S. Crafts and C. E. Crisp, *Phloem Transport in Plants* (W. H. Freeman and Co., San Francisco, 1971).
10. M. Frost and M. A. Abo-El-Seoud, "Fate and Metabolism of [^{14}C] parathion methyl as examined by soybean and wheat cell cultures", *Proc. 2nd Euro. Conf. on Ecotoxicology*, 11–15 May, 1992, Netherlands, (Elsevier Science Publishers B. V., Amesterdam, 1993) pp. 681–687.
11. M. A. Abo-El-Seoud and M. Frost, "Metabolism and degradation of ^{14}C-parathion methyl applied to leaves of soybean and wheat plants grown under sterile conditions", *Nachrich-tenblatt* 46, 195–198 (1994).
12. E. G. Bligh and W. J. Dyer, "A rapid method of total liquid extraction and purification". *Can. J. Biochem. Physiol.* 37, 911–917 (1959).
13. A. El-Refai and T. L. Hopkins, "Malathion absorption, translocation and conversion to malaoxon in bean plants". *J. Agric. Offic. Analyt. Chem.* 55, 526–533 (1972).
14. K. A. Hassal, *The Chemistry of Pesticides* (MacMillan, London, 1981) pp. 67–96.
15. M. Frost and M. A. Abo-El-Seoud, Penetration; movement and translocation of ^{14}C-parathion in plants". *Int. J. Envir. Studies* 47, No. 7, 37–42 (1995).
16. F. M. Ashton and A. S. Crafts, *Mode of Action of Herbicides* (Wiley-Interscience Publication, New York, 1981) pp. 25–39.