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Translocation, Accumulation and Persistence of Carbofuran in Paddy, Ground Nut, and Cotton

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In recent years, the phytotoxic effects of pesticides have been reported by several investigators. COX & LILLY (1952) reported that germination and early growth of several field crops were affected by aldrin and dieldrin. Laboratory and greenhouse studies by CHANG & FOY (1971) revealed that picloram inhibited germination of soybean and safflower whereas radish and barley were not affected. GAWAAD et al. (1972) observed that lindane was highly toxic to clover seedlings and suppressed their growth. COPPING & DAVIS (1972) found that both atrazine and ametryne increased the percentage germination of lettuce and tabacco seeds. KRISHNAIAH et al. (1976) recorded that carbofuran seed treatment has not affected the okra plant's growth even when the seeds were stored for two months.

PLESS et al. (1971) have reported the stimulatory effect of carbofuran under field condition. However, it was not established by them that the stimulatory effect on plants is caused due to the pesticides. From long-term laboratory studies of LEE (1975) it was clear that two of its metabolites, carbofuran phenol and 3-OH carbofuran phenol were found to stimulate plants growth in the presence of low concentrations of indole acetic acid (IAA). Reports have also been made on their translocation, their mechanisms and factors influencing absorption of these chemicals. SIDDARAMAPPA (1978) has studied the distribution of ^{14}C-carbofuran in rice plant and found out that leaf blade showed maximum level than root and stem. TALEKAR et al. (1977) observed the accumulation of carbofuran residues in the leaf margins of bean plants. So, experiments were conducted to study the mechanism of carbofuran action on germination, growth, translocation, distribution and accumulation in tropical plants.

MATERIALS AND METHODS

Analytical grades of carbofuran, its metabolites, and ^{14}C-ring labelled (26.73 mCi/mmol) carbofuran were gifts from Dr. Robert A. Robinson, FMC Corporation, U.S.A. A 75% wettable powder was a gift from Rallis India, Bangalore, India.

Seeds of paddy (Oryza sativa) variety TKM9 for dry conditions and seeds of cotton (Gossypium hirsutum) variety MCU5 were obtained from paddy research center, Ambasamuthram and regional cotton research station, Kovilpatti, Tamilnadu, India. TMV-7-variety of

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groundnut (Arachis hypogea) seeds were collected from Madurai Agriculture College and Research Institute, Madurai, Tamilnadu, India.

Studies on seed germination: Seeds of paddy, cotton and groundnut were surface sterilized and treated with 75% wettable powder of carbofuran at varying concentrations of 100 and 200 ug of formulation/g dry weight of the seed. The seeds were soaked for 24 h in carbofuran (initially carbofuran was dissolved in 2 ml acetone and made up to particular concentration with distilled water) and then washed with sterilized water. The seeds were distributed on moist filter paper kept in sterilized petri dishes (20 cm diameter) and incubated at 25°C for 72 h in triplicates. Sterilized water was added periodically to prevent the seeds from drying. After 72 h of incubation, the percentage of seed germination was calculated. Length of the root, the number of lateral roots and the number of leaves formed were measured as parameters for reckoning phytotoxicity. 72-h old seedlings were analyzed for its carbofuran residue level. The residue extraction methods were followed as delineated by CASSIL et al. (1969). Quantitative estimations were done by the procedures described by GUPTA & DEWAN (1971, 1976).

Studies on translocation and distribution: Seeds of paddy, groundnut and cotton were grown in sterilized pots. Irrigation was done on alternate days to keep the moisture level near field capacity. The plants were grown without any insecticide spray and care was taken to maintain them without infection and nutritional deficiency. The 10-day old seedlings of 15 to 20 cm height were taken without causing any damage to the root system, washed and rinsed with distilled water and kept in culture solution containing ^{14}C-carbofuran and incubated at 25°C. After 6, 12, and 24 h of incubation, the plants were washed thoroughly with cold carbofuran solution to remove the labelled compound adsorbed outside of the plant parts. The plants were blot dried at room temperature for 72 h, pressed and exposed to x-ray film for 20 days in darkness. The intensity of the image on the film was correlated to the amount of labelled carbofuran.

Recovery: The efficiency of the extraction method was determined by fortifying the untreated plants with carbofuran and the recovery ranged from 82-88%.

RESULTS

Studies on seed germination: Seed treatment of carbofuran did not alter the efficiency of seed germination in cotton and goundnut (Table 1), but 8 to 23% inhibition was observed in paddy at 100 and 200 µg/g dry weight of the seed.

Table 1. Effect of carbofuran on the germination of seeds of paddy, groundnut and cotton[1]

Treatment	Percentage of seeds germinated[2]		
	Paddy	Groundnut	Cotton
Control	100	100	100
100 µg	92	100	100
200 µg	77	98	100

[1] Seeds treated with carbofuran (75% WP) at the concentrations of 100 and 200 µg/g of dry seeds and 24 h soaking.

[2] Germination percentage calculated after 72 h of germination at 25°C and 2000 lux illumination.

Studies on growth and development: The results presented in Table 2 show a two-fold increase at 100 µg/g level in all the three types of plants when compared to control. However, at higher concentration of 200 µg/g the increase in length was not as high as that obtained at 100 µg/g level. Similar effect was observed with lateral root formation also. The effect of carbofuran on the leaf development showed no effect at 200 µg/g level in paddy, while there was a stimulation at low concentration. From the growth and development studies, it is clear that carbofuran stimulated the root and leaf growth and promoted lateral root formation at 100 µg/g level.

Table 2: Effect of carbofuran on growth and development of crop plants like paddy, groundnut and cotton

Plant	Treatment[1]	Root Length[2] cm	No. of Lateral Roots	No. of Leaves
Paddy	Control	2.5	83	3
	100 g	4.3	101	3
	200 g	3.1	98	2
Groundnut	Control	1.1	-	1
	100 g	3.8	7	4
	200 g	3.05	5	-
Cotton	Control	5.3	8	3
	100 g	10.2	22	5
	200 g	7.6	17	3

[1]Seeds were soaked in carbofuran (75% WP) at the concentration of 100 and 200 µg/g seeds for 24 h.

[2]Measurements were taken from 72 h seedlings grown at 25°C and 2000 lux illumination.

Studies on residue analysis of seeds and seedlings: Results of the residue analysis of 24 h soaked seeds and 72 h germinated seedlings treated at 100 and 200 µg/g levels are given in Table 3. From the results it was observed that 17.5, 23.3 and 28.1 µg of carbofuran had been taken up by paddy, groundnut and cotton seeds, respectively, when soaked in 100 µg concentration for 24 h. But the treatment of 200 µg/g seeds under similar conditions of incubation, the residue level was found to be 24.1, 28.2 and 30.4 µg, respectively, which shows that there was no proportionate increase with corresponding increase in the concentration of treatment. But the residue levels in 72 h germinated seedlings showed decrease in the carbofuran level after germination.

Table 3. Analysis of carbofuran residue in 24 h soaked seeds[1] and 72 h seedlings[2] of paddy, groundnut and cotton

Plant	µg of carbofuran residue[3]			
	24 h soaked seeds		72 h seedlings	
	100 µg	200 µg	100 µg	200 µg
Paddy	17.5	24	0.1	2.3
Groundnut	23.3	28.2	4.7	2.5
Cotton	28.1	30.4	2.6	3.8

[1]Seeds treated with carbofuran (75% WP) at the concentrations of 100 and 200 µg/g seeds.

[2]24 h soaked seeds were grown at 25°C for 72 h at 2000 lux illumination.

[3]Residues were calculated using colorimetric method.

Studies on translocation and accumulation of carbofuran: Results of autoradiographic studies are presented in Figures 1 to 3. These figures have shown that the kinetics of uptake, accumulation and translocation varies with the type of plant species studied. From figure 1, it is clear that the labelled compound had got into the root system within 6 h in paddy and was translocated to the leaves after 12 h. But after 24 h of incubation, most of the material had been translocated to the leaves. It is also significant to observe that there is no accumulation of labelled compound in the root system of paddy. The autoradiograph of groundnut plants presented in figure 2 had shown that ^{14}C-carbofuran had taken more than 24 h to reach the stem tip, although it

could make the entry within 6 h. Even though the compound could reach the stem tip, the distribution and accumulation was found to be more in roots and lower branches which is in contrast to the pattern seen in paddy. Autoradiographic analysis of cotton plants depicted in figure 3 showed a similar behaviour as that of groundnut in uptake and translocation, but differential accumulation was found; in which more accumulation was observed in the terminal leaves than the lower leaves. Thus, the autoradiographic studies clearly indicate that the pattern of uptake, movement and accumulation of carbofuran in tropical plants vary from plant to plant.

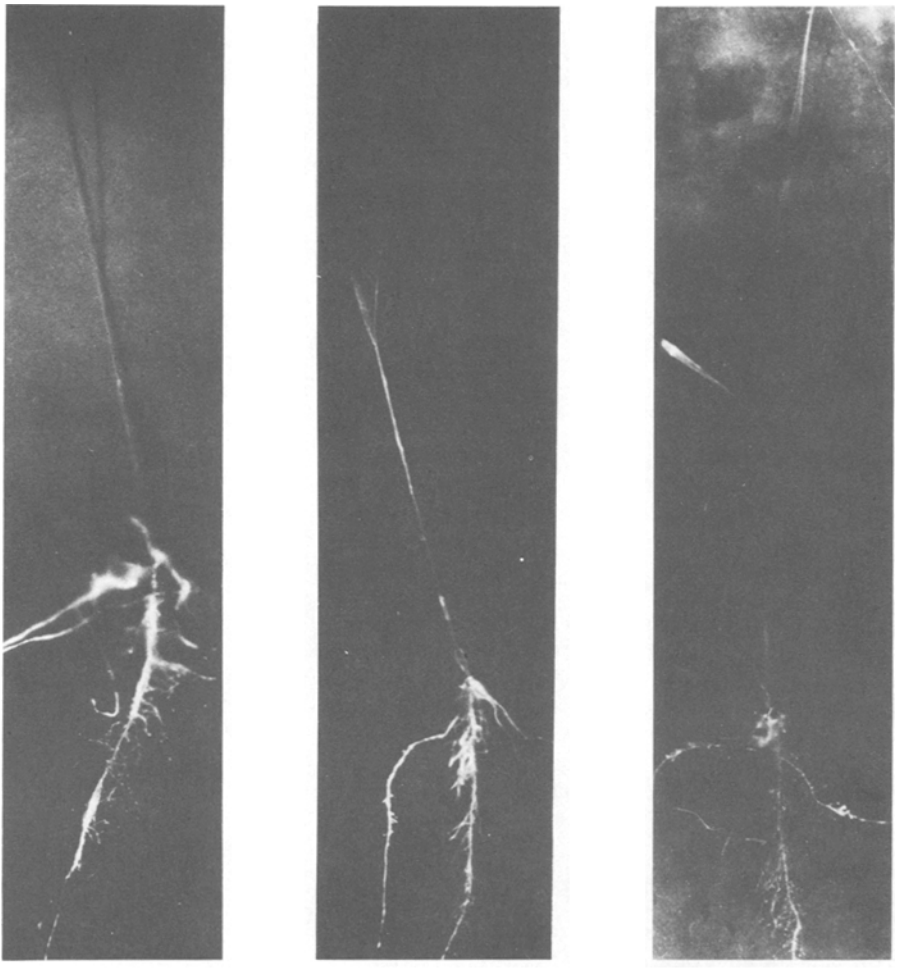

Figure 1. Radioautogram showing the movement and accumulation of carbofuran residues in paddy plant at different hours of treatment in water.

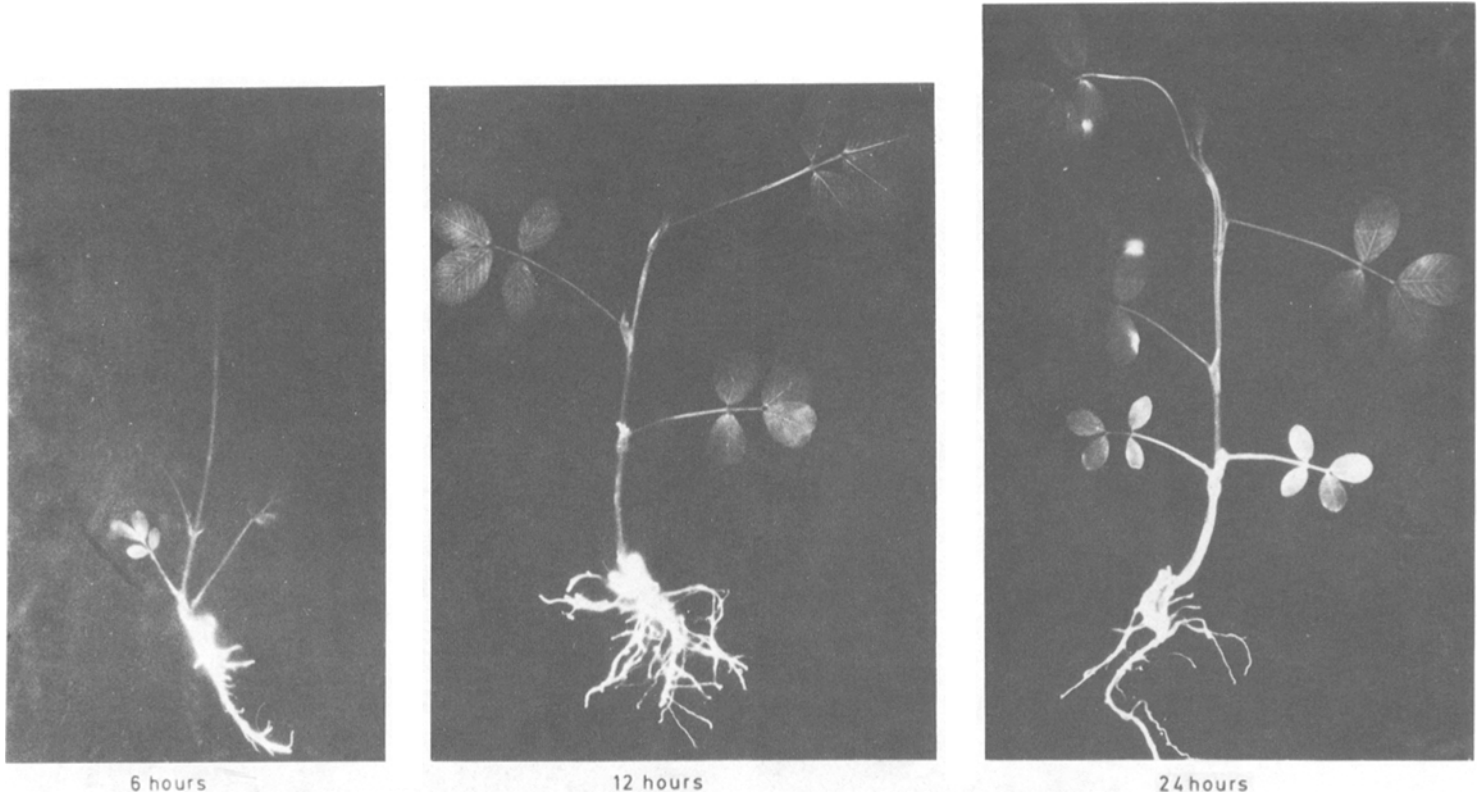

Figure 2. Radioautogram showing the movement and accumulation of carbofuran residues in ground nut plant at different hours of treatment in water.

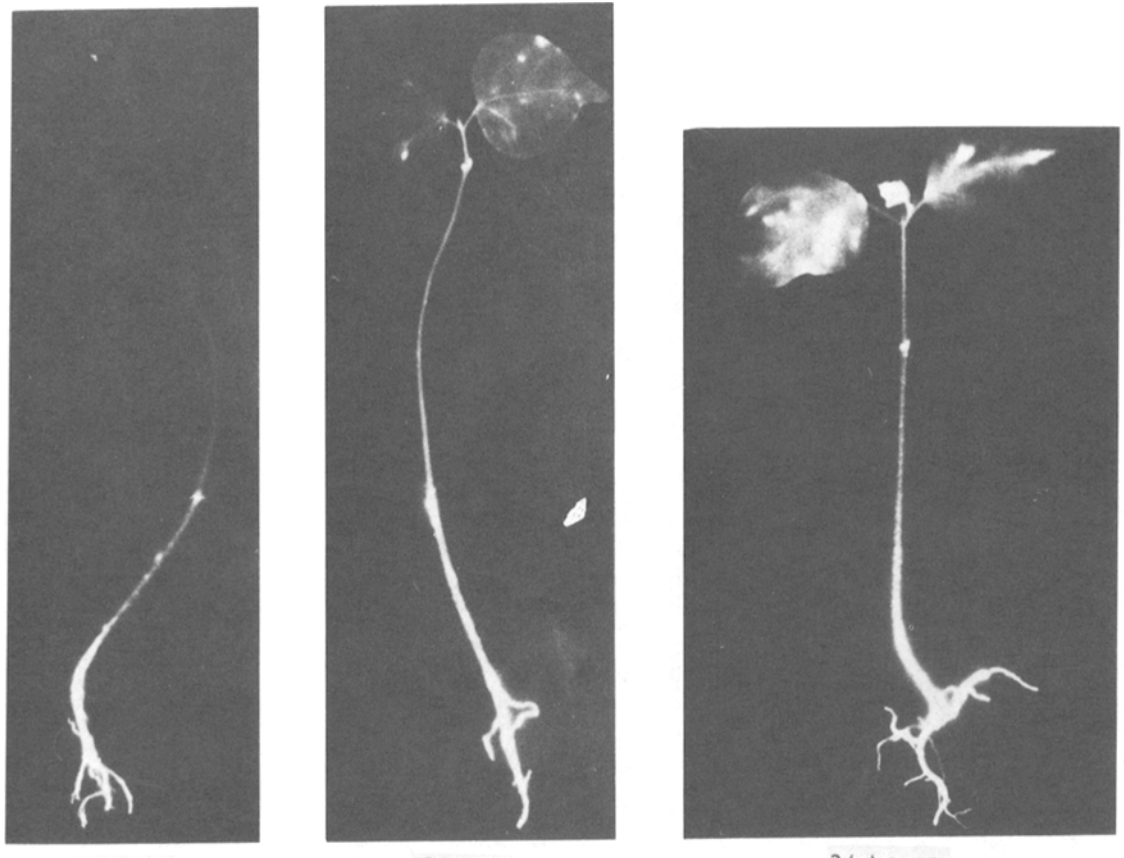

Figure 3. Radioautogram showing the movement and accumulation of carbofuran residues in cotton plant at different hours of treatment in water.

DISCUSSION

The observations made from the above studies show that at 100 µg/g level of treatment carbofuran did not alter the efficiency of germination in all the three plants. But the 23% reduction at 200 µg/g level of treatment observed in paddy may be due to rapid diffusion of carbofuran at higher level. However, the suppression of germination in crop plants by insecticides and herbicides have been demonstrated by early workers and they could not fully resolve the exact mechanism and mode of toxidity on germination(BETTAIYA-RAJANNA & CRUZ 1975).

The growth and development studies showed a more stimulatory effect on roots than on leaves of carbofuran on IAA oxidase system (LEE 1975). LEE & CHAPMAN (1977) have also reported the interaction of carbofuran and its metabolites with IAA in terms of regulation of IAA oxidase activity and plant growth. However, such a growth stimulation may not be observed always with plants under natural conditions or in long term laboratory assays. This is because of variations in the stage of growth, the level of uptake and degradation of the specific metabolites which are the effective IAA oxidase inhibitors. PLESS et al. (1971) have observed the stimulating effect of carbofuran on plant growth under field conditions, but they did not explain the mechanism of action.

The differential uptake and persistence of carbofuran in the seeds depend on the type of seed, the type and the concentration of carbofuran treatment. The more accumulation of the compound in cotton and groundnut may be due to its oily nature, whereas paddy seeds are starchy. Such a differential uptake of pesticides depending on the nature of seeds have been reported by SMITH (1971). The decrease of carbofuran residue level in seedlings followed the pattern of uptake. The reduction of carbofuran content in seedlings may be due to the rapid dissipation of the compound or due to the dilution factors owing to the growth of the plant. These results are in conformity with the findings of RAJUKKANNU (1978) in Okra plants.

The results of translocation have shown that maximum level of distribution was observed in leaf blade and terminal bud. This may be due to the rapid movement of the compound to the growing parts above ground level through the transpiration stream. The accumulation of ^{14}C-carbofuran into the intercellular spaces of root parenchyma cells (SALISBURY & ROSS 1969). The gradual decrease of the absorbed carbofuran may be due to the vapour loss of carbofuran as CO_2 in to the atmosphere from plant parts. The evidence for vapour loss of systemically applied ^{14}C-carbofuran has been reported by SIDDARAMAPPA (1978) in rice plants.

REFERENCES

BETTAYA RAJANNA and A. DE LA CRUZ: Bull. Environ. Contam. Toxicol. 14, 77 (1975).

CASSIL, C.C., R.P. STANOVICK and R.F. COOK: Residue Rev. 26, 74 (1969).

CHANG, I.K. and C.L. FOY: Weed Sci. 19, 58 (1971).

COPPING, L.G. and D.E. DAVIS: Weed Sci. 20, 86 (1972).

COX, H.C. and J.H. LILLY: J. Econ. Entomol. 45, 421 (1952).

GAWAAD, A.A., A.S. SOLIMAN, F.E. RAHEB and N.M. ALI: Phytopath. Z. 73, 189 (1972).

GUPTA, R.C. and R.S. DEWAN: In: Progress and problems in pesticide residue analysis, A joint publication of PAV and ICAR, Ludhiana, 208-214 (1971).

GUPTA, R.C. and R.S. DEWAN: Pesticides 10, 29 (1976).

KRISHNAIAH, K., P.L. TANDON, A.C. MATHUR and N. JAGANMOHAN: Indian J. Agric. Sci. 46, 178 (1976).

LEE, T.T.: Life Sciences 18, 205 (1975).

LEE, T.T. and R.A. CHAPMAN: Phytochemistry 16, 35 (1977).

PLESS, C.D., E.T. CHERRY and J.R. MORGAN: J. Econ. Entomol. 64, 172 (1971).

RAJUKKANNU, K.: Ph.D. Thesis submitted to Tamilnadu Agricultural University, Coimbatore, India (1978).

SALISBURY, F.B. and C. ROSS: In: Plant Physiology, Prentice Hall Ltd., N.Y., 167-184 (1969).

SIDDARAMAPPA, R.: A report submitted to IRRI, Philippines (1978).

SMITH, D.T.: Agron. J. 68, 945 (1971).

TALEKAR, N.S., E.M. LEE and L.T. SON: J. Econ. Entomol. 70, 685 (1977).