PERSISTENCE AND FATE OF SOIL APPLIED ^{14}C- LINDANE IN A MAIZE ECOSYSTEM

P.O. YEBOAH
Department of Chemistry,
Ghana Atomic Energy Commission

K.G. MONTFORD
Biotechnology and Nuclear Agricultural Research Institute,
Ghana Atomic Energy Commission

W. APOH, S. DODOO
Department of Chemistry,
University of Cape-Coast

Legon, Ghana

Abstract

^{14}C-lindane applied to soil surface in a maize ecosystem (one month after planting) was taken up by the plant. Within the first 25 days of treatment, ^{14}C-lindane or its metabolites were found within the entire plant with the greatest concentration in lower leaves (from the ground level); and a sharp build up of lindane concentration towards the tip of each leaf. Radioactivity and hence pesticide concentration was uniformly distributed in the plant with time; to the extent that measurable levels of ^{14}C-compounds were detected in the tussel cob and the grain. This indicated that soil applied lindane was available to the maize plant. The persistence of ^{14}C-lindane in soils of variable organic matter content was also studied. Evidence is presented to show that ^{14}C-lindane dissipated faster in soils of lower organic matter content. Levels of surface applied pesticides that became bound in the soil increased with time after application and also with increasing organic matter content. ^{14}C-activity was mainly associated with the top soil layer (0-30 mm).

1 INTRODUCTION

The following study was designed to complement observations made in the previous paper [1].

2 MATERIALS AND METHODS

2.1. Chemicals

Uniformly labelled ^{14}C-lindane (specific activity 647 MBq mmole^{-1}) was obtained from Sigma Chemical Co. St Louis, USA, through the International Atomic Energy Agency (IAEA) in Vienna. The ^{14}C-concentration of the lindane (supplied as toluene solution) was found to be 1 kBq ml^{-1}. The scintillators 2,5-diphenyloxazole (PPO) and 2,2-phenylenebis-(4-methyl-5-phenyoxazole) (DMPOPOP) were purchased from Eastman Kodak Co., Rochester, N.Y., USA. All other chemicals were Analar grade.

2.2. Studies on the persistence of ^{14}C-lindane

Fifty-one PVC tubes (length, 300 mm; internal diameter, 70 mm) were buried in the soil in the rows between plants (in another plot), with 30 mm projecting above ground level. The tubes were arranged into groups of fifteen and in accordance with the organic matter content of the soils they contained. The soil in each of these group tubes were treated with ^{14}C-lindane (185 kBq) at the same time that plants on the field were sprayed with

commercial lindane. Two tubes in each soil were not treated with ^{14}C-lindane to serve as the control. The tubes were dug out carefully at intervals, wrapped in polythene bags and stored in a refrigerator pending extraction and determination of pesticides. The soil in each of these tubes was sprayed with ^{14}C-lindane (185 kBq) in hexane (100 mL).

2.3. Studies on the uptake of ^{14}C-lindane into plants

Twenty plastic buckets (length, 220 mm; internal diameter, 240 mm and open at both ends) were filled with soil from one of three sources, as described preciously [1]. They were buried in the crop row with 30 mm projecting above ground level. Fifteen tubes of each soil type were grouped together. Maize was planted in each bucket on the same day that planting was done in the field. The soils in the buckets were treated with ^{14}C-lindane (370 kBq) on the same day that the plants on the experimental farm were sprayed with commercial lindane. Three plants were taken periodically and analysed for uptake of ^{14}C-activity. Both anatomical and sectional distribution of ^{14}C-lindane residues in the maize plants were studied.

2.4. Extraction and analysis

2.4.1. Soils

The soil contained in the PVC tubes was scooped out from top (end exposed to the atmosphere) in successive 150 mm layers. Each soil layer was weighed, dried, ground separately (using a pestle and mortar) and sieved through a 2 mm mesh sieve. Samples (40 g) of ground soil were weighed into cellulose extraction thimbles (size 43 × 123 mm) and soxhlet extracted for 2.5 h using methanol. The extracts were concentrated at 50 ± 5 ° C under vacuum to a volume of 5 mL which was then transferred into scintillation vials and analysed for ^{14}C-activity. Recovery was 80.2%.

2.4.2. Plants

Anatomical sections of maize plants above ground level (leaves, stem, cob, etc.) were removed at intervals and stored in a refrigerator for analysis. Stem and leaves were carefully removed from points of attachments cut into 30 mm segments and analysed for ^{14}C-activity using the dry combustion method.

2.5. ^{14}C-activity measurements

Total and bound residues in soils as well as in plant parts were determined by combusting weighed samples in a model 600 Biological Material oxidiser (R.J. Harvey Instrument Corporation, New Jersey, USA). The $^{14}CO_2$ was absorbed in absorber + cocktail (1+1 by volume, 2 mL). The absorber was made up of ethanolamine + methanol (2.5 + 17.5 by volume) and the cocktail consisting of PPO (5 g) + DMPOPOP (50 g) dissolved in toluene (1 L). ^{14}C-activity was measured by liquid scintillation counting (LSC) in a Tri-Carb liquid scintillation Analyser model 100 using the sample channel ratio method for quench correction.

3. DISCUSSION

3.1. Uptake and translocation in maize

Within 25 days of pesticide application to the soil, it was observed that the plants had taken up a measurable amount of ^{14}C-activity with the greatest amount of 0.08% of applied found in the lowest leaf, i.e. the first leaf from the ground level (Fig. 1). There was then a gradual decrease in pesticide concentration in the higher leaves and the stem. The upwards movement of ^{14}C-activity in the maize plant was further shown by the gradual build up of ^{14}C-activity towards the tip of lower leaves (Figs 3, 4). With time, i.e.within 50 days after

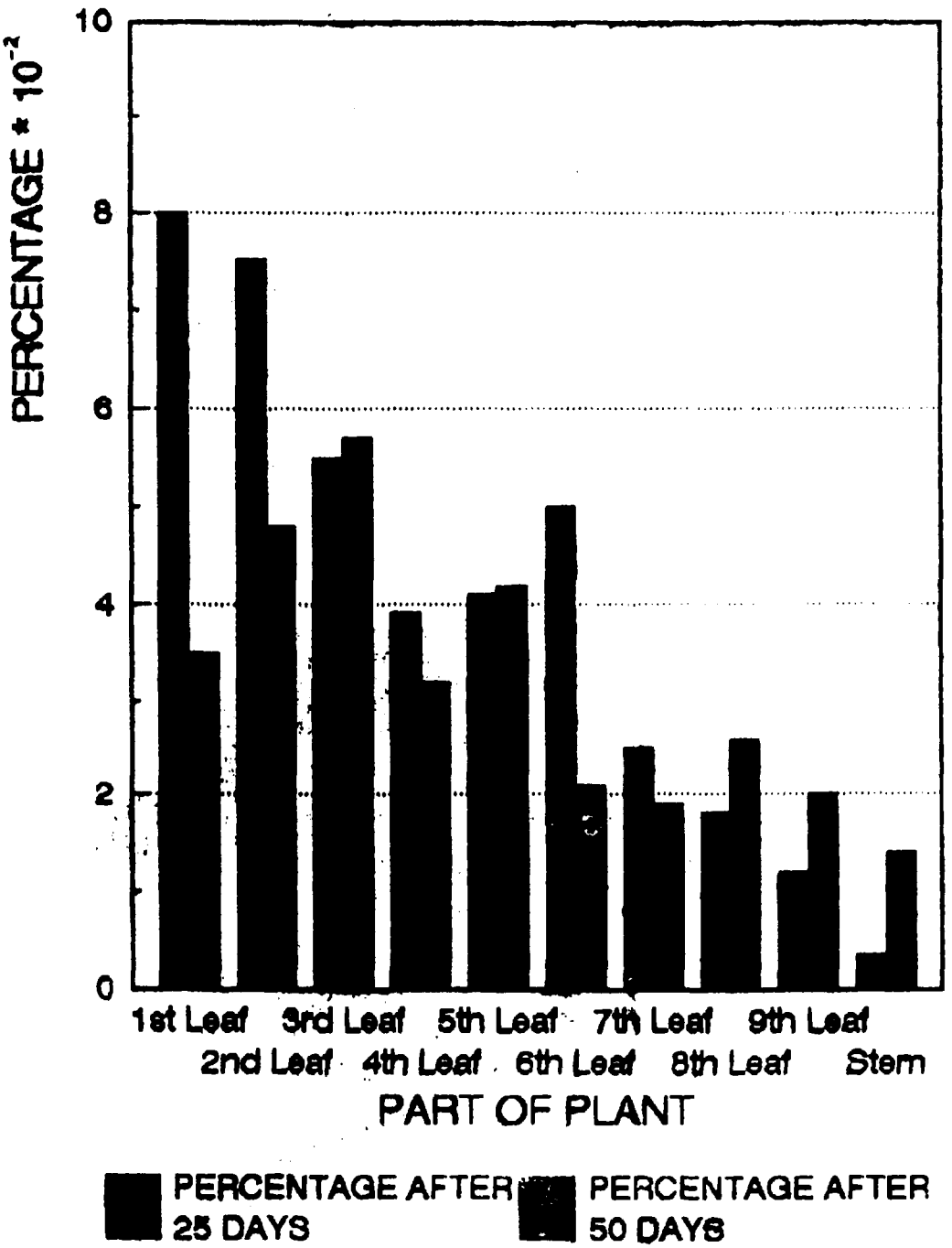

Fig 1. Percentage of initial dose recovered from leaves and stem.

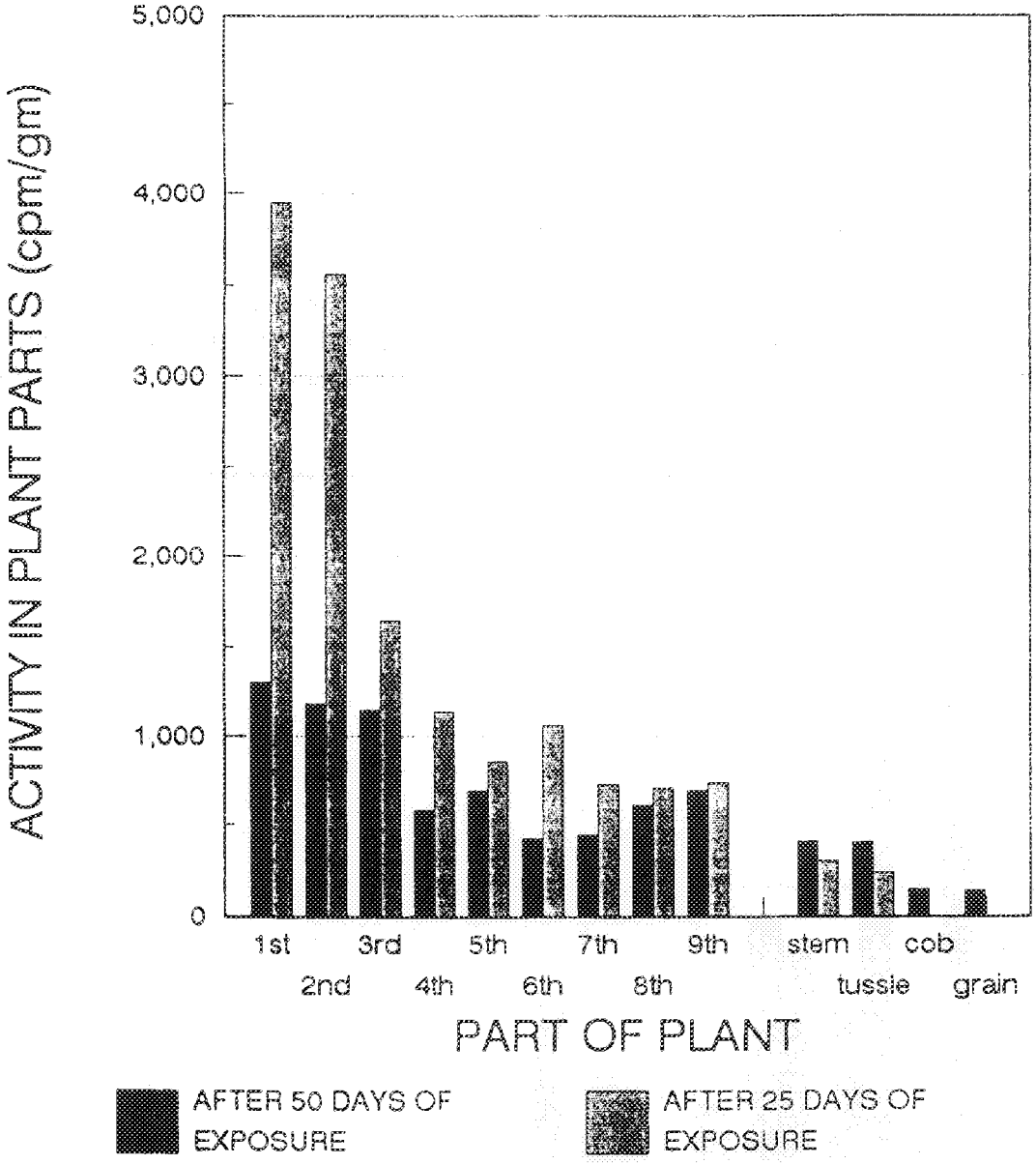

Fig 2. Anatomical distribution of ^{14}C lindane in maize plant.

pesticide treatment, the ^{14}C-activity tended to spread out more uniformly throughout the plant though the greatest concentrations of ^{14}C-activity remained within the bottom three leaves with smaller ^{14}C-activity in the uppermost leaves and the stem (Fig. 2). Some ^{14}C-activity was also found in the tussel, the cob and the grain 50 days after treatment (Fig. 2) indicating that soil applied lindane or its metabolites were available for uptake by the plant. The translocation of soil applied lindane and its metabolites have been investigated in detail [2, 4, 5, 6]. Neither lindane nor its metabolites were evenly distributed within the plants. Comparatively high residue levels were always detected in the leaves whereas small amounts were translocated into the stems, leaves, and fruits. Paasivirta et al. [5] showed that in water plants, lindane concentrations were similar in both the roots and the stem. Differences in residue levels have been shown to be dependent on plant species. Of a series of edible crops grown in soils containing lindane, carrots were shown to have higher levels than beans, tomatoes and potatoes in that order. In soils with low organic matter contents, as in this study, insecticide residues are more available and hence susceptible to uptake by plants [7].

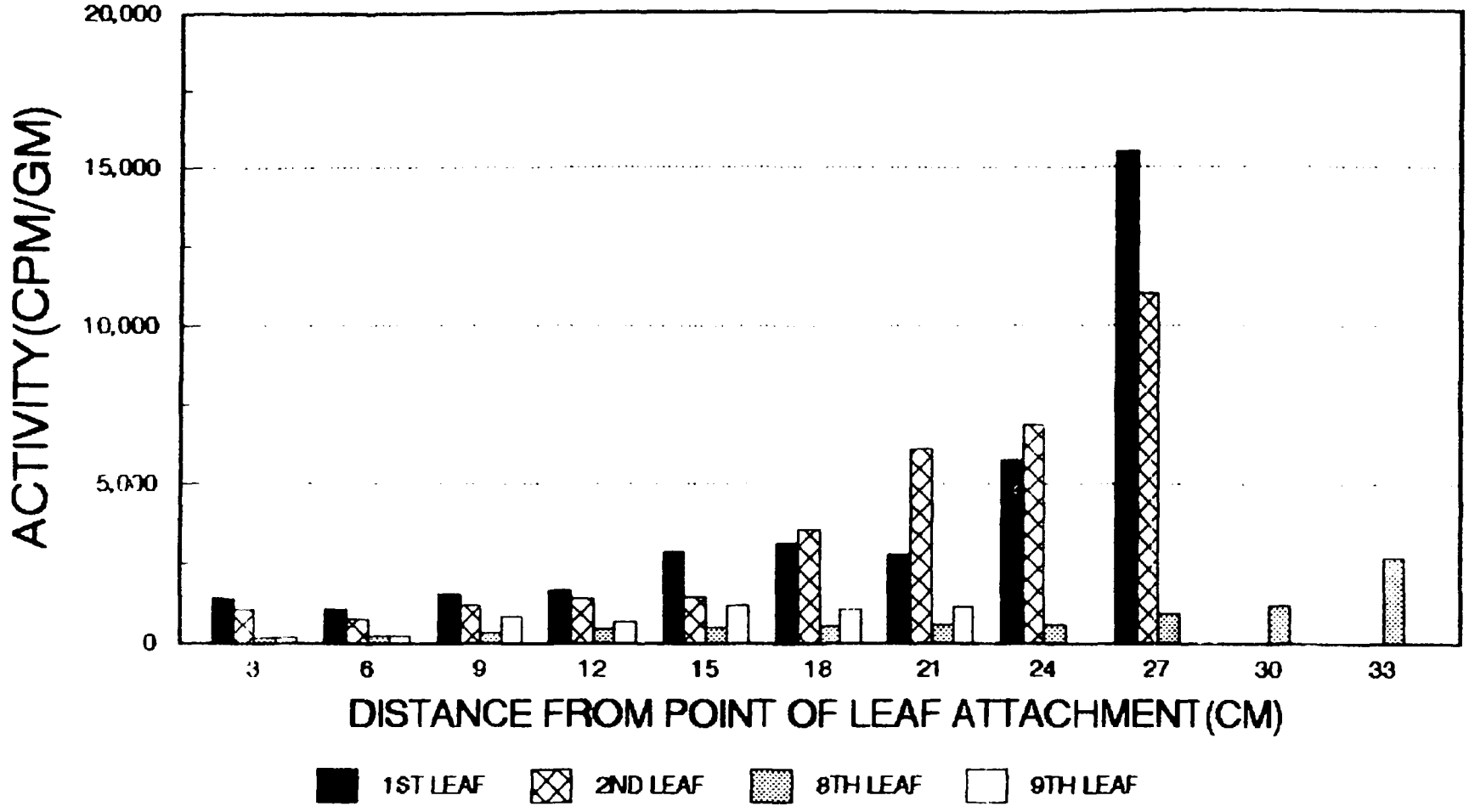

Fig 3. Distribution of ^{14}C lindane in maize leaves (25 days).

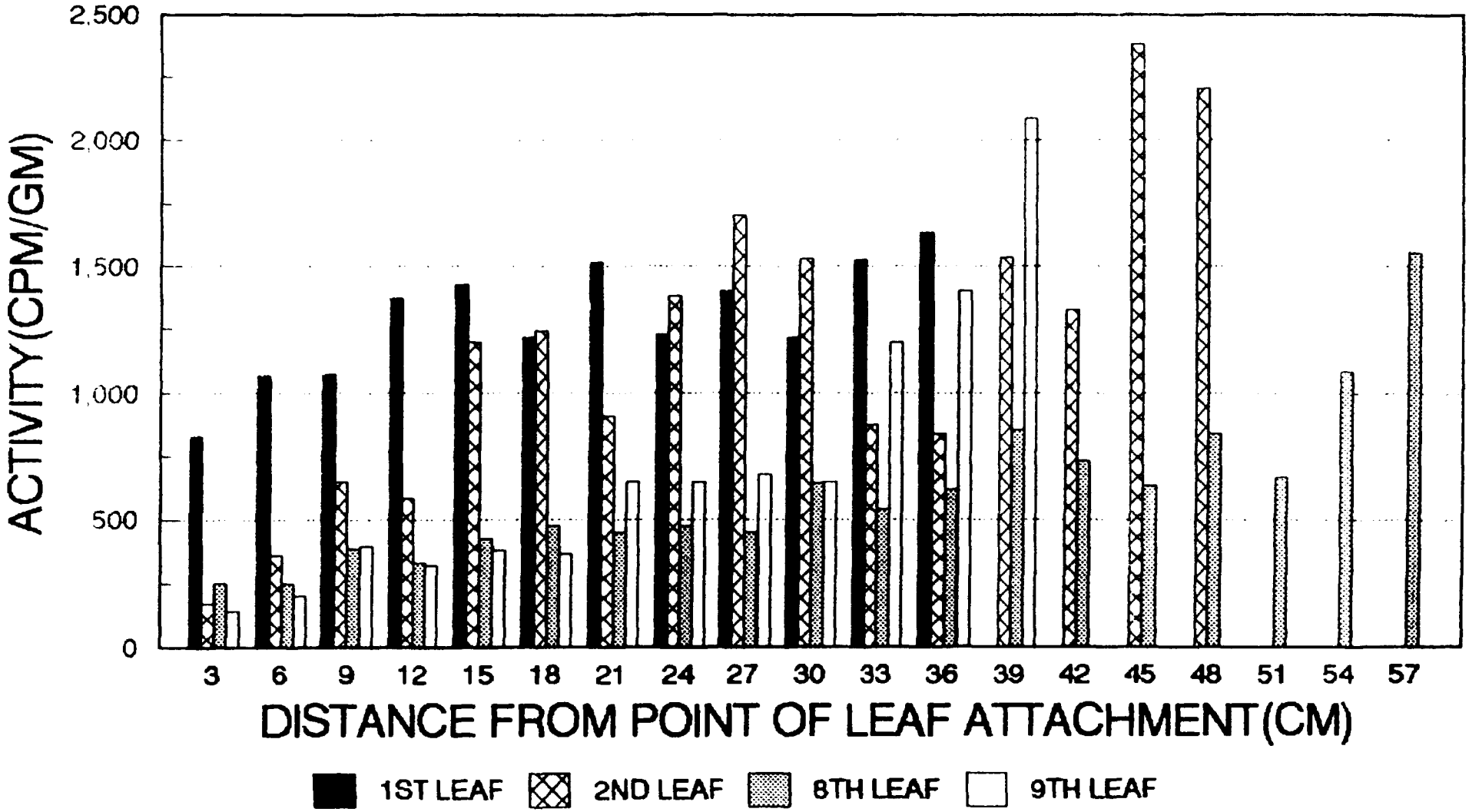

Fig 4. Distribution of ^{14}C lindane in maize leaves (50 days).

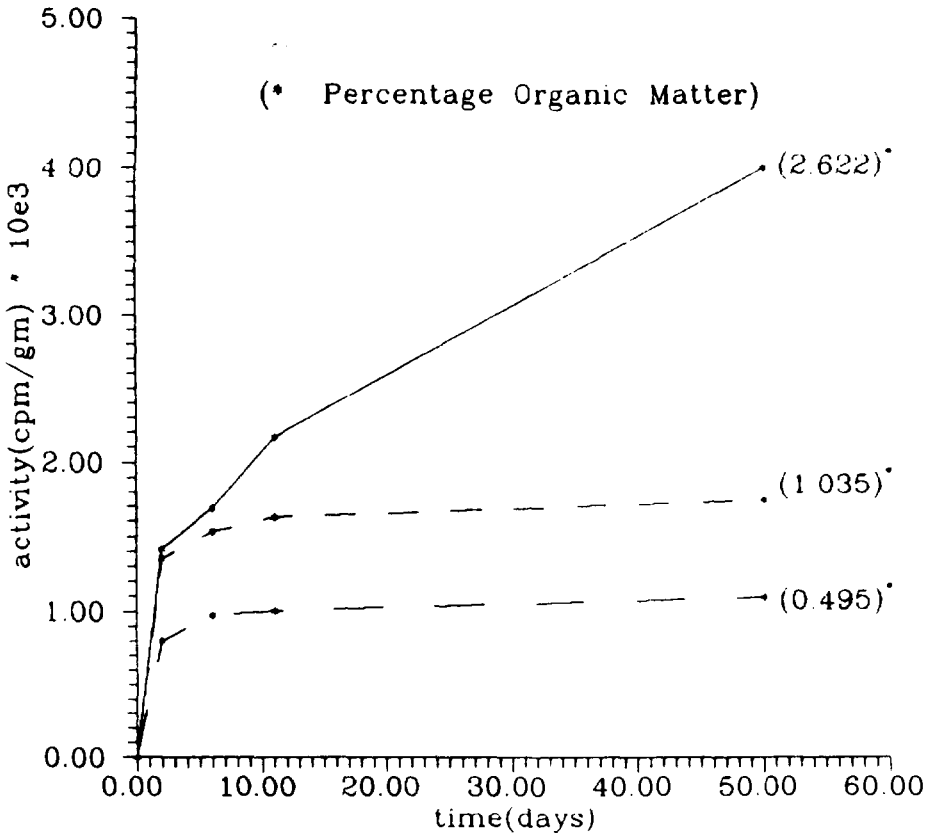

Fig 5. Bound residues of ^{14}C lindane in soils of different organic matter content.

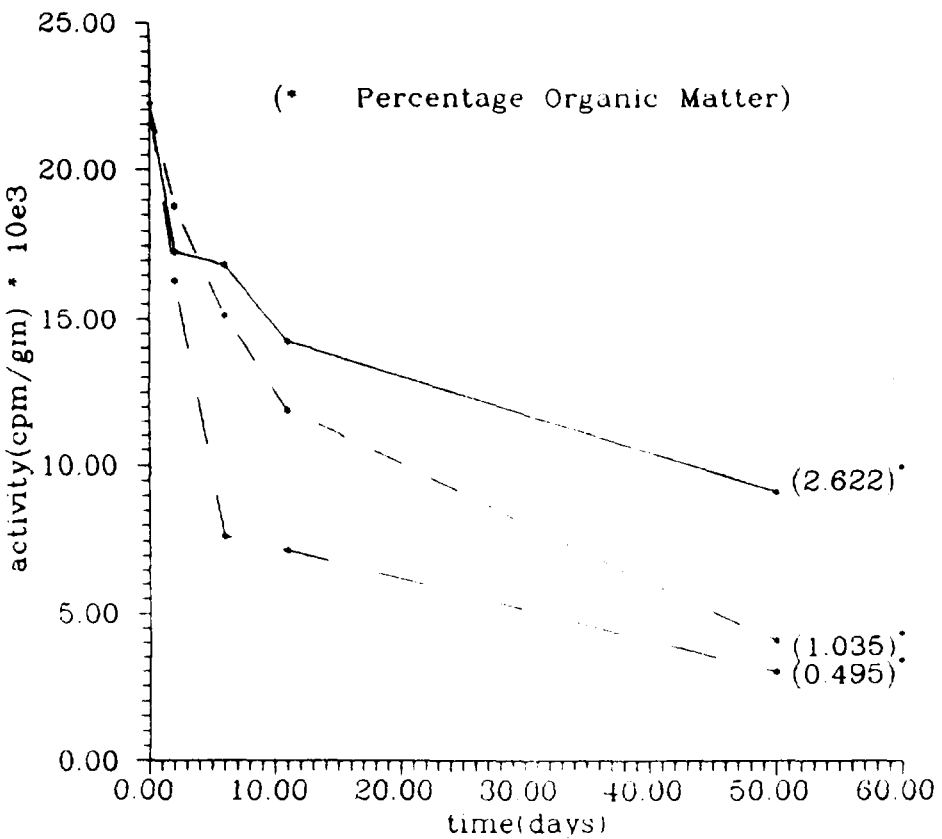

Fig 6. Dissipation of ^{14}C lindane in soils of different organic matter content.

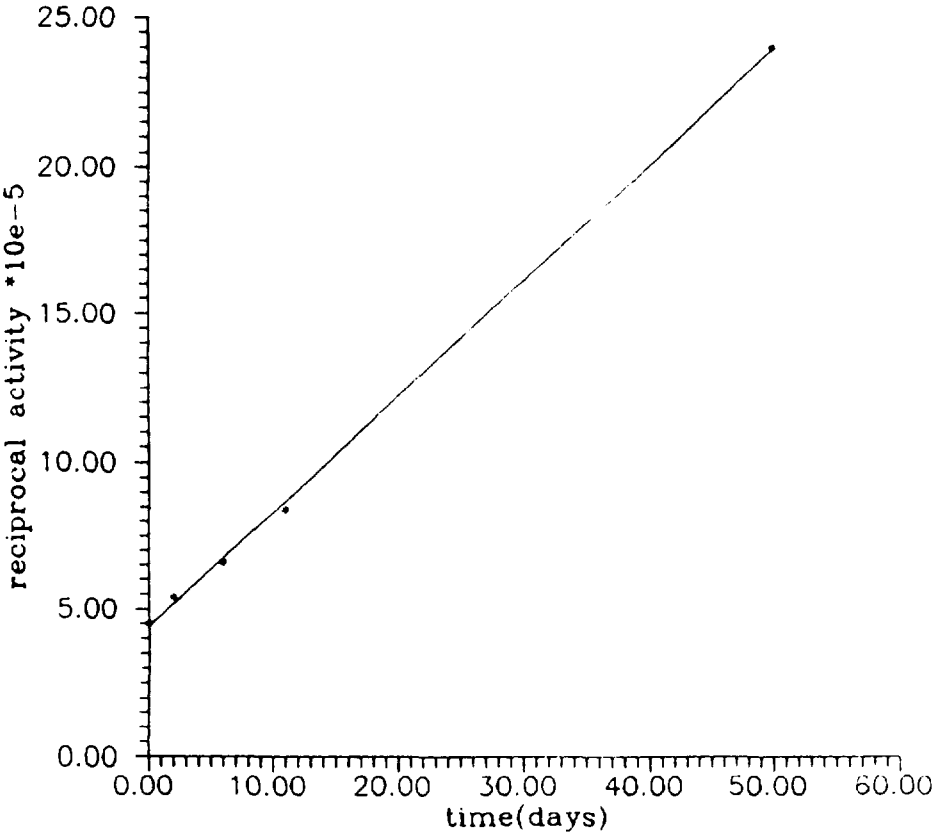

Fig. 7. Reciprocal value of activity against time.

3.2. Movement in soils

Lindane dissipated faster in soils of lower organic matter contents (Fig.5). In the three soils tested, there was a rapid rate of dissipation of ^{14}C-lindane within the first 10 days of application followed by a gradual decline in this rate. This rate of dissipation was attributed to the low organic matter content of the soils in this study. Although there were copious amounts of rainfall during the period after pesticide application (104 mm in 2 months), residues of ^{14}C-lindane were found only within the first 0-30 mm layer of the soil surface in agreement with Cliath and Spencer [7] who observed no mobility of lindane in clay soils.

ACKNOWLEDGEMENTS

This work was supported by SIDA through the International AtomicEnergy Agency under Research Contract No. 6754. The authors acknowledge the contributions of Messrs B.Q. Modzinuh and S. Afful of the Chemistry Department of the NNRI for their assistance during sample collection.

REFERENCES

[1] YEBOAH, P.O., MONTFORD, K.G., KLAKE, R.K., AKPABLI, C.K., this TECDOC.

[2] ITOKAWA, H., SCHALA, A., WEISBERGER, I., KLEIN, W., KORTE, W., Tetrahedron **26** (1970) 763-773.

[3] BALBA, M.H., SABA, J., Environ Lett. **7** (1974) 181-194.

[4] BRADBURY, F., Ann. Appl. Biol. **52** (1963) 361-370.

[5] PAASIVIRTA, J., PALM, H., PAUKKA, R., AKHABUHAYA, J., LODENIUS M., Chemosphere **17** (1988) 2055-2062.

[6] FUHREMANN, T., LICHTENSTEIN, E., J. Agric. Food Chem. **28** (1980) 446-452.

[7] CLIATH, M., SPENCER, W., Environ Sci. Technol. **6** (1972) 910-914.