



Volatilization patterns of tri-allylate formulations

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1. Introduction

Tri-allate is a selective and volatile herbicide and is applied pre- or post-emergence, with soil incorporation. The herbicide is absorbed principally by the coleoptiles (Tomlin, 1994). Soil incorporation reduces the loss of the herbicide by volatilization (Grover, 1978) and brings the herbicide in close contact with the coleoptile at an early stage of development (Billet & Ashford, 1978). Known formulation types of tri-allate are granules (GR) or an emulsifiable concentrate (EC) (Tomlin, 1994).

Volatilization of technical tri-allate from a plexiglass surface in a volatilization cell was such that 73% of the initial deposit was emitted from the surface after 29 h (Grover *et al.*, 1978). A field study, using tri-allate in a GR formulation without soil incorporation, reported a volatilization loss of 21 % after 24 days (Smith *et al.*, 1997). A field study, using tri-allate in an EC formulation without soil incorporation, reported a volatilization loss of 29 % after 14 days (Bor *et al.*, 1995). The volatilization pattern of tri-allate and other pesticides depends on soil and weather factors. Soil factors are: surface roughness, moisture content, organic matter content, bulk density and soil temperature. Weather factors are: temperature, wind speed, relative humidity, solar radiation and rainfall (Smit *et al.*, 1997). A dry soil will have a lower tri-allate volatilization than a moist soil (Bor *et al.*, 1995, Smit *et al.*, 1997, Smith *et al.*, 1997).

The producer of tri-allate, Monsanto Company, has an interest to develop effective spray-able liquid formulations. Both availability to the germinating seeds and the volatilization determine the efficacy of a formulation. In this study, we measured the volatilization pattern of two liquid formulations and one granular formulation and that of technical tri-allate. Volatilization was measured in a chamber from a glass surface and from soils differing in organic matter content.

2. Materials and methods

2.1 Volatilization measurements

A modified full glass aquarium (48 cm long, 30 cm wide and 30 cm height) was used as volatilization compartment. Modifications were an air-inlet and an air-outlet in the left and right side, respectively. The air-inlet is furnished with a 10 cm diam. funnel that contains a stainless steel sponge to create an equal air-flow in the aquarium. Just before the air-inlet, an active coal (Supelco Inc., Bellefonte, PA, USA) filter was inserted to remove organic contaminants in the air. The outlet is furnished with a column containing 10 g XAD (Amberlite XAD-4, Rohm and Haas Company, Philadelphia, PA, USA) for trapping of tri-allate. The aquarium upper edges were taped with Teflon tape and the aquarium was covered with a glass plate. Five compartments were connected with one pump. The air-flow rate was adjusted with flow meters and the total volume of air was measured with volumetric gas meters. The air-flow could be measured for each aquarium and was such (4.7 m³/h) that the air-change in the 43-L space of the aquarium was 1.8 times/min. The compartments were placed in a greenhouse at a constant temperature of 20 °C and at 70% RH.

2.2 Tri-allate formulations

Two liquid EC formulations (Avadex 480 EC and FOR 00017), one granular formulation (Avadex 10G) and technical tri-allate were used in this study. Avadex 480 EC contained 480 g ai/L, FOR 00017 contained 290 g ai/L, Avadex 10G contained 10% (w/v) tri-allate and the technical tri-allate had an ai content >95%.

Note: It must be mentioned that the sheet accompanying the tri-allate samples describes Avadex 10G as a WG (water-dispersible granulates) formulation. As we understood, that the aim was to compare spray-able liquid formulations with a not spray-able granular formulation we did not dilute the WG formulation with water. This was mutually agreed by exchange of protocol with Monsanto in 2000. Therefore, the granules of the granular formulation were carefully deposited on the glass or soil surface and the liquid formulations were diluted with water in all experiments.

2.3 Volatilization experiments from a glass surface

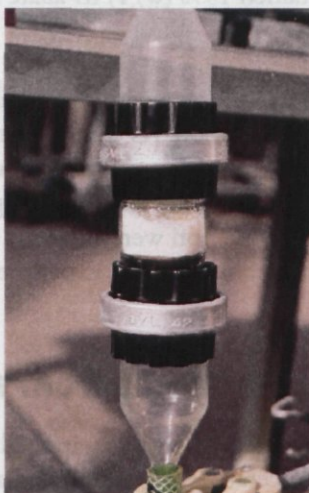
Per compartment, 1 mg of tri-allate (active ingredient) was applied on a 11 cm-diam. petri-dish. The technical tri-allate was dissolved in ethyl acetate (5 mg ai/ml) and a volume of 200 µl equivalent to 1 mg ai was brought directly on the petri-dish. Due to the rapid volatilization of ethyl acetate, we did not conduct a drop-wise application on the glass surface. Demineralized water was used as carrier for the two liquid formulations of tri-allate (Avadex 480 EC and FOR 00017). The solution (5 mg ai/ml) was applied as 40 drops of 5 µl on the glass surface such that there is a uniform distribution. The granulate formulation (Avadex 10G) was brought directly on the glass surface (10 mg product containing 1 mg ai) such that there is a uniform distribution of the granulates on the glass surface.

Immediately after deposition of the solutions on the glass surface the petri-dish is closed and placed on a marked place in the center of the compartment at 10 cm height. After removal of the petri-dish cover the compartment is closed rapidly and the experiment starts when the air starts to flow through the compartment. Periods between the start times of the different compartments are such that there is sufficient time for changing the XAD filters per compartment.

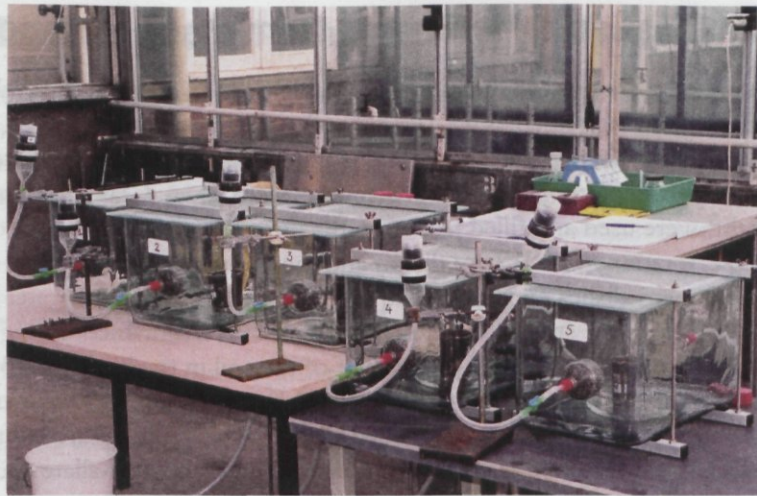
Preparatory experiment on the break-through of tri-allate demonstrated that the XAD trapping system is so robust that tri-allate was trapped continuously during the experiment. The loaded XAD filters were replaced by fresh ones at 2, 4, 8, 23, and 36 h after the start of the experiment.



Picture 1. Glass compartments and pump used for volatilization experiments. On the left side the air-inlet with active coal filter. A petri-dish is placed on a glass beaker for measurement of tri-allate volatilization from a glass surface.



Picture 2. Column with 10 g XAD connected with the air-outlet of the compartment.



Picture 3. Volatilization measurement from glass beakers filled with soil placed in the compartments.



Picture 4. Glass Beaker with soil in the compartment. On the background the air-inlet with stainless steel sponge. On the foreground the air-outlet.

In each experiment we checked the dose of tri-allate applied by applying the same amount of solutions or granulates in the same way directly into a vial. The tri-allate is extracted with ethyl acetate and analyzed. Per separate experiment the dose applied was checked 3-fold for the granulate and 1-fold for the technical tri-allate and the liquid formulations.

To be sure that the XAD is not contaminated during the experiment as result of saturation of the active coal in the air-inlet or unexpected release of organic compounds from the pump plus compartment system we include one compartment without tri-allate. The XAD filter in this compartment was not changed during the experiment and was sampled after 36 h.

Three separate experiments with each one replicate were conducted. In each experiment the three tri-allate formulations, the technical tri-allate and a control without tri-allate were included. The five treatments are randomized over the five compartments in each experiment.

2.4 Volatilization experiments from a soil surface

Sand, loam and humic sand were used to measure the volatilization of tri-allate from the soil surface. The content of organic matter, expressed as g C/kg dry soil, was 0.30 g/kg for sand, 11.3 g/kg for loam and 24.3 g/kg for humic sand. To prevent drying-out of the soil surface when subjected to the air-flow in the volatilization compartment, the following precautions were taken. Glass beakers (400 ml, 8.5 cm diam. and 10 cm height) were used and filled just up to the upper edge. The bottoms of the beakers were perforated (five perforations with 0.7 cm diam.) and the beakers were placed on sub-irrigation matting in 18.5 cm diam. petri-dishes containing 250 ml demin. water. This soil-water system was equilibrated during 16 h before the start of the experiment and was maintained during the volatilization experiment. The moisture content of the soil (upper half of the soil in the beaker) at 36 h after the start of the experiment and calculated on a dry matter basis was 14% for sand, 28% for loam and 25% for humic sand. Calculation on a total matter basis resulted in the following moisture contents: 12% for sand, 22% for loam and 20% for humic sand. Soil sampled for analysis of tri-allate and soil sampled in the control compartment (no tri-allate) were used for determination of the moisture content.

Demineralized water was used as carrier for the liquid tri-allate formulations and the treatment solutions were applied with an air-pressured laboratory track sprayer having 1.2 mm nozzles fitted with a perforated (0.6 mm) whirling pin and delivering 400 L/ha at 303 kPa. Spray application was such that approximately 1 mg of tri-allate was deposited on the soil surface. Taking into account the soil surface in the glass beaker, this is equivalent to 1.76 kg ai/ha. This rate is higher than the common rate which is around 1.2 kg ai/ha. The tri-allate content in the treatment solutions was 5.82 g/L (Avadex 480 EC) and 5.53 g/L (FOR 00017). Granules of the tri-allate 10G formulation (10 mg product containing 1 mg) were manually distributed over the soil surface without incorporation. The outer-sides of the glass beakers were taped with Parafilm before treatment and this film was removed before the beakers were placed in the volatilization compartments. This was done to prevent that tri-allate volatilization from the outer-sides contributes to the measurements.

To have a rather accurate estimation of the amount of tri-allate deposited on the soil surface by the spray application we placed one paper filter (8.4 cm diam., Schut Company, Heelsum, The Netherlands) 5 cm before and one filter 5 cm behind the beaker parallel to the direction of the track sprayer. These filters were at the same height (10 cm) as the soil surfaces in the beakers. Both the increase of weight and the tri-allate content of two these filters were determined. By taking into account the concentration of ai in the spray solution, the weight increase could be used to estimate the amount of tri-allate deposited on the filter. The extraction of tri-allate from the paper filters was checked by measuring one mg of tri-allate (amount of treatment solution of the two liquid formulations equivalent to 1 mg ai) directly and after deposition on a paper filter. The tri-allate content of 10 mg granular formulation (equivalent to 1 mg ai) was determined in each experiment.

Trapping of the tri-allate present in the air-flow was conducted as described in the previous section ('Volatilization experiments from a glass surface'). The loaded XAD was changed for a clean one at 2, 4, 8, 23 and 36 after the start of the experiment. The upper and lower half of the soil in the compartments was collected after 36 h and immediately frozen at -20 °C.

As described in the previous section, we included one compartment without tri-allate treatment and sampled the XAD after 36 h. The upper half of the soil in this compartment was sampled to determine the water-content after 36 h.

The three tri-allate formulations (Avadex 480EC, FOR 00017 and Avadex 10G) and one of the three soil types were included in each separate experiment. Loam was tested in the experiments 4 and 5, sand was tested in experiments 6 and 8, and humic sand was tested in experiments 7 and 9. The treatments were randomized over the compartments.

2.5 Extraction of tri-allate from XAD samples

The XAD was extracted within 2 days after sampling. The XAD-4 in each tube was transferred to 250 ml Schott flasks and about 50 ml distilled ethyl acetate was added by weighting. The samples were extracted by shaking them at a rate of 150 rpm for 30 minutes. Three ml of each extract was transferred into a 4 ml vial and then stored at deep freeze ($< -20^{\circ}\text{C}$) before analysis.

2.6 Clean-up and recovery from adsorbent

The tri-allate vapour was trapped on the polystyrene adsorbent XAD-4 (SERDOLIT[®], Serva, purity research grade). The particle diameter of the XAD-4 grains ranged from 0.3 to 1.0 mm. The size of the pores within the grains was 5 nm and the massic surface area of the XAD-4 grains was $750\text{ m}^2\text{ g}^{-1}$.

All XAD-4 was delivered by Alterra, Green World Research, Wageningen, that has conducted field studies on the volatilization of tri-allate after spraying onto a sandy and a bar loamy soil (Bor *et al.*, 1995). After use in these studies the XAD-4 was stored in methanol at room temperature. As the XAD-4 could contain impurities from the studies in 1995, a clean-up was performed in a chromatographic column to remove former contents of tri-allate. Samples of 100 g methanol saturated XAD-4 were transferred into a stainless steel tube with a stainless steel wire netting and then rinsed ten times with 60 ml ethyl acetate. Thereafter the XAD-4 was dried in a stove at 50°C for 3 days and stored in an airtight steel container or 500 ml Schott flasks.

After cleaning the XAD-4, a check was made on the efficiency of the removal of the impurities. Samples of 10 g of the cleaned XAD-4 were shaken mechanically with 50 ml ethyl acetate at 150 rpm for 30 min and then analyzed by gas-chromatographic analysis with electron capture detection. A background peak in the chromatogram appeared (under the described conditions) at a level of $2.8 \pm 0.5\ \mu\text{g l}^{-1}$ ($n=3$) which resulted in a detection limit of $8.4\ \mu\text{g l}^{-1}$ (three times the standard deviation) in the XAD-extracts.

2.7 Retention and breakthrough

The retention of tri-allate on XAD-4 was studied by drawing air through a combination of 3 sampling tubes (length 70 mm, i.d. 35 mm) with 10 g cleaned XAD-4 each. The middle tube had been spiked with $500\ \mu\text{g}$ tri-allate ($100\ \mu\text{l}$ of a standard solution containing 5 g/L tri-allate, technical grade). The first tube was included as a control for any volatilization of tri-allate against the direction of the air-flow. Air was also drawn through combination of two sampling tubes with 10 g XAD per tube after spiking the first tube with $500\ \mu\text{g}$ tri-allate. The sampling tubes were connected to a high-volume vacuum pump (Siemens, type ELMO-G) and air was drawn for 15 and 24 hours, respectively. Then, the content of each tube was transferred into 250-ml glass flasks (type Schott) and 50 ml ethyl acetate was added to each flask. The mass of ethyl acetate added to each flask was weighed (density of ethyl acetate 0.900 g ml^{-1} at 20°C). The flask were then shaken mechanically during 30 min at 150 rpm. About 3 ml of each extract was stored in deep freeze until analysis.

2.8 Extraction of tri-allate from soil samples

The soil samples of the pots were stored (during 70-120 days) in polyethene bags at -20°C until extraction and analysis. Soil samples were very wet and the lower layers (5-10 cm) of the split up pots were almost water saturated. This moisture state complicated mixing of the soil samples to take representative sub samples for extraction. The total mass of wet soil (about 350 g) was too much to extract it entirely. Drying the soil to create better conditions for mixing was not desirable as this would have resulted in partly volatilization of the remaining tri-allate. That should be avoided because the soils

were analysed to determine the remaining masses of tri-allate at the end of each volatilisation experiment. Therefore it was decided to mix the soil samples in the wet condition as they were.

After thawing of the soil sample the content of the plastic bag was entirely put in a steel bowl and the content was then thoroughly mixed with a spoon and finally spread over a thin layer. A mass of wet soil (about 60 g) was weighted into a 250 ml glass flask by taking a number of small portion from the bowl (stratification method). A second portion of wet soil was taken in the same way to determine the moisture content by drying to constant weight at 105 °C. Water (50 ml) and n-hexane/ethyl acetate mixture (1:1/, v/v) (50 ml) was added to the 250 ml flask, which was then gas tight closed with a screw cap provided with an aluminium coated inlay. The flask was shaken for 1 hour and the organic layer was separated by standing overnight or by centrifuging the liquid layers. About 8 ml of the organic layer was transferred into a tube with screw cap and some anhydrous sodium sulphate to dry the organic solvent. These tubes were stored for four weeks in a refrigerator before they were analyzed for tri-allate concentration by gas chromatography.

Recovery of the extraction en analysis procedure was tested by analysing spiked soil samples with the method described. Moist soil samples (about 60 g) of each of the three soil types were weighted into 250 ml glass flasks. Solutions of ethyl acetate (500 µl) containing 250 ng/ml tri-allate were added to the soils and the flasks were closed air tight with screw caps provided with aluminium coated inlays. Duplicate samples were prepared for each soil/concentration combination. The doses resulted in soil contents that were expected to remain in the experimental samples. The treated flasks were stored overnight at 5 °C to achieve sorption equilibrium and were extracted then as described. The extracts were analyzed for tri-allate concentration by gas chromatography.

2.9 Analysis of tri-allate

The concentration of tri-allate in the extracts was measured by gas-chromatographic analysis. Samples of 2 µl of the extracts were injected automatically into a gas-chromatograph (Hewlett Packard type 5890) at 225 °C. The injection mode was splitless. A medium bore fused silica column (length 25 m; internal diameter 0.32 mm; film thickness 1.2 µm) with polysiloxane (CP-Sil 19 CB) as stationary phase was used. The flow rates of the carrier (helium) and make-up (nitrogen) gases were maintained at 2 and 60 ml min⁻¹, respectively. The initial column temperature was kept at 140 °C for 1.5 min. Thereafter, the temperature was raised at a rate of 45 °C min⁻¹ to 270 °C and maintained at his temperature for 1.75 min. The detector temperature was 325 °C. Tri-allate was measured with a ⁶³Ni electron capture detector. Data acquisition and processing were done during 7 min with Atlas (LabSystems). The retention time of tri-allate under this condition was 5.4 min. The detection limit in the solvent was 0.5 µg l⁻¹.

3. Results and discussion

3.1 Preparatory experiments

Breakthrough of tri-allate was less than 0.01% of the applied amount after a period of 14 h and after 24 h (separate experiments). The tri-allate was retained quite well by XAD. We concluded that a 10 g XAD column is sufficient for trapping tri-allate after application of 1 mg ai in the compartment.

A paper filter was used for dose control in the spray application. Analysis of paper filter plus 1 mg tri-allate (amount of treatment solution equivalent to 1 mg ai) and 1 mg tri-allate directly did not indicate that the paper filter interfered with the analysis of tri-allate. Extraction and analysis of the soils without any application of tri-allate did not result in compounds possibly interfering with the tri-allate analysis. Inclusion of a known amount of tri-allate in the soils before extraction resulted in a 100% recovery.

3.2 Volatilization experiments from a glass surface

In two of the three experiments technical tri-allate is completely (Figure 1) or almost completely (Figure 3) released from the Petri-dish in the compartment. For unknown reasons, the volatilization was lower (75% of the applied amount) in the second experiment (Figure 2). The strong volatilization of technical tri-allate agrees well with a previous study demonstrating a loss of 73% after 29 h (Grover *et al.*, 1978). It is obvious (Figures 1, 2 and 3) that the granular formulation (Avadex 10G) retains the tri-allate much better than the two liquid formulations (Avadex 480 EC and FOR 00017). The average volatilization of this formulation after 36h was 11% (Figure 4). The average volatilization of the two liquid formulations was 66% (Avadex 480 EC) and 63% (FOR 00017) after 36 h (Figure 4). Thus the two liquid formulations did not differ. In the third experiment we also measured the tri-allate left on the Petri-dish after 36 h and calculated the total recovery in the experiment by adding this amount to the amount volatilized. Recoveries were 99.8% for Avadex 10G, 94.7% for Avadex 480 EC, 85.4% for FOR 0017 and 97.8% for Avadex 10G. This indicates that there were no or little unwanted losses due to adsorption on surfaces or emission to the environment. Analysis of tri-allate in the XAD columns connected with a compartment without tri-allate did not demonstrated contamination with substantial amounts of tri-allate or other organic contaminants.

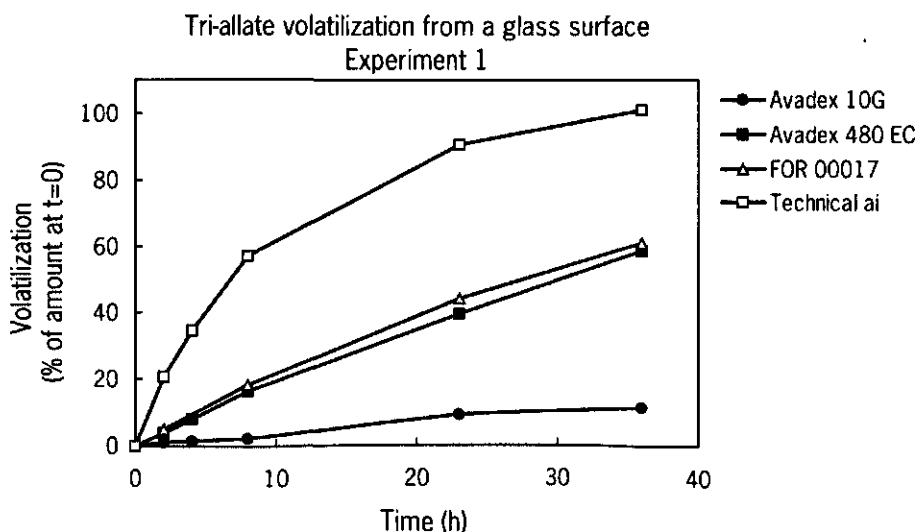


Figure 1. Volatilization of tri-allate from a petri-dish. Applied amount of ai was approximately 1 mg.

Table 1. Dose controls of tri-allate in the petri-dish experiments.

Formulations	Amount of tri-allate at t=0 (μg)		
	Experiment 1	Experiment 2	Experiment 3
Avadex 480 EC	907	983	1064
FOR 00017	961	982	984
Technical tri-allate	828	843	916
Avadex 10G ¹	1118	1026	1038

¹ n=3; other formulations n=1

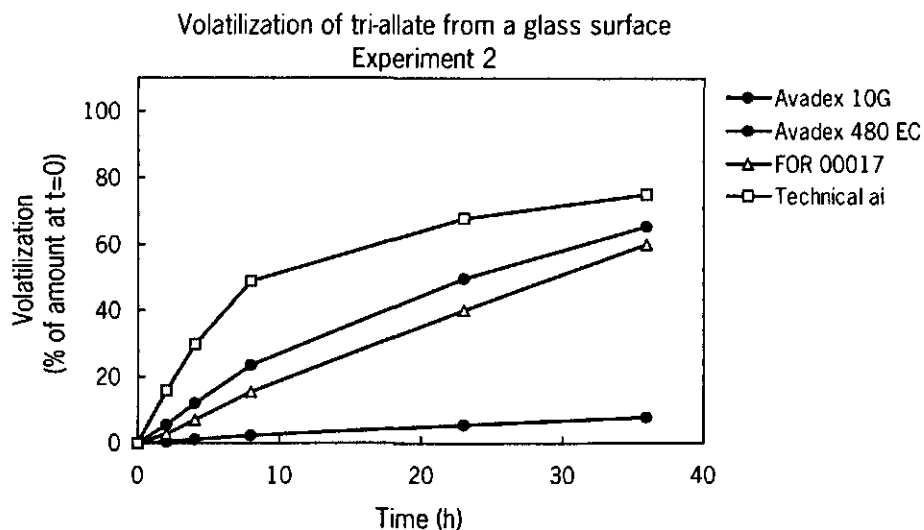


Figure 2. Volatilization of tri-allate from a petri-dish. Applied amount of ai was approximately 1 mg.

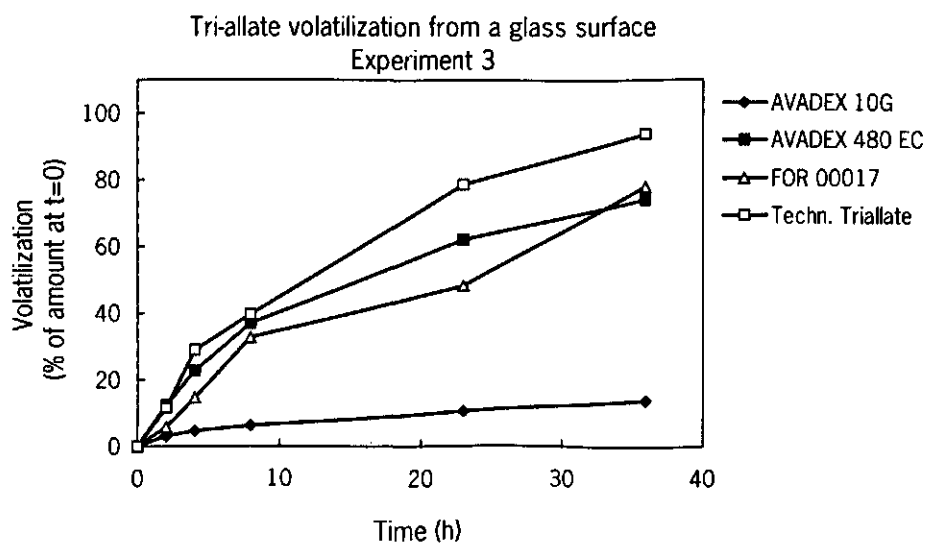


Figure 3. Volatilization of tri-allate from a petri-dish. Applied amount of ai was approximately 1 mg.

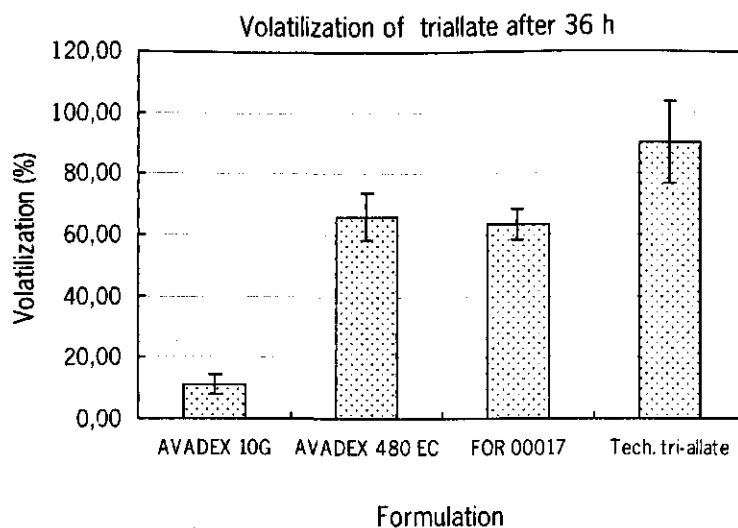


Figure 4. Volatilization of tri-allate after 36 h. Values are the means (bar=SD) of three experiments.

3.3 Volatilization experiments from a soil surface

The data of the dose controls of the two liquid formulations Avadex 480 EC and FOR 00017 (Table 2) demonstrate that the conditions of the spray application were such that an amount of approximately 1 mg was deposited on the soil surface. The tri-allate content of the filters calculated by weighting the filters agreed reasonable with the chemical analysis of tri-allate. Taking into account the completely different methods (weighting and analysis) we mention it reasonable. The chemical analysis was considered as the most reliable method and was used as the best estimation for the amount of tri-allate on the soil surface at $t=0$. Analysis of tri-allate in the XAD columns connected with a compartment without tri-allate did not demonstrated contamination with substantial amounts of tri-allate or other organic contaminants.

With all soil types tested, the application of the two liquid formulations (Avadex 480 EC ad FOR 00017) resulted in a higher volatilization than the application of the Avadex 10G granular formulation (Figures 5-10 and Table 3). There was no obvious difference between the two liquid formulations as was observed also in the volatilization experiments using petri-dishes. In experiment 9 (Figure 10 and Table 3) there was a difference but this was not found in the replicate experiment no. 7 (Figure 9 and Table 3). After 36 h, the two liquid formulations demonstrated almost the same volatilization if one compares the volatilization from the sand surface (Figures 5 and 6, Table 3) with that from the glass surface (Figures 1-3). Apparently, the sand surface did not have a strong interaction with these two formulations. In contrast with this observation, the volatilization from the granular formulation on sand (Figures 5 and 6, Table 3) was two to three times higher than observed on glass (Figures 1-3). Based on visual observation, we suggest that the relatively wet sand surface may have wetted the granules. This wetting may have promoted the release of the apolar tri-allate. On the glass surface the granules were completely dry, which may have maintained their capacity to retain tri-allate. This agrees with the observations that a soil will have a lower volatilization of tri-allate when the soil dries out (Bor *et al.*, 1995, Smith *et al.*, 1997).

Table 2. Dose controls of tri-allate in the soil experiments.

Soil	Experiment no.	Formulation	Amount of tri-allate (μg)	
			Dose control by weight ¹	Dose control by analysis ¹
sand	6	480 EC	896	1091
sand	6	FOR 00017	868	1042
sand	6	10G		1161
sand	8	480 EC	855	972
sand	8	FOR 00017	812	921
sand	8	10G		1270
loam	4	480 EC	nd	1109
loam	4	FOR 00017	nd	1053
loam	4	10G		1264
loam	5	480 EC	995	894
loam	5	FOR 00017	868	825
loam	5	10G		1205
humic sand	7	480 EC	797	1032
humic sand	7	FOR 00017	846	1076
humic sand	7	10G		1101
humic sand	9	480 EC	821	774
humic sand	9	FOR 00017	719	580
humic sand	9	10G		1162

¹ The two liquid formulations (480 EC and FOR 00017) were applied by spray. A paper filter was placed 5 cm before and one was placed 5 cm behind the beaker with soil. The two filters were weighted and analyzed. Values are the means of the two filters per experiment.

A higher organic C-content of the soils resulted in a lowering of the volatilization of tri-allate from the two liquid formulations (Table 3, Figure 11). In spite of only three levels of C-content, this lowering was linearly related to the C-content. The release of tri-allate from the granular formulation from loam and humic sand had the same level after 36 h (Table 2) as was observed from the glass surface (Figure 4). This does not prove but indicates that this release was not influenced by these soils and that the granules remained relatively dry on these soils. It must be stressed that the granules were not incorporated into the soil. Incorporation will undoubtedly have reduced the volatilization in these soils with a much higher C-content than the sand. The recovery of tri-allate in these experiments (Table 2) was not always 100%. We suggest that the splitting up of the soil samples and taking small sub-samples after mixing the wet soils introduced variability. Degradation of tri-allate in the soil during the 36 h period may have contributed to a lower recovery. As a result, we tend to conclude that the analysis of the tri-allate left in the soil after 36 h was more vulnerable to losses or overestimations than the XAD-trapping system and the subsequent extraction of tri-allate.

Our experimental system was such that the soils remained equilibrated with a water supply by sub-irrigation. As a result the soils were moist (Table 2). Based on the literature (Bor *et al.*, 1995, Smith *et al.*, 1997) we can expect lower volatilization rates when conducting the same experiments with much drier soils.

The relatively low volatilization of tri-allate in the granular formulation from glass (Figures 1-4) and soil surfaces (Figures 5-10) agrees with a previous observation of a loss of 21% from the field after 24 days (Smith *et al.*, 1997). Bor *et al.* (1995) reported a loss of 29% after 14 days for an EC formulation of tri-allate applied on humic sand and at a temperature around 10 °C. The rate of volatilization was the highest on the first day after treatment and the 29% levels agrees with the average 25.5% level we

measured for the 480 EC formulation after 36 h at 20 °C on humic sand (Table 2). However we have to take into account the temperature difference. Hence we estimate that during the first 36 h, the volatilization in the field study was considerably lower than 25.5% of the applied dose.

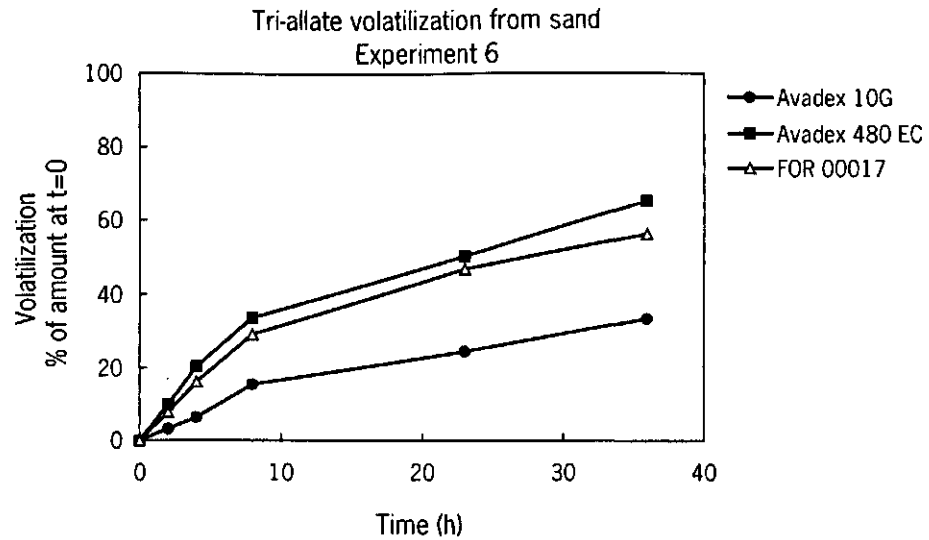


Figure 5. Volatilization of tri-allate from the three formulations after application on sand.

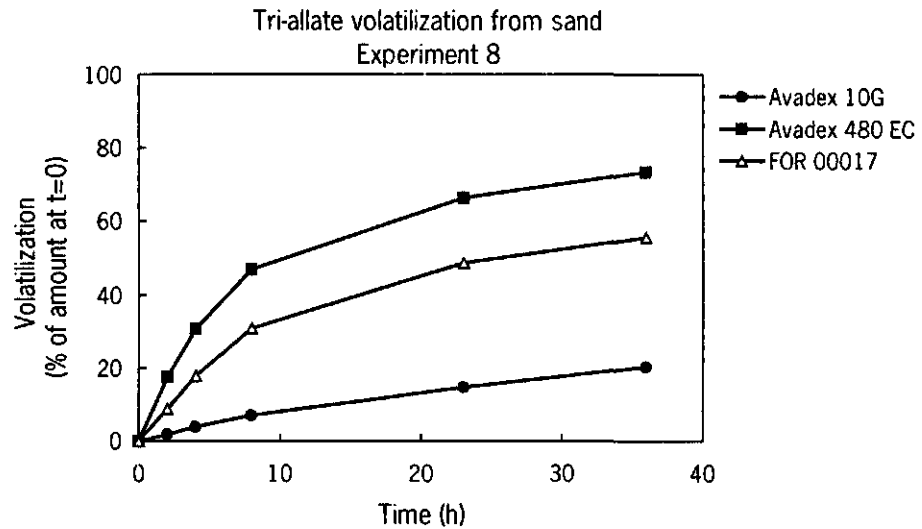


Figure 6. Volatilization of tri-allate from the three formulations after application on sand.

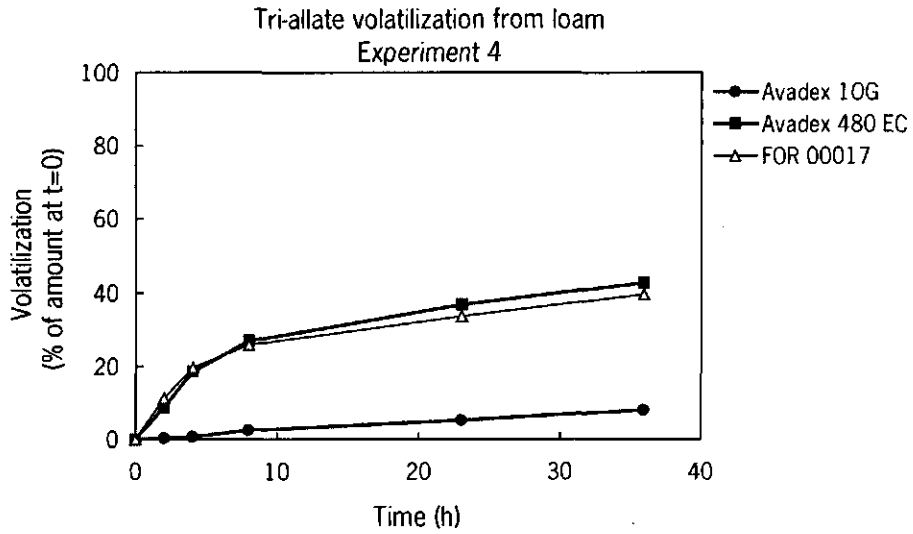


Figure 7. Volatilization of tri-allate from the three formulations after application on loam.

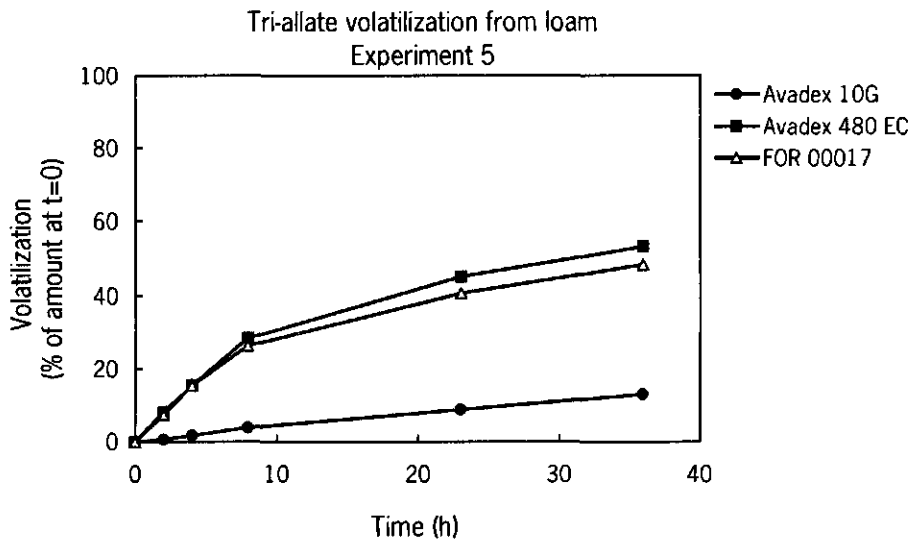


Figure 8. Volatilization of tri-allate from the three formulations after application on loam.

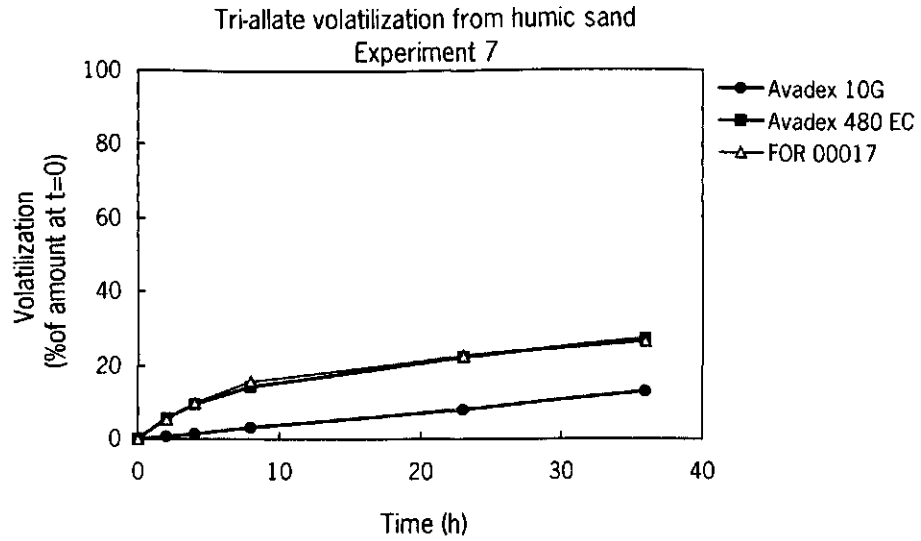


Figure 9. Volatilization of tri-allate from the three formulations after application on humic sand.

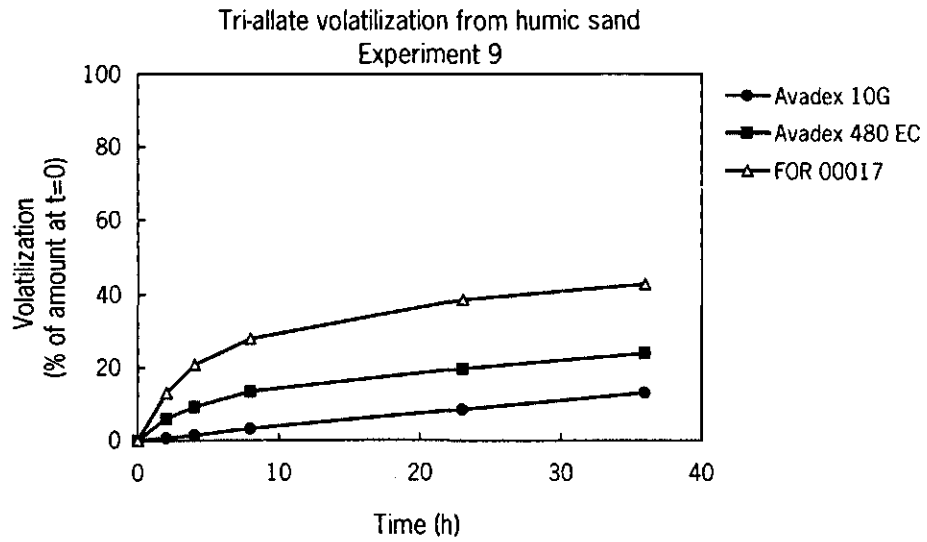


Figure 10. Volatilization of tri-allate from the three formulations after application on humic sand.

Table 3. Volatilization and recovery of tri-allate from different soils.

Soil	C-content (g C/kg dry soil)	H ₂ O-content (% on dry matter basis)	Experiment no.	Formulation	Volatilization after 36 h (% of amount at t=0) ¹	Tri-allate in soil after 36 h (% of amount at t=0) ^{1,2}	Recovery (% of amount at t=0) ³
sand	0.3	14	6	480 EC	65.3	17.5	82.8
sand			6	FOR 00017	56.2	16.1	72.3
sand			6	10G	33.1	31.9	65
sand			8	480 EC	73.4	16.7	90.1
sand			8	FOR 00017	55.7	22.2	77.9
sand			8	10G	20.4	32.9	53.3
loam	11.3	28	4	480 EC	42.7	57.3	100
loam			4	FOR 00017	39.4	65.9	105.3
loam			4	10G	8	92.4	100.4
loam			5	480 EC	53.2	70.6	123.8
loam			5	FOR 00017	48.1	83.6	131.7
loam			5	10G	12.9	84.2	97.1
humic sand	24.3	25	7	480 EC	27.3	77.5	104.8
humic sand			7	FOR 00017	26.3	91.1	117.4
humic sand			7	10G	12.8	107.9	120.7
humic sand			9	480 EC	23.7	65.9	89.6
humic sand			9	FOR 00017	42.8	90.3	133.1
humic sand			9	10G	13.1	71.8	84.7

¹ Dose control based on analysis of paper filters (Table 2) was used as amount on t=0.

² Along the upper half of the soil in the glass beaker was used because the lower half contained no or a minor amount of tri-allate.

³ Sum of volatilization and soil content after 36 h.

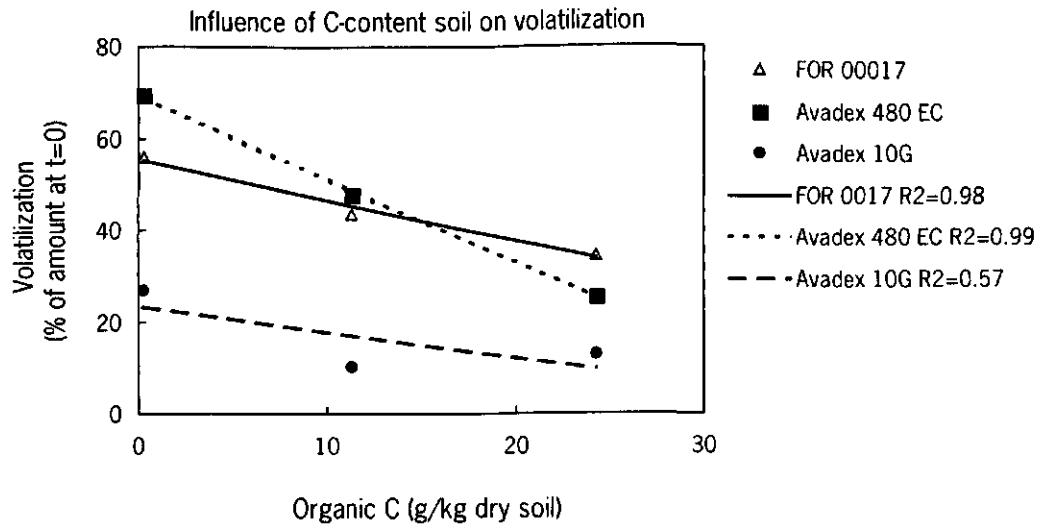


Figure 11. Volatilization of tri-allyl from sand, loam and humic sand with organic C-contents of 0, 3, 11.3 and 24.3 g C/kg dry soil, respectively.

4. Conclusions

The two liquid formulations Avadex 480 EC and FOR 00017 demonstrated a similar volatilization pattern on a glass surface and on the surface of sand, loam and humic sand. The volatilization of tri-allylate from the granular formulation (Avadex 10G) was lower than that of the two liquid formulations.

The volatilization of tri-allylate from the liquid formulation was correlated quite well with the organic C-content of the soil. Lower emission at a higher C-content.

5. Recommendations

A comparison of the same formulations regarding their bio-efficacy (without and with soil incorporation) is a useful next step. Then a correlation between volatilization pattern and efficacy can be made.

6. Acknowledgements

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7. Literature cited

Billet, D. & R. Ashford, 1978.

Weed Sci. 26: 273-276.

Bor, G., F. van den Berg, J.H. Smelt, R.A. Smidt, A.E. van de Peppel-Groen & M. Leistra, 1995.

'Volatilization of tri-allate, ethoprophos and parathion measured with four methods after spraying on a sandy soil, Alterra Green World Research, Wageningen, The Netherlands.

Grover, R., W.F. Spencer & W.J. Farmer, 1978.

Weed Sci. 26: 505-508.

Smit, A.A.M.F.R., F. van den Berg & M. Leistra, 1997.

pp. 17-19 in 'Estimation method for the volatilization of pesticides from fallow soil', Environmental Planning Bureau series 2, Alterra, Wageningen, The Netherlands.

Smith, A.E., L.A. Kerr & B. Caldwell, 1997.

J. Agric. Food Chem. 45: 1473-1478.

Tomlin, C. (Ed.), 1994.

pp. 1003-1004 in 'The Pesticide Manual', BCPC and RSC, London.