Dispersion and persistence of aldicarb in soil water of nematode - infested citrus soils

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SUMMARY

Total concentrations of aldicarb and its toxic derivatives, aldicarb sulfoxide and aldicarb sulfone were determined in soil leachates from glasshouse pots and in surface and soil water from an irrigated citrus orchard. The aldicarb residues in the soil leachates from pots dropped rapidly during the first ten days after application and then slowly for the next 65 days. In the field, aldicarb was more uniformly distributed and gave better nematode control in the soil after a broadcast application, rototill incorporation and sprinkler irrigation than after furrow injection and furrow irrigation. Some aldicarb was redistributed in the furrow and removed from the field in furrow irrigation water.

RÉSUMÉ

Dispersion et persistance de l'aldicarb dans l'eau du sol des plantations d'agrumes infestées par les nématodes

Les concentrations d'aldicarb et de ses dérivés (sulfoxyde et sulfone) ont été déterminées dans des percolats de sol obtenus en pots et dans les eaux d'irrigation dans un verger de citrus. Dans ce dernier cas, les eaux étaient recueillies soit à la surface du sol soit dans les couches supérieures de celui-ci (0-90 cm) dans des parcelles irriguées par canaux ou par aspersion.

En pots, les concentrations en résidus d'aldicarb dans les percolats de sol peuvent atteindre 4 ppm. Elles tombent rapidement pendant les dix premiers jours et plus lentement pendant les 65 jours suivants. Après 25 jours, un travail superficiel du sol dans les pots en vue d'assurer une meilleure aération a provoqué une augmentation de cette concentration.

Au champ, les prélèvements opérés dans les eaux de surface pendant les 24 heures qui suivent l'irrigation montrent que l'aldicarb est rapidement solubilisé, ces eaux en contenant jusqu'à 1-2 ppm dans les deux types d'irrigation.

Si l'irrigation est appliquée par canaux, la concentration en aldicarb et en ses dérivés est très faible dans les 30 premiers centimètres du sol et augmente avec la profondeur dans les 60 cm suivants. Si elle est appliquée par aspersion, la concentration est uniforme à tous les niveaux. Bien que le produit soit solubilisé de la même manière, il semble que dans le cas de l'irrigation par canaux une partie importante en soit entraînée hors du champ par les eaux de ruissellement alors que dans le cas de l'irrigation par aspersion la presque totalité du produit pénètre dans le sol avec les eaux d'infiltration.

Parallèlement, la réduction du nombre des nématodes, très forte à tous les niveaux dans les parcelles irriguées par aspersion, est presque nulle dans la couche superficielle et augmente avec la profondeur dans celles irriguées par canaux.

The diversity of the biological data concerning the effect of aldicarb on the control of soil-inhabiting plant-parasitic nematodes might be clarified by a better understanding of its dispersion and persistence in soil-water. A good distribution of the toxic material in the soil will help insure maximum benefits of nematode control and crop yield while using the least possible amounts of pesticide. Aldicarb is water soluble (6.000 µg/g) and its distribution in soil depends on the method of application and on subsequent redistribution by movement in surface and by leaching in irrigation water. The speed of these processes is influenced by the properties of the chemical, soil type, and the amount and method of applying irrigation water.

The fate and persistence of aldicarb in insects, mammals, plants and soils has been extensively studied by many workers : Metcalf *et al.* (1966), Bull, Lindquist and Coppedge (1967), Knaak, Tallant and Sullivan (1966), Coppedge *et al.* (1967), Bull (1968), Hendrickson and Meagher (1968), Bartley *et al.* (1970), Bull *et al.* (1970), Andrawes, Bagley and Herrett (1971*a*, 1971*b*), Bromilow (1973) and Jamet, Piedallu and Hascoet (1974). The pattern of breakdown was found similar in all cases. Aldicarb was rapidly oxidized to aldicarb sulfoxide which was slowly oxidized to aldicarb sulfone and oximes. Aldicarb sulfoxide is approximately five-fold more soluble than aldicarb. The oximes are transformed by further reactions into other nontoxic components. Most of the published data concerning the persistence of aldicarb in soil indicate that the toxic material present in the soil was determined by the chemical analysis of the whole soil samples and/or by bioassay techniques. Few chemical studies have been published on its movement and persistence in soil water by Den Ouden (1977), Minze, Smek and Lexmond (1976), Hough, Thomason and Farmer (1975) and Brodie (1971).

The present work studied the occurrence of aldicarb in surface and leaching soil water under furrow and sprinkle irrigation and its persistence in the leaching soil water, particularly in connection with the danger of ground water pollution.

Materials and methods

Glasshouse test

Plastic pots 12 cm in diameter and 17 cm high, with a drainage tube in the bottom, were prepared for collecting leachate (Fig. 1). The inside portion of the drainage tube was covered with a 300 mesh wire screen. The outside portion was inserted into a clean 250 ml bottle for collecting the leachates. Pots were filled with sufficient amounts of small rocks to cover the inside portion of the drainage tube, then potted with a loamy sand heavily infested with the citrus nematode, *Tylenchulus semipenetrans* Cobb. They were planted with 60-day-old seedlings of sweet orange, *Citrus sinensis* (L.) Osbeck Madam Vinus cultivar, previously grown in steam sterilized soil (50% sand + 50% peat). One week after transplanting, Aldicarb (Temik ® 15G) was applied at the rates of 33.6 kg/ha (a.i.), 16.7 kg/ha (a.i.) and 8.4 kg/ha (a.i.) for each of the high, medium and low treatments, respectively. The pots were irrigated every five days with tap water. Soil leachates were collected and analyzed for aldicarb at day five and then at the first ten-day interval during the following 60 days.

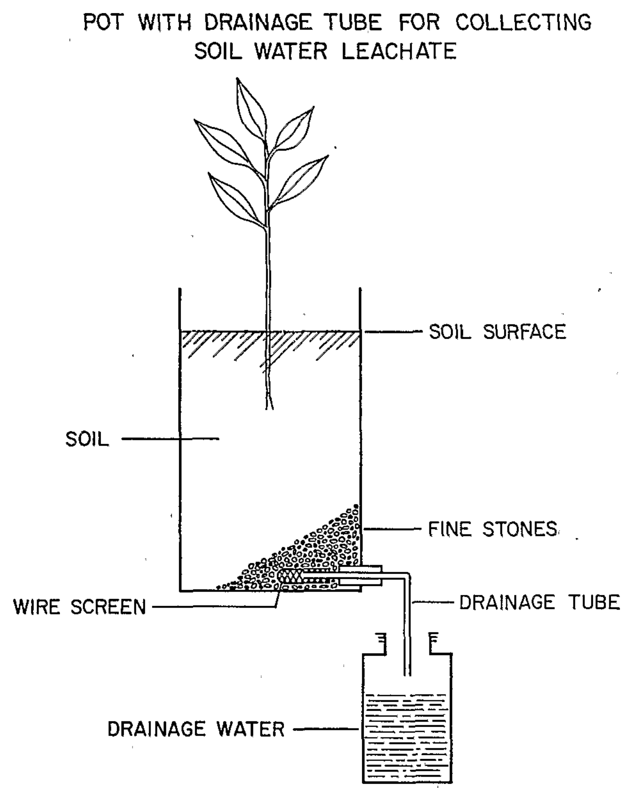

Fig. 1. Diagram of greenhouse pot system used for collecting aldicarb in soil leachates.

FIELD TEST

A field of 25-year-old Valencia orange trees on Troyer rootstock on the Citrus Experiment Station, Riverside, California, was used for this test. The trees were planted on a 6.09×7.31 m spacing. Aldicarb (Temik ® 15G) was applied on two sides of the trees at rates of 18.5 kg/ha (a.i.) and 9.2 kg/ha (a.i.) in the treated area. For each treatment, one-half of the trees were irrigated with sprinklers or furrows continuously for 48 hours. Approximately 17 cm of water was applied in each irrigation. In plots irrigated in furrows, aldicarb was loosely chiseled 7.5 cm deep into the soil in the furrow bottom with a tractor-drawn Clampco ® granule applicator. The furrows were spaced 1.5 m apart and the quantity of aldicarb necessary to treat the entire area was concentrated in the furrows. In plots irrigated by sprinklers, the chemical was broadcasted and rototilled into the soil surface (7.5 cm).

IRRIGATION WATER

Samples of irrigation water on the soil surface or in the furrows were collected 2, 10 and 24 hours after the start of irrigation. Samples were taken from three sites along the furrows : head, medium and tail. Leachate water was collected at 30.5 and 61 cm below the soil surface with special instruments (Fig. 2). Plastic tubes with ceramic cups sealed at one end were inserted into the soil at 30.5 and 61 cm depths. The upper ends of the plastic tubes were connected to a vacuum gauge and an Erlenmeyer flask. Two replicate sets of these water collection instruments were inserted into the soil each in the furrow and the sprinkle irrigated plots. Four hours after completion of the irrigation, a suction of about 60 cb was induced into the plastic tube through the Erlenmeyer flask by using a hand pump or by vacuum reservoirs. The water collected in the Erlenmeyer flask during a 24-hour recovery period was analyzed immediately for aldicarb and its breakdown products.

Three months after application of aldicarb, the 11.2 kg/ha plots were sampled for citrus nematode larvae in the soil of three replicated plots. Soil samples were taken with a soil tube at 0-30.5, 30.5-61 and 61-91 cm depths in the furrow of each plot. Citrus larvae were extracted from two 50 cm^3 soil samples for each replicate and placed on Baermann funnels for 48 hours.

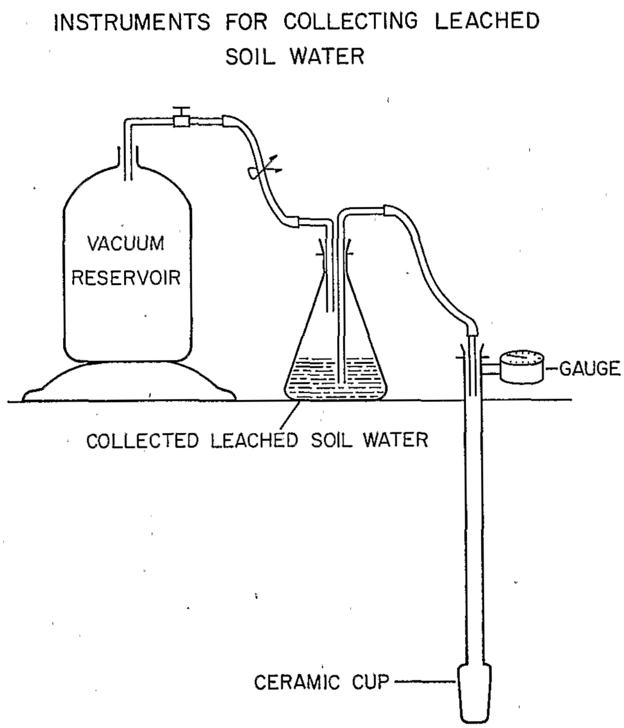

Fig. 2. Diagram of the field system used for collecting aldicarb in the subsurface soil water to a depth of 61 cm.

EXTRACTION AND ANALYSIS OF ALDICARB

The total amount of aldicarb and its toxic derivatives, aldicarb sulfoxide and aldicarb sulfone were determined as aldicarb sulfone by a method supplied by Union Carbide Corporation. Surface and leaching soil water samples collected from pot and field tests were filtered through Whatman ≠ 2V filter paper and 100 ml were placed in a 250 ml Erlenmeyer flask. 2 ml of 40% peracetic acid were added, capped and stirred for 30 min at 22 °C to accomplish the oxidation of aldicarb and aldicarb sulfoxide to aldicarb sulfone. 30 ml of 10% sodium bicarbonate was then added to the oxidized solution and stirred for another 30 min.

The neutralized solution was transferred to a 250 ml separatory funnel, the flask was rinsed with a small volume of tap water and 50 ml chloroform was added. The separatory funnel was well shaken accompanied with the periodic release of CO_2. The layers were allowed to separate and the chloroform layer was drained through anhydrous sodium sulfate into 50 ml boiling flask. The partitioning was separated two more times each time adding 30 ml chloroform to the water extract. The sodium sulfate bed was then washed with 50 ml chloroform which was added to the boiling flask. The chloroform was evaporated under vacuum at 50 °C just until dryness was attained. The residue was dissolved in acetone and transferred to screw capped test tubes and stored in the refrigerator for analysis. A Tracor ® 550 gas chromatograph equipped with a flame-photometric detector specific for sulfur (394 nm filter) was used. A standard curve for aldicarb sulfone determination was obtained by dissolving 505 mg aldicarb sulphone (99% purity) in 100 ml acetone. A series of dilutions were made to obtain different concentrations and 5 µl from each were injected into the gas chromatograph. The resulting peak heights were plotted on a log-log scale, which resulted in a straight line from which aldicarb sulfone unknowns were calculated.

Experimental results

Persistence of aldicarb in greenhouse leachate

Concentrations of aldicarb and its toxic metabolites in the leachate from the pot test were measured as ppm of aldicarb sulfone for a period of 75 days. Data are presented in Figure 3. In general, they reveal that considerable amounts of the applied chemical was dissolved in the irrigation water and was leached from soil. Five days after application, the leachate from the 33.6, 16.7 and 8.4 kg/ha treatments contained 3.82 ppm, 2.95 ppm and 1.39 ppm, respectively. By 20 days, the concentrations of aldicarb had dropped to 0.47 ppm, 0.21 ppm and 0.15 ppm, respectively (Fig. 3) or about 11% of the initial residue levels found during the first irrigation. At the end of 75 days, the leachates contained 0.11 ppm, 0.11 ppm and 0.03 ppm or about 3%, 4% and 0.1% of the initial residues. Thirty days after application, the soil surface was disturbed to increase aeration for root respiration. This resulted in unexpected increases in aldicarb concentrations in the leachate (Fig. 3). No citrus nematode larvae were found in any of the aldicarb treatments.

Distribution of aldicarb in surface and subsurface irrigation water

The concentrations of total aldicarb and its toxic derivative residues in surface and subsurface irrigation water from an aldicarb-treated citrus orchard are presented in Tables 1 and 2 and Figures 4 and 5. In general, aldicarb was readily solubilized and dispersed in irrigation water. The concentration of aldicarb found varied with time of sampling, method of application and amounts of irrigation water. Two hours after starting the irrigation in furrows, the surface water contained 0.66 ppm and 1.91 ppm in the 11.2 and 22.4 kg/ha, respectively (Table 1). Although these concentrations decreased with length of irrigation, aldicarb concentrations did accumulate in the drainage water. In the sprinkler irrigation, the same trend was observed ; however, concentrations of 11.2 kg/ha were approximately double the concentrations in furrows. In the sprinkler irrigation, however, the surface water eventually moved into the soil rather than off the field in drainage water.

Movement of aldicarb by the water current in irrigation furrows was detected by measuring concentration at the head, middle and tail of the furrows during irrigation. Figures 4 and 5 show that aldicarb was picked up in the surface water moving down the furrow and was concentrated in the tail water at the end of the furrow. Concentrations of aldicarb at the end of the furrow were approximately double the same concentrations at the head end 2 hours after starting irrigation.

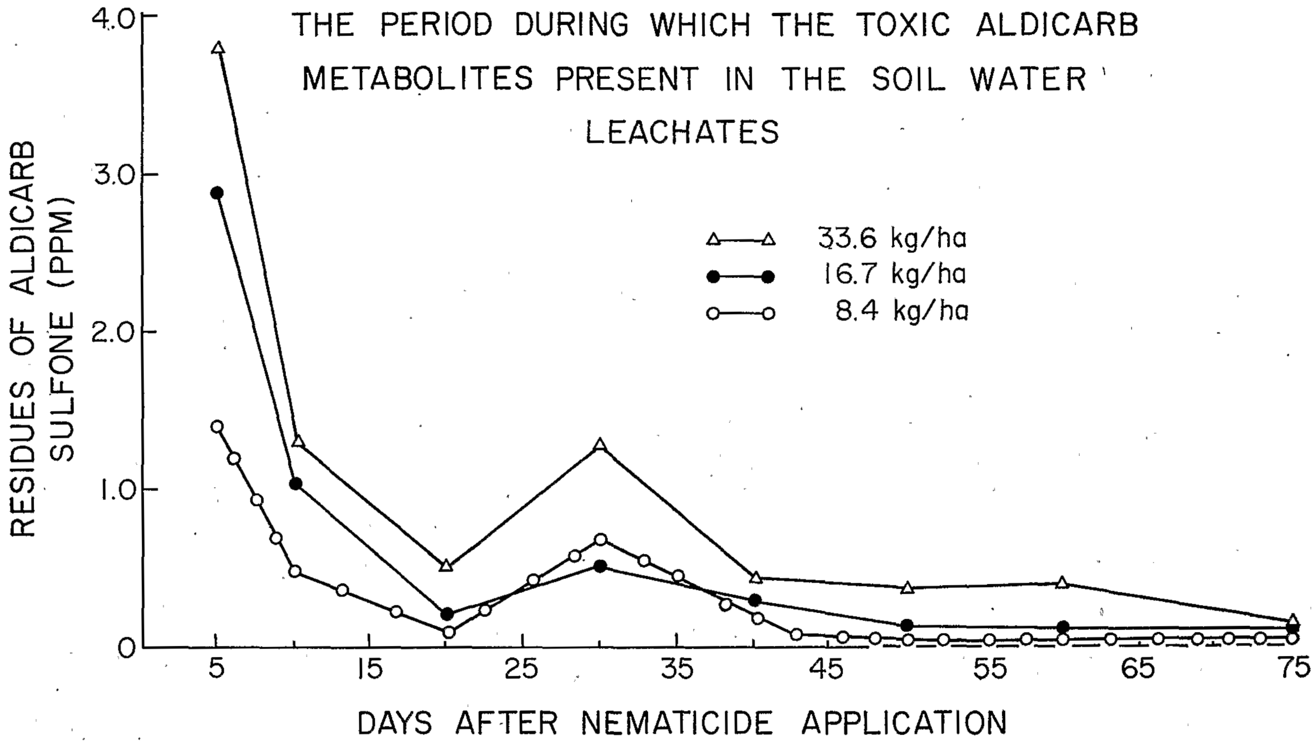

Fig. 3. Aldicarb residues collected from glasshouse pots containing a citrus seedling.

Table 1

Dispersion of aldicarb and its toxic metabolites as aldicarb sulfone in surface soil water from furrow and sprinkle irrigated citrus orchards.

Aldicarb treatment (kg/ha)	*Time of sampling (hours)*	*Aldicarb residues in ppm*	
		Furrow irrigation (*)	*Sprinkle irrigation*
11.2	2	0.66	1.20
	10	0.31	0.87
	24	0.14	0.27
22.4	2	1.91	1.82
	10	1.17	0.83
	24	0.16	0.11

(*) Averages of head, middle and tail of furrow.

Table 2
Dispersion of aldicarb and its metabolites as aldicarb sulfone in subsurface soil water four hours after completion of the irrigation.

Aldicarb treatment (kg/ha)	*Irrigation*	*Soil depth (cm)*	*Aldicarb residue in ppm*				
			Site along furrow			*Total*	*Average*
			Head	*Middle*	*Tail*		
11.2	furrow	30.5	3.00	3.15	5.05	10.20	3.40
		61.0	0.28	0.23	0.57	1.08	0.36
	sprinkler	30.5	15.00	10.50	7.80	33.30	11.10
		61.0	5.40	1.70	9.00	16.10	5.36
22.4	furrow	30.5	3.25	2.92	4.75	10.92	3.64
		61.0	0.41	3.44	0.28	4.13	1.37
	sprinkler	30.5	21.60	22.50	15.00	59.10	19.70
		61.0	5.00	7.95	4.75	17.70	5.90

Dispersion of aldicarb in subsurface water is presented in Table 2. Aldicarb moved downwards into the soil with the irrigation water. Its distribution in the top 61 cm of soil was better and more uniform in the sprinkler irrigation plots. The chemical analysis data are confirmed by biological data (Table 3). The reduction in the number of citrus nematode larvae indicates that toxic concentrations of the chemical in the furrow irrigation plots occurred only at greater depths. There may have been two reasons for this. In furrow irrigation plots, some aldicarb was removed from the field surface in the drainage runoff and the concentration of 17 cm of water in the furrow as compared with the distribution over the total area under sprinklers moved most of the toxicant through the soil with the water front into the 61-91 cm zone.

Discussion

Aldicarb is a very toxic pesticide (LD50 in rat is 0.9 mg/kg) that may be used for insect and nematode control both in the glasshouse and in the field. Aldicarb in soil is rapidly oxidized to aldicarb sulfoxide which is equally toxic to mammals as aldicarb. Since aldicarb is normally applied as a granule and then distributed through the soil mass in the irrigation water, there is great concern about its occurrence in runoff water. In this study, 1-4 ppm of aldicarb and its toxic breakdown products occurred in leachate from glasshouse pots for up to 15 days after application rates of 8.4-33.6 kg/ha (Fig. 3). A disturbance of the soil 25 days after incorporation brought about an increased release of aldicarb residues from the soil. It would appear that glasshouse workers should be particularly careful when working around recent aldicarb-treated and watered plants. Drainage water from containers or greenhouse beds treated with aldicarb should be carefully controlled. Treatment of the nematode-infested soil at planting time controlled infection of the citrus roots for 75 days.

Open drainage water from aldicarb-treated and irrigated fields also contain sizeable quantities (1-2 ppm) of pesticide for several hours during irrigation. Although there were little differences in the concentration of aldicarb in the surface water between the sprinkler and furrow irrigations, there was no loss of water from the field in the sprinkler application. It appeared that some aldicarb was being removed from the field in the irrigation water under furrow application (Fig. 4 and 5). The amount of aldicarb removed in the irrigation water probably could be reduced some by injecting the chemical deeper in the soil and by using equipment to drag soil into and over the shank traces. In addition to problems associated with aldicarb contamination in drainage water, there also appeared to be a loss of nematode control because of chemical loss in the soil-surface soil (Table 2 and 3).

Applications of aldicarb by incorporation and sprinkler irrigation gave safer and better distribution of the pesticide in the upper 60 cm of soil which also resulted in better nematode control than applications in furrows and furrow irrigation. Den Ouden (1977) also found in pot tests that insufficient mixing of the chemical with the soil could not be made good by excess watering.

Table 3

Percent decrease in numbers of *Tylenchulus semipenetrans* larvae in citrus soils after treatment with 11.2 kg/ha a.i. of aldicarb and irrigated by furrows or sprinklers.

	Soil depth in cm		
Irrigation method	0-30.5	30.5-61	61-91
furrow	3	49	90
sprinkler	93	99	97

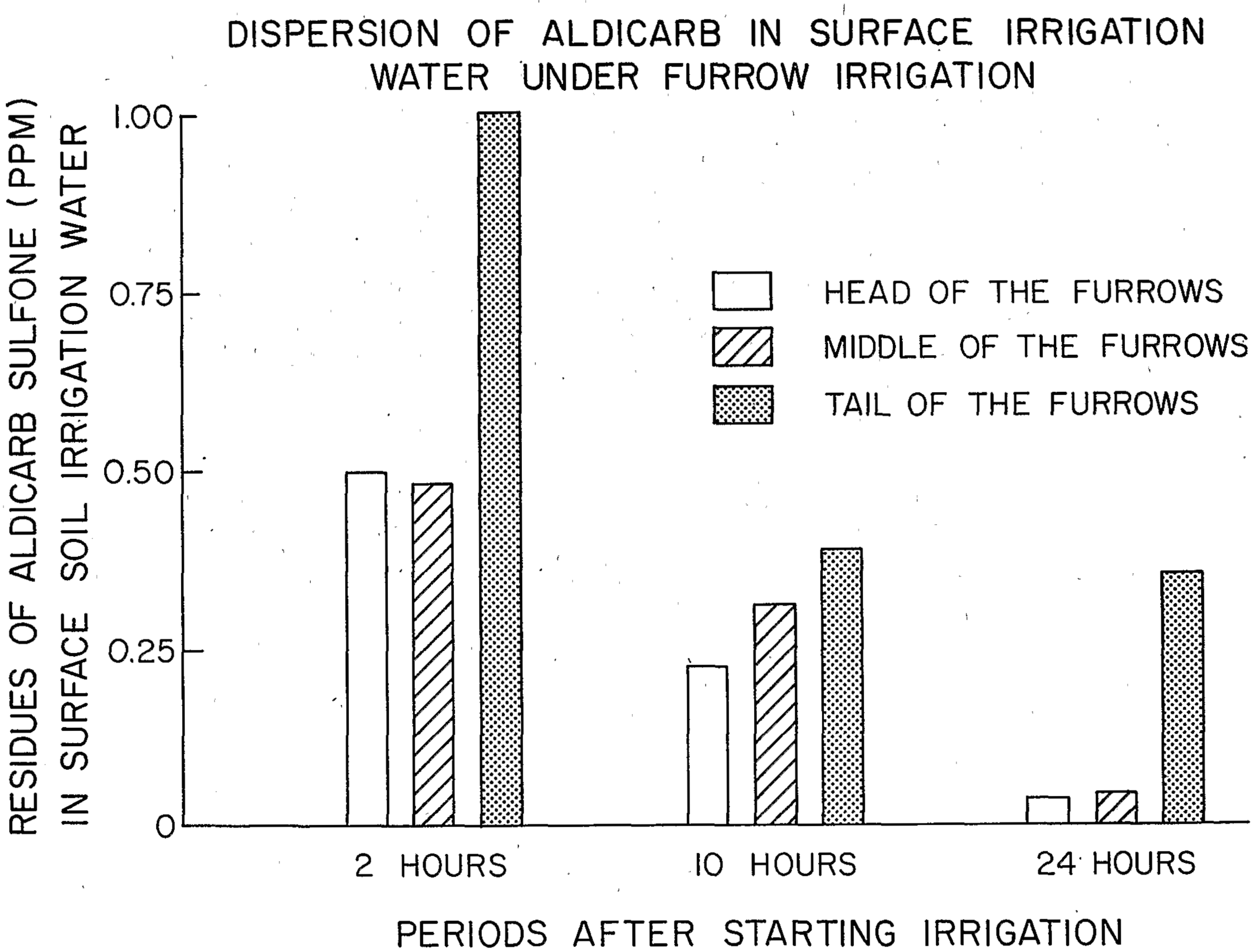

Fig. 4. Aldicarb residues in the surface irrigation water collected from a citrus orchard treated with 11.2 kg/ha a.i. of aldicarb and furrow irrigated.

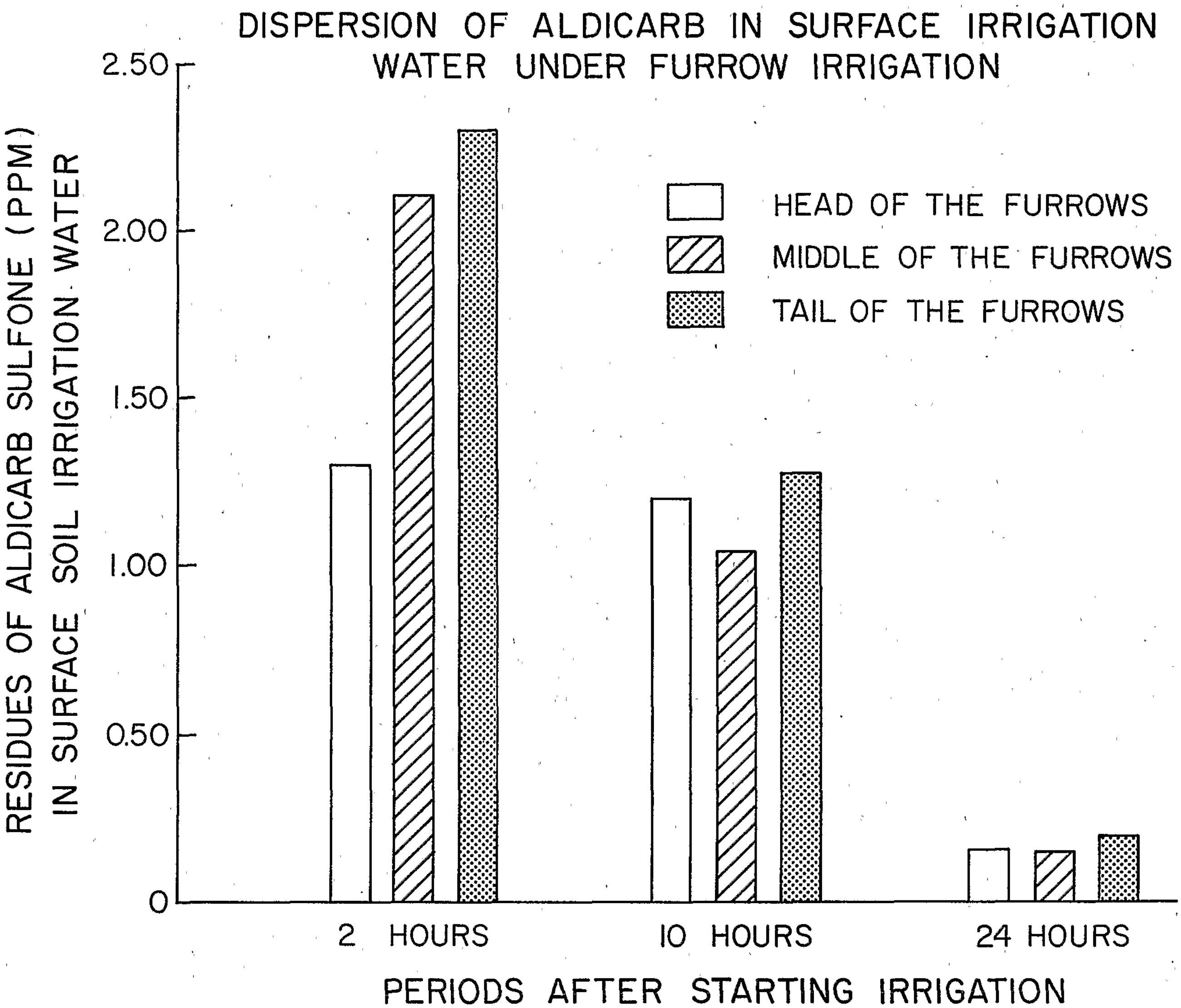

Fig. 5. Aldicarb residues in the surface irrigation water collected from a citrus orchard treated with 22.4 kg/ha a.i. of aldicarb and furrow irrigated.

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