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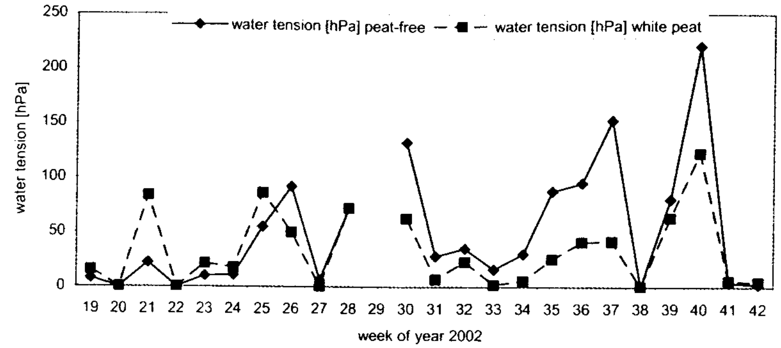


Fig. 3. Water tension in a peat-free and in a white peat (1) substrate during cultivation of *Weigela* 'Bristol Ruby'.

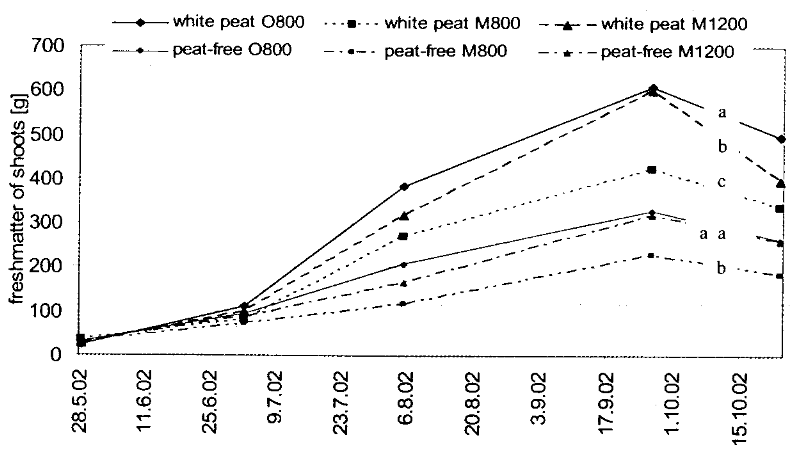


Fig. 4. Freshmatter [shoots, g] of *Weigela* 'Bristol Ruby' in a peat-free and in a white peat (1) substrate with different fertilizers. O800: Osmocote 800 mg $N \cdot L^{-1}$, M800 resp. 1200: Maltaflor univ. 800 resp. 1200 mg $N \cdot L^{-1}$. Different letters: significant differences within a substrate for $p < 0.05$.





# Leaching of Pesticides through Container Peat Medium in Forest Seedling Production

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**Keywords:** agricultural pollution, chlorothalonil, cypermethrin, forest nursery, groundwater propiconazole, triadimefon

**Abstract**

**Most of the pesticides used in container production are sprayed on the very densely growing forest seedlings. Therefore pesticide load into the ground is composed of leachates from the growing medium in the containers and the amounts sprayed outside seedlings. Leaching of propiconazole (Tilt 250 EC®) and chlorothalonil (Bravo 500®) through light *Sphagnum* peat medium in containers was monitored in nursery production of Scots pine (*Pinus sylvestris* L.) seedlings. The data concerning the leaching of the fungicide triadimefon (Bayleton 25®) and the insecticides cypermethrin (Ripcord ®) and alpha-cypermethrin (Fastac®) was collected from silver birch (*Betula pendula* Roth) production. In addition, leaching of these pesticides was studied in experiments with simulated rainfall. The seedling canopy and light *Sphagnum* peat medium adsorbed pesticides effectively. During the growing period, less than 4% of the applied chlorothalonil, triadimefon, cypermethrin and alpha-cypermethrin leached from the container trays. Propiconazole was an exception; almost 30% of applied amounts leached. Fluctuations were typical for the concentrations of the pesticides in leachates; the concentrations were usually highest after application and decreased before new applications. In experimental studies the concentrations were highest on the first day after application and then decreased rapidly during the following ten days. Greater proportion of the applied pesticide amounts leached under experimental conditions than did in field studies. In conclusion, irrigation and rain removed pesticides from seedlings and leached them from containers, especially during the first three days after pesticide application, therefore it is important to plan the irrigation schedules so that the percolation of water from containers is as small as possible during these days.**

## INTRODUCTION

Pollution of ground water and surface waters due to agriculture has been reported worldwide. The risk posed by the production of forest tree seedlings is poorly known. Although the total use of pesticides and fertilizers in forest nurseries is small compared to that in agriculture and horticulture (Juntunen, 2002), there can be local risks, because some nurseries are situated on areas where ground water reservoirs form and/or near lakes and rivers.

Container seedling production has largely replaced bareroot production of forest seedlings in the Nordic countries and Canada. Production of container seedlings is similar to horticultural production. However, there are some differences, for example, forest seedlings are grown in small pots, 40 to 300 ml in volume, while most of the horticultural crops are grown in large, individual pots. The individual pots, in forest nursery terminology often referred to as containers, are usually produced in aggregates called trays (Landis et al., 1990). The number of containers in trays (40 cm x 40 cm) for birch seedlings is usually 25, whereas in trays for conifers it varies, mostly from 64 to 121.

In conifer seedling production the trays are kept together whereas in birch production they are separated from each other by 20 cm of free space around them about at the end of June (Juntunen and Rikala, 2001). Due to doubled growing area, about half

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of the pesticide could be applied between containers. Irrigation and rain could also wash-off pesticides from leaves straight onto the ground, when seedlings grow and canopy covers part of the isles between containers.

Peat is the most frequently used growing medium in container seedling production in Fennoscandia, while in North America other components such as vermiculite, perlite and sawdust are mixed into the peat based growing medium (Juntunen, 2002).

As far as we know, there are only a few studies concerning the leaching of herbicides through media used in container nurseries (Wehtje et al., 1993; Mahnken et al., 1994; Grey et al., 1996) and none about leaching of fungicides and insecticides. Nor have we found any published results about studies on these aspects during actual production of container forest seedlings. The objective of this study was 1) to determine leaching of some pesticides through peat growing medium into the ground during commercial production of container Scots pine and silver birch seedlings 2) to increase the knowledge about leaching processes on seedlings and in peat medium by doing experiments with simulated rainfall.

## MATERIAL AND METHODS

### Field Studies

Leaching of chlorothalonil (Bravo 500®) and propiconazole (Tilt 250 EC®) from peat container medium into the ground was monitored during three growing seasons in nursery production of Scots pine seedlings. Fungicides were applied at about 20 day intervals from the end of July until November. The study design is presented in detail by Juntunen and Kitunen (2003). The leaching of triadimefon (Bayleton 25®) and (alpha-) cypermethrin (Fastac® and Ripcord®) was studied in container birch production during two growing seasons and the study design is presented in detail by Juntunen (2002) and Juntunen et al. (2003).

### Experimental Studies

The leaching of chlorothalonil and propiconazole was studied over ten days in July and September after one pesticide application to Scots pine seedlings. With silver birch seedlings the leaching of triadimefon and alpha-cypermethrin was monitored only in July. Simulated rainfall was applied by irrigator to the seedlings 1, 2, 3, 6, 8 and 10 days after the application of pesticides. The amount of water applied to pine about 7 mm (days 1–6) and 15 mm (days 8–10) and to birch 12 mm (days 1–2, 6–8) and 24 mm (days 3, 10). The water rate sprayed by irrigator was about 5 mm $h^{-1}$.

### Collection of Leachates

The percolated water from the container medium was collected with sloped polystyrene plates (40 x 40 cm) equipped with a hole and a sampling vessel placed under container trays. In the field studies the trays were placed systematically among the commercial production stock and the leachates were collected weekly from May to October. In rain experiments leachates were collected half on hour after simulated rainfall had been stopped. The samples were stored frozen (-18°C) for 4–6 months until they were analyzed for pesticides.

### Application of Pesticides

The chlorothalonil was applied by irrigation boom mounted with TeeJet 11003VB nozzles (Spraying Systems Co.). The propiconazole and other pesticide applications before the simulated rainfall experiment were peformed by a special system, which imitated the tractor boom spraying. In this system Teejet 11003VB nozzles were also used (Juntunen and Kitunen, 2003). In the birch field studies applications were made with a backpack sprayer (Solo 40123, Solo Kleinmotoren GmbH, Germany) (Juntunen, 2002).



### Analyses of Pesticides

Pesticides were extracted from water samples with dichlorometan; the extraction was concentrated and pesticides were analyzed by gas chromatography-mass spectrometry using the SIM-technique. In addition to triadimefon, the degradation product, triadimenol, was also determined. The limit of detection for the analyzed pesticides was as follows: 0.05 $\mu g\ L^{-1}$ for triadimefon and triadimenol, 0.1 $\mu g\ L^{-1}$ for chlorothalonil, 0.25 $\mu g\ L^{-1}$ for propiconazole and alpha-cypermethrin, and 1 $\mu g\ L^{-1}$ for cypermethrin.

## RESULTS AND DISCUSSION

### Percolation of Water through Container Trays

Water management is an important factor for controlling the discharge of pesticides to surface and ground waters, because water acts as a carrier of pesticides. Depending on tree species, a total of 28 to 126 mm of water leached from the containers during the follow-up period (Table 1), whilst in the study of Dumroese et al. (1995) the amounts of discharged water were as large as 450 to 800 mm for the whole growing period. The use of different irrigation methods could explain this difference. The irrigation method used in Finnish forest nurseries is based originally on the studies of Puustjärvi (1977) and is confirmed by Heiskanen (1995). According to their conclusions, the water availability and aeration are at optimum for the growth of tree seedlings, when the water content of the light *Sphagnum* peat medium in containers is between 40–50% by volume. During the greenhouse period, the water content of the peat medium could be maintained within the optimum range, but in August, and later in autumn, the water content of the peat medium exceeded the container capacity during rainy periods, along with decreased evapotranspiration. The amount of precipitation influenced the water amounts percolated, and as much as 50 to 70% of rainwater could occasionally percolate through the trays.

### Leaching of Pesticides in Field Studies

During field studies, less than 4% of the applied chlorothalonil, triadimefon, cypermethrin and alpha-cypermethrin leached from the container trays (Table 1). Propiconazole was an exception; almost 30% of the applied amounts leached from containers in 1997. The amounts leached per unit area were, however, many times smaller than the amounts applied per unit area (Table 1).

Pesticide concentrations in leachate waters were usually highest after application and decreased before a new application (Juntunen and Kitunen, 2003). The pesticide concentrations did not correlate with the amount of percolated water, and the repeated applications did not increase the concentrations of pesticides in the leachates.

### Leaching of Pesticide in Experimental Studies

Experiments with simulated rainfall could be seen as worst-case studies because the simulated rainfall was applied only one day after pesticide applications and the rain treatments were repeated for six days out of ten. Greater proportions of applied pesticides, 5–25%, leached in these studies than in the field studies (Table 1).

The concentrations of pesticides in leachates were highest on the first day, on the second day they were about half of the value on the first day, and after that they decreased gradually (Figs. 1C and 2C). In the pine experiment, the concentrations of both pesticides, especially of propiconazole, were higher in leachates in September than in July (Fig. 1C). Due to the greater water content of peat medium (Fig. 1A), the amounts of leachates were also greater in September (Fig. 1B). The higher concentrations of pesticides and greater amounts of leachates also caused greater pesticide load per area in September than in July (Fig. 1D, Table 1).

Due to taller shoots and greater needle mass (area) of pine seedlings, greater proportion of pesticides fell on the seedlings instead of the peat surface in September than in July. When pesticides were removed by rain from the foliage in September, they obviously flowed along the shoot and root channels from containers onto the ground more easily than in July. Bruhn and Fry (1982) have shown that rainfall removed cholorothalonil from the leaves of potatoes; the sooner the rainfall occurred, the greater was the removal of chlorothalonil. In our study, the removal of propiconazole from needles seemed to be even greater than that of chlorothalonil. The higher water solubility of propiconazole compared to that of chlorothalonil, 100 and 0.8 mg $L^{-1}$ (Tomlin, 1997), respectively, could explain this result.

In the birch experiment, the rain removed pesticides from leaves straight onto the ground. The amount would have been greater if we had made measurements on the first day as well after the application. The amount of removed triadimefon (4.4 g $ha^{-1}$) was, however, much less than the amount that leached from the peat medium (30.3 g $ha^{-1}$) onto the ground (Fig. 2C). Only very low concentrations of triadimenol (< 0,06 μg $L^{-1}$) were found in rain leachates. In leachates from containers, triadimenol was already measured on the first day, and during the last three days, it's concentrations were higher than the concentrations of tridimefon in leachates (Fig. 2B). It seems that triadimefon was rapidly metabolized to triadimenol in the peat medium. Alpha-cypermethrin was also removed by rain from leaves onto the ground. The amount per area was, however, less (2.5 g $ha^{-1}$) than that leached from the peat container medium (8.2 g $ha^{-1}$).

Much higher proportions of applied pesticide amounts leached in birch experiments than in the field studies. The spraying technique could partly explain this result. In field studies the pesticides were applied by a backpack sprayer, which sprays and also blasts part of pesticides onto adaxial leaf surfaces. The tractor system sprayed only on the abaxial leaf surfaces where pesticides may be removed by rain much easier.

Regardless of the pesticide and the total amount of pesticide that leached during the ten day experiment, the proportions of the total amount of leached pesticides in different days after application were quite similar (Fig. 3). About one third leached during the first day and from 60 to 80% of total amount was leached during the first three days after application. During the last three days the leached amounts of pesticide were smaller than earlier although the amounts of leachate were greater.

## CONCLUSIONS

The leached amounts of pesticides per unit area were many times smaller than the amounts applied per unit area. Obviously, adsorption of pesticides on foliage and in peat medium was the most important cause for the small amounts. The concentration of pesticides in leachates decreased rapidly after application, therefore it is important to plan the irrigation schedules so that the percolation of water from containers is as small as possible during growing, especially during the first few days after pesticide application.

It is not possible to know for sure whether the reason for the small amount of leaching was due to the adsorption of pesticides by the peat and/or degradation of pesticides to their metabolites because triadimenol, the degradation product of triadimefon, was the only degradation product measured.

If the crop does not cover the whole growing area, it is important to determine the amount of pesticides that evades seedlings during pesticide application and the amount which is washed off during seedling irrigation and rain. If the growing area without seedlings is large compared to the area covered by seedling containers, it is important to try to minimize this area.

## ACKNOWLEDGEMENTS

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## Tables

Table 1. Amounts of pesticides applied and leached from peat medium in containers in field and experimental studies of Scots pine and silver birch seedling production (n = 4, mean ±SEM). The amounts of leached water (=leachate) are also presented. Applied water amount includes irrigation and rain.

| | Total amount leached (g ha$^{-1}$) | Total amount applied (kg ha$^{-1}$) | % of applied | Number of applicat. | Leachate (mm) | % of applied (irrig.+ rain) |
|---|---|---|---|---|---|---|
| **Chlorothalonil** | | | | | | |
| Field studies | | | | | | |
| 31.7.-5.11.1997 | 10.3 ± 1.0 | 7.2 | 0.1 | 5 | 40 ± 1 | 24 |
| 29.7.-5.11.1998 | 24.4 ± 1.2 | 26 | 0.1 | 4 | 105 ± 3 | 38 |
| 10.9.-5.11.1998 | 12.3 ± 3.0 | 4.1 | 0.3 | 3 | 42 ± 3 | 47 |
| Experimental studies | | | | | | |
| 15.-24.7.1998 | 96.4 ± 21.7 | 2.0 | 4.8 | 1 | 28 ± 1 | 47 |
| 16.-25.9.1998 | 118.6 ± 20.4 | 2.0 | 5.9 | 1 | 41 ± 3 | 60 |
| **Propiconazole** | | | | | | |
| Field studies | | | | | | |
| 31.7.-5.11.1997 | 183.1 ± 32.1 | 0.625 | 29.3 | 5 | 36 ± 1 | 21 |
| 29.7.-5.11.1998 | 117.8 ± 8.2 | 0.750 | 15.7 | 4 | 96 ± 7 | 35 |
| Experimental studies | | | | | | |
| 15.-24.7.1998 | 6.1 ± 0.8 | 0.125 | 4.9 | 1 | 32 ± 1 | 55 |
| 16.-25.9.1998 | 32.2 ± 6.7 | 0.125 | 25.8 | 1 | 41 ± 3 | 60 |
| **Tridimefon + triadimenol** | | | | | | |
| Field studies | | | | | | |
| 30.7.-14.10.1997 | 0.9 ± 0.33 | 0.118 | 0.8 | 2 | 98 ± 15 | 42 |
| 1.8.-13.10.1998 | 1.9 ± 0.9 | 0.118 | 1.6 | 2 | 77 ± 11 | 40 |
| Experimental study | | | | | | |
| 15-24.7.1998 | 30.3 ± 4.5 | 0.125 | 24.3 | 1 | 47 ± 3 | 49 |
| **Cypermethrin** | | | | | | |
| Field study | | | | | | |
| 30.7.-14.10.1997 | 0 | 0.024 | 0 | 1 | 98 ± 15 | 42 |
| **Alpha-cypermethrin** | | | | | | |
| Field study | | | | | | |
| 15.7.-13.10.1998 | 1.8 ± 0.5 | 0.048 | 3.7 | 2 | 126 ±17 | 64 |
| Experimental study | | | | | | |
| 15-24.7.1998 | 8.1 ± 2.0 | 0.050 | 16.2 | 1 | 47 ± 3 | 49 |



## Figures

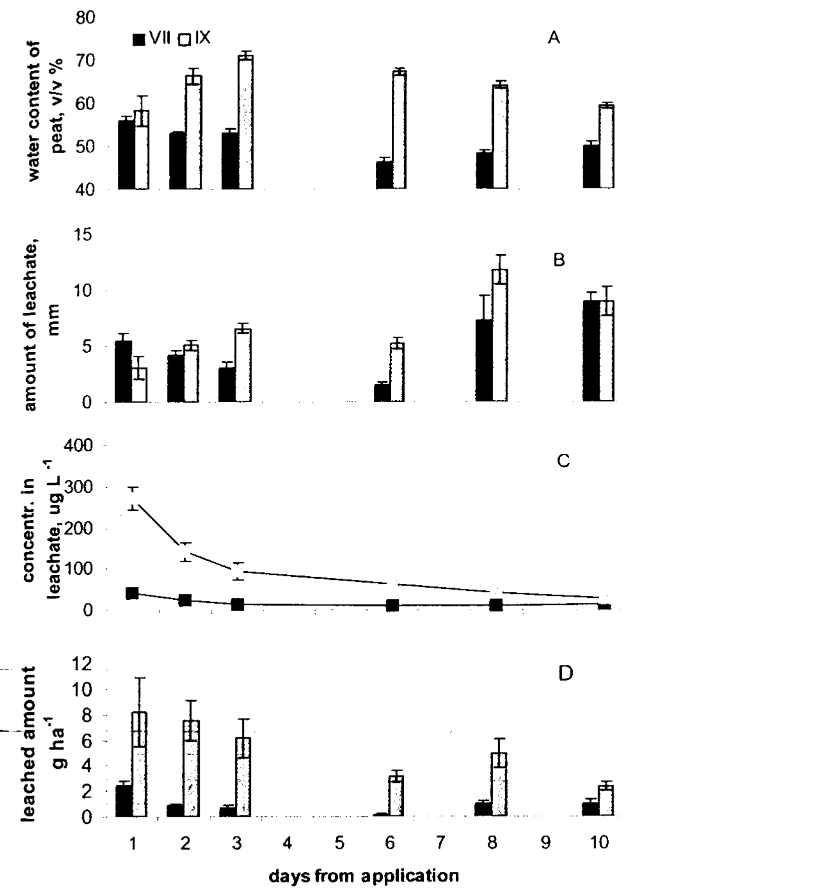


Fig. 1. Leaching of propiconazole in experiments with simulated rainfall in July (VII) and in September (IX) (number of trays = 4, mean ±SEM). A) the water content of peat in container tray before rain, v/v%, B) amount of leached water (=leachate) after rain period, mm, C) concentration of propiconazole in leachate, µg L$^{-1}$, D) the leached amount of propiconazole, g ha$^{-1}$.

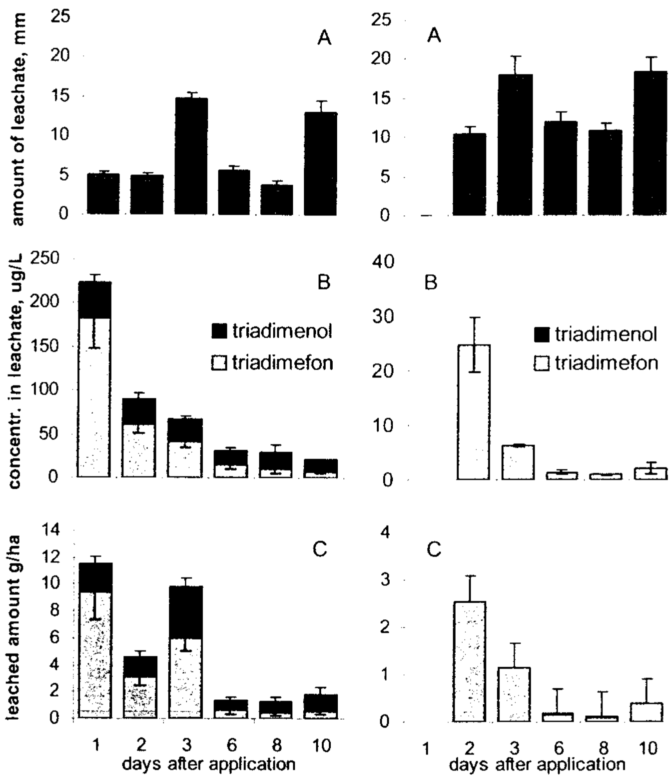


Fig. 2. Leaching of triadimefon (including triadimenol) in a birch experiment with simulated rainfall in July, leaching through peat in containers (on the left) and wash-off from leaves onto the ground (on the right) (number of trays = 4, mean ±SEM). A) amount of leached or removed water (=leachate), mm, B) concentration of triadimefon and -menol in leachates, μg $L^{-1}$, C) leached amount of triadimefon and –menol, g $ha^{-1}$.



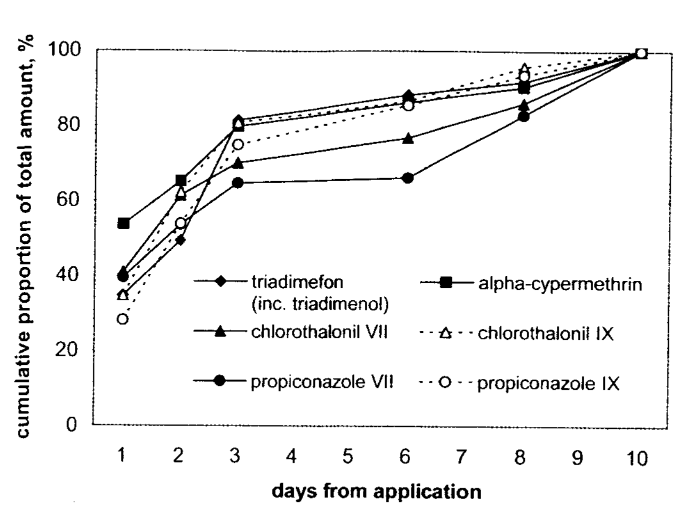


Fig. 3. Cumulative proportion of the total amount of leached pesticides at different days after application during a ten day experiment with simulated rainfall.

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