Use of Pesticides in Finnish Forest Nurseries in 1996

Marja-Liisa Juntunen

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In 1996 a questionnaire on seedling production and use of pesticides was sent to 33 forest nurseries in Finland. Twenty-eight nurseries answered the questionnaire; thus the survey covered about 80% of the Finnish production of forest seedlings. According to this study, the Finnish nurseries together are using about 1000 kilograms of pesticides (as active ingredient, a.i.) annually. The most used herbicide was terbutylazine (Gardoprim-Neste®), and half of the total amount of fungicide used was chlorothalonil (Bravo 500®). Three fourths of the insecticide products had permethrin as the active ingredient. The nurseries applied, on average, 1.7 kg pesticides (a.i.)/ha annually, although the amount varied considerably between nurseries. In production of container seedlings the highest mean amounts of pesticides were applied to pine seedlings (9.5 kg/ha) and the lowest to spruce seedlings (0.9 kg/ha). To the fields of bareroot seedlings the nurseries applied, on average, 3.9 kg pesticides (a.i.)/ha. Mean amounts of pesticide (a.i.) per 1000 seedlings grown in containers were almost the same for birch and pine production, 1.6 and 1.7 grams, respectively; for production of spruce seedlings the comparable values were less than 0.5 grams. For production of bareroot seedlings the nurseries used about four times more pesticides than for container seedlings.

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Author's address The Finnish Forest Research Institute, Suonenjoki Research Station, FIN-77600 Suonenjoki, Finland
Phone +358 17 513 811 **E-mail** marja-liisa.juntunen@metla.fi
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1 Introduction

During the 1980s and the beginning of the 1990s, production of container seedlings to a large extent replaced production of bareroot seedlings in Finland. In 1996 about 85% of all nursery seedlings were grown in containers (Västilä and Herrala-Ylinen 1998). New nursery technology and systems of production have decreased the growing time for nursery seedlings from four years to one year. In spite of the short growing time needed to produce seedlings, nurseries still have problems with pests (Uotila 1995, Lilja et al. 1997).

Finnish forest nurseries try to control seedling

losses due to weeds, diseases and insects by using good hygiene and culturing practices. Although interest in using non-chemical methods of control in pest management has increased among forest nurseries, chemical control is still needed to diminish seedling losses (South 1991, 1995, Lilja et al. 1997). Use of pesticides may, however, also have an impact on the environment (Landis et al. 1991).

Kangas et al. (1980) estimated that at the end of the 1970s Finnish nurseries used at least 18 000 kilograms of pesticides (a.i.) annually. However, no information has been available concerning the recent use of pesticides in forest nurseries in Finland. From the annual statistics on amounts of pesticides sold, it is not possible to separate the amounts sold to forest nurseries from those sold to other consumers of such products. Nor are the practices used by the nurseries for pest control well known.

In 1996 information about the actual systems and practices used by nurseries to grow seedlings was gathered by using a questionnaire-based survey. The questionnaire was divided into three parts. The general questions in the first part of the questionnaire dealt with amounts and areas of production, equipment and growing methods including use of pesticides and fertilizers. In the second part of the questionnaire more detailed information was collected concerning cultural practices and the growing schedule of some of the largest seedling lots. In the third part of the questionnaire the nurseries gave information about disease and insect problems in their nursery during the 1996 growing season. The growing practices of the nurseries and the use of fertilizers in the nurseries (Juntunen and Rikala 2001) as well as disease and insect problems (Juntunen 2000) have been reported elsewhere.

This article deals with the use of pesticides in production of container- and bareroot seedlings. The chemical-control practices used in production of container seedlings are described in more detail than those for bareroot seedlings. Both area- and seedling-based values for use of herbicides, fungicides and insecticides in production of container seedlings of different tree species are presented.

2 Materials and Methods

2.1 Questionnaire and Nurseries

The use of pesticides was asked in two ways on the questionnaire: total use during the growing season and use in growing certain seedling lots. First, nurseries gave the amounts and trademarks of pesticides used on different target sites and areas, e.g. for container- and bareroot seedlings, for open areas without containers, fallow fields and edges. Second, the nurseries gave such information as the application dates, trademarks of the pesticides used, and the doses used per hectare in growing each special seedling lot.

The questionnaire was sent to 33 forest nurseries (at latitudes 59–66°N) in Finland. Twenty-eight nurseries returned the completed questionnaire. Of these twenty were large nurseries (annual production 4–10 million seedlings) owned by commercial enterprises and eight were smaller (annual production 0.1–1.5 million seedlings), family-owned nurseries. The mean size of each enterprise-owned nursery was 30 hectares and that of a family-owned nursery was less than one hectare.

About half of the total area of the nurseries consisted of bareroot fields (290 ha). However, less than half of the bareroot fields were in seedling production (108 ha); the largest part was fallow fields. Only 12 enterprise-owned nurseries produced bareroot seedlings, but all produced container seedlings. The family-owned nurseries, on the other hand, grew only container seedlings. The area used to produce container seedlings was 105 hectares, of which 26 hectares were greenhouses and the rest was outdoor growing areas. Nurseries estimated that a large part (144 ha) of their area consisted of yards (54 ha), roads (46 ha) and edges (44 ha).

Areas used to produce container seedlings were covered. As a covering material, asphalt or a layer of stone chips (10–30 cm) or sand (20–30 cm) was used. In eight nurseries the bottoms of the greenhouses were made from asphalt, but only five nurseries had covered more than 70% of the greenhouse area. The most commonly used material was sand, which was used by 16 nurseries to cover over 70% of their greenhouse area. Outdoor growing areas were also usually covered with sand.

2.2 Representativeness of Results and Production of Nurseries

This survey covered about 80% of the total seedling production in Finland. The numbers of produced seedlings reported by nurseries (119 million seedlings) were compared to those given in official statistics (144 million seedlings) (Västilä and Herrala-Ylinen 1998). The actual coverage depended on tree species and stock types (Juntunen and Rikala 2001). During 1990–96, family-owned nurseries produced about ten per cent of all seedlings produced annually in Finland, even though the proportion of family-owned nurseries in this study was only five per cent.

In this article 'produced seedlings' refers to those seedlings that, according to the autumn inventory of the nurseries, were delivered for planting in autumn 1996 or were ready for planting in spring 1997. 'Growing stock' refers to all seedlings growing in the nurseries during the 1996 growing season. For container seedlings, the numbers of grown and produced seedlings are very similar, because over 90% of all pine and birch seedlings were delivered for planting as one-year-old seedlings. The only difference was in the number of two-year-old spruce seedlings. About 57% of the container-produced spruce seedlings were delivered for planting at the age of two years and the rest (43%) at the age of one year (Juntunen and Rikala 2001). The nurseries gave such detailed information about the production of container seedlings that the use of pesticides could also be calculated for grown seedlings.

On the other hand, for production of bareroot seedlings there was not enough information available to calculate the use of pesticides separately for each growing year. About 70% of the bareroot seedlings were spruce, 20% were birch and the rest were pine. In terms of age, the greatest number was four-year-old spruce seedlings (Juntunen and Rikala 2001). The use of pesticides could be calculated only per number of seedlings produced. The values per number of seedlings produced are valid if the numbers of different seedling types produced do not vary markedly between years.

2.3 Calculations

The use of pesticides in forest nurseries was calculated either per unit area or per seedling. The mean area-based values were calculated as nursery averages. Zero values, which meant that pesticides were not used, were not included in the mean values. Thus the per area values can be used to describe the differences between nurseries; and if seedlings were sprayed, the mean value described the real load on the nursery environment associated with the applications.

The area-based values were transformed to seedling-based values with the help of growing densities. The mean seedling-based values were calculated weighted by the numbers of seedlings produced by nurseries; and the zero values were included because, if these values are used in life-cycle analyses (Aldentun 1999), this is related to information about the total production of forest seedlings.

3 Results

3.1 Number of Pesticide Products Used

In 1996 the nurseries surveyed in this study used a total of 39 different pesticide products, of which 17 were herbicides, 12 fungicides and 10 insecticides. One nursery used, on average, eight different products. Two family-owned nurseries had sprayed with only one product and another two with two products. Six nurseries had used more than 12 products for chemical control. The maximum number of products, 17, was used in two nurseries. Although the number of products was quite large, in kilograms (as a.i.) the use of most products was very small. The six most commonly used products, two from each pesticide group, made up 76% of the whole amount.

The largest number of products was used in growing of pine seedlings (Table 1). For growing birch, all nurseries had used fungicides, about half had used insecticides and none had used herbicides. Some nurseries grew container spruce seedlings without pesticides. For growing spruce, most of the nurseries used, on average, one fungicide and one insecticide product.

Table 1. Number of pesticide products used in growing different species of container seedlings in 1996. The use of permethrin products is excluded from the results of all but two nurseries, because the other nurseries sprayed in spring 1997. n = number of nurseries.

Number of products	Number of nurseries according to detailed growing information				
	Pine, 1-y	Birch, 1-y	Spruce, 1-y	Spruce, 2-y	Spruce, 2-y
	n = 16	n = 13	n = 9	1st year n = 13	2nd year n = 15
None			1	3	5
1		2	5	6	5
2–3	9	7	1	4	2
4–5	5	3	2		3
6–7	2	1			

Table 2. Number of pesticide applications to container seedling growing stock in 1996. n = number of nurseries.

Number of applications	Number of nurseries according to detailed growing information				
	Pine, 1-y	Birch, 1-y	Spruce, 1-y	Spruce, 2-y	Spruce, 2-y
	n = 16	n = 13	n = 9	1st year n = 13	2nd year n = 15
None			1	3	5
1–5	5	9	6	10	8
6–10	6	3	2		1
11–15	3				1
15–20	2	1			

3.2 Frequency and Timing of Applications

The number of pesticide applications was greatest for growing pine (Table 2). The variation between nurseries was high; during the whole growing season one nursery sprayed 19 times and another only three times. The maximum number of applications used for growing one birch seedling lot was 19 and the minimum was two. Spruce seedlings were sprayed one to three times during the growing season.

The chemical control season was longest for growing pine. One nursery carried out the first pesticide application in April and six nurseries made the last applications in November. Almost all nurseries that grow pine applied fungicides from July to October, while most of those that grow birch applied fungicides from July to September. For growing spruce the fungicide applications were concentrated to October, when the nurseries sprayed in an attempt to prevent snow blight. About half of the nurseries, regardless of tree species, prevented insect damage with chemical control in June and July. Only a few nurseries used chemical control in an attempt to prevent weeds in containers. These applications were most frequent in second-year spruce stands in May, at which time three nurseries applied herbicides.

3.3 Amounts of Pesticides Used

Altogether, the nurseries used 662 kilograms of pesticides (as a.i.). These pesticides included herbicides (42%), fungicides (40%) and insecticides (18%) (Tables 3–5). One enterprise-owned nursery gave no information about use of pesticides, and another gave only information about production of bareroot seedlings. One enterprise-owned nursery informed only about the total use, but not the proportions used on different target sites.

During the 1996 growing season the nurseries had applied 17 different herbicide products. The most used herbicide was terbutylazine (Gardoprim-Neste®), which nurseries used, in particular, to control weeds in seedling crops (bareroot and container) (Table 3). Glyphosate (Roundup®) was used almost as much as terbutylazine, mostly for chemical control of weeds on areas without seedlings. Quinoclamine (Mogeton®) was sprayed on container seedlings to prevent the growth of liverworts.

The four most commonly used products accounted for three-fourth of the total use of herbicides (Table 3). Other products were used for chemical control of weeds on bareroot fields and also on empty outdoor areas. However, the amount of any single product used was less than five kilograms (a.i.). Herbicides other than terbutylazine and glyphosate were sprayed more on an experimental scale than on an operational scale.

About half of the total amount of herbicides

Table 3. Total use of different herbicides (active ingredient and trade name) as a.i. at different nursery sites. n = number of nurseries that had used the herbicide.

Herbicide	Container seedlings		Bareroot seedlings		Outdoor areas		Fallow fields		Edges		Total[a)]	
	kg	n=25	kg	n=10	kg	n=25	kg	n=12	kg	n=25	kg	n=27
Terbuthylazine (Gardoprim-Neste®)	19.4	11	57.0	9	17.5	2			12.3	3	122.7	17
Glyphosate (Roundup®)	2.9	1	12.2	5	23.7	6	33.2	9	14.8	11	87.8	18
Quinoclamine (Mogeton®)	14.3	8									14.3	8
Glufosinate-ammonium (Basta®)					0.2	1	6.0	1	4.0	2	10.2	2
Others (13 products)	0.7	2	17.8	6	16.2	4			5.9	5	42.2	13
Total	37.3	13	87.0	10	57.6	9	39.2	9	37.0	15	277.2	21

[a)] One nursery gave only the total use, not the proportions used at different target sites.

Table 4. Total use of different fungicides (active ingredient and trade name) as a.i. in production of container and bareroot seedlings. n = number of nurseries that had used the fungicide.

Fungicide	Container seedlings		Bareroot seedlings		Total[a)]	
	kg	n=25	kg	n=10	kg	n=27
Chlorothalonil (Bravo®)	86.5	19	41.5	7	136.9	21
Maneb (Maneba®)	19.0	7	27.8	6	46.8	10
Tiram (Tirama 50®)	13.8	7			13.8	7
Propiconazole (Tilt 250 EC®)	8.1	16	9.1	8	24.9	19
Benomyl (Benlate®)	6.5	10			10.9	11
Triadimefon (Bayleton®)	3.2	15	3.1	5	8.3	16
Others (6 products)	22.3	9	5.0	2	26.1	11
Total	159.4	23	86.5	8	267.7	25

[a)] One nursery gave only the total use, not the proportions used at different target sites.

used was applied on sites without seedlings, such as outdoor areas, fallow fields and edges, i.e. not on bareroot or container stock. Of the 50% used on growing stock, the majority (70%) was used on bareroot fields and the remainder on container seedlings.

The nurseries used a total of 12 different fungicide products. Two thirds of the total amount of fungicides was used in production of container seedlings (Table 4). Two nurseries, both of which produced only bareroot spruce seedlings, sprayed no fungicides on their bareroot fields. The most used fungicide was chlorothalonil (Bravo 500®), which accounted for half of the total amount of fungicide used.

Nurseries used 10 different insecticide products, three of which contained permethrin (Table 5). Almost 80% of the total amount of insecticides were products that had permethrin as the active ingredient. To prevent seedling damage by the pine weevil in the forest after planting, seedlings were sprayed with permethrin products some days before they were shipped to the forest for planting, usually in spring. All nurseries located at 62°N or farther south sprayed pine and spruce seedlings with permethrin products.

Table 5. Total use of different insecticides (active ingredient and trade name) as a.i. in production of container and bareroot seedlings. n = number of nurseries that had used the insecticide.

Insecticide	Container seedlings		Bareroot seedlings		Total[a)]	
	kg	n = 25	kg	n = 10	kg	n = 27
Permethrin (Gori 920®, F-permetriini®, Ambush®)	75.4	11	8.8	3	92.4	13
Dimethoate (Roxion®, R-Dimetoaatti®)	4.7	11	4.8	3	9.6	12
Oxydemoton-methyl (Metasystox R®)	4.0	4	3.4	3	14.0	7
Cypermethrin (Ripcord®)	0.4	9	0.4	2	1.0	9
Others (3 products)	0.2	3	1.4	2	1.6	5
Total	84.7	20	18.8	6	118.6	24

[a)] One nursery gave only the total use, not the proportions used at different target sites. Two nurseries gave no specific amounts, only indicating that they had used a little of the insecticide in question.

Products other than those containing permethrin were used to prevent insect damage during the summer. The nurseries included in this study used only about 25 kilograms of these other insecticides (a.i.), and the amounts used per nursery were small. Dimethoate (Roxion®, R-Dimetoaatti®) was the most used insecticide in terms of amount as well as number of nurseries.

Three nurseries, two enterprise-owned and one family-owned, used no insecticides in production of container seedlings. For production of bareroot seedlings the respective number of nurseries was four out of ten. Over 80 per cent of the insecticides were used in production of container seedlings (Table 5).

One estimate of annual pesticide use can be calculated by dividing the total quantity of pesticides by the area of the nursery. The amounts used varied between nurseries; southern enterprise-owned nurseries used 1.8 kg pesticides (a.i.) per hectare, northern enterprise-owned nurseries used 1.2 kg and family-owned nurseries used 1.5 kg. The best explanation for these differences was insecticide applications against pine weevil in the southern nurseries.

The nurseries applied, on average, 3.9 kg of pesticides (a.i.) per hectare to the fields of bareroot seedlings. The variation between nurseries was 0.6 to 13.2 kg/ha. The highest mean doses of herbicides were sprayed on the edges (2.4 kg/ha), the next highest on outdoor areas without seedlings (1.2 kg/ha) and the smallest amount on fallow fields (0.5 kg/ha). These values are, however, imprecise because the questionnaire did not ask about exact areas of application.

According to the seedling lot information for production of container seedlings, all nurseries used fungicides for growing birch and pine, and about half of the nurseries used fungicides for growing spruce. The largest doses per hectare were applied to the pine seedlings, for which the mean value was 8.4 kg fungicides per hectare as a.i. (Fig. 1). The mean amounts of fungicide used for production of birch (1.3 kg/ha) and spruce (0.9–1.3 kg/ha) seedlings were about the same.

Insecticides were also sprayed most on pine seedlings (2.5 kg/ha). The permethrin applications, which two nurseries carried out already in autumn on the monitored seedling lot, explain the high mean value. In Fig. 1 the amounts of permethrin used are marked on the bars with a dotted line. Otherwise, the difference in insecticide doses between tree species was not as great as the difference in fungicide doses. Herbicides were used in large amounts only on second-year spruce stocks (3 kg/ha).

In terms of total amounts of pesticides, the variation between nurseries was great (Fig. 1). However, there was no tendency for those nurseries that used large amounts of pesticides, e.g. in pine production, also to do so for spruce production. Pesticides were applied in accordance with the recommended rates given on the product labels. Only one nursery sprayed regularly with insecticide throughout most of the growing season.

Another estimate of pesticide usage can be expressed as amount used to produce 1000 shippable seedlings. The values per 1000 produced seedlings makes it possible to compare container-

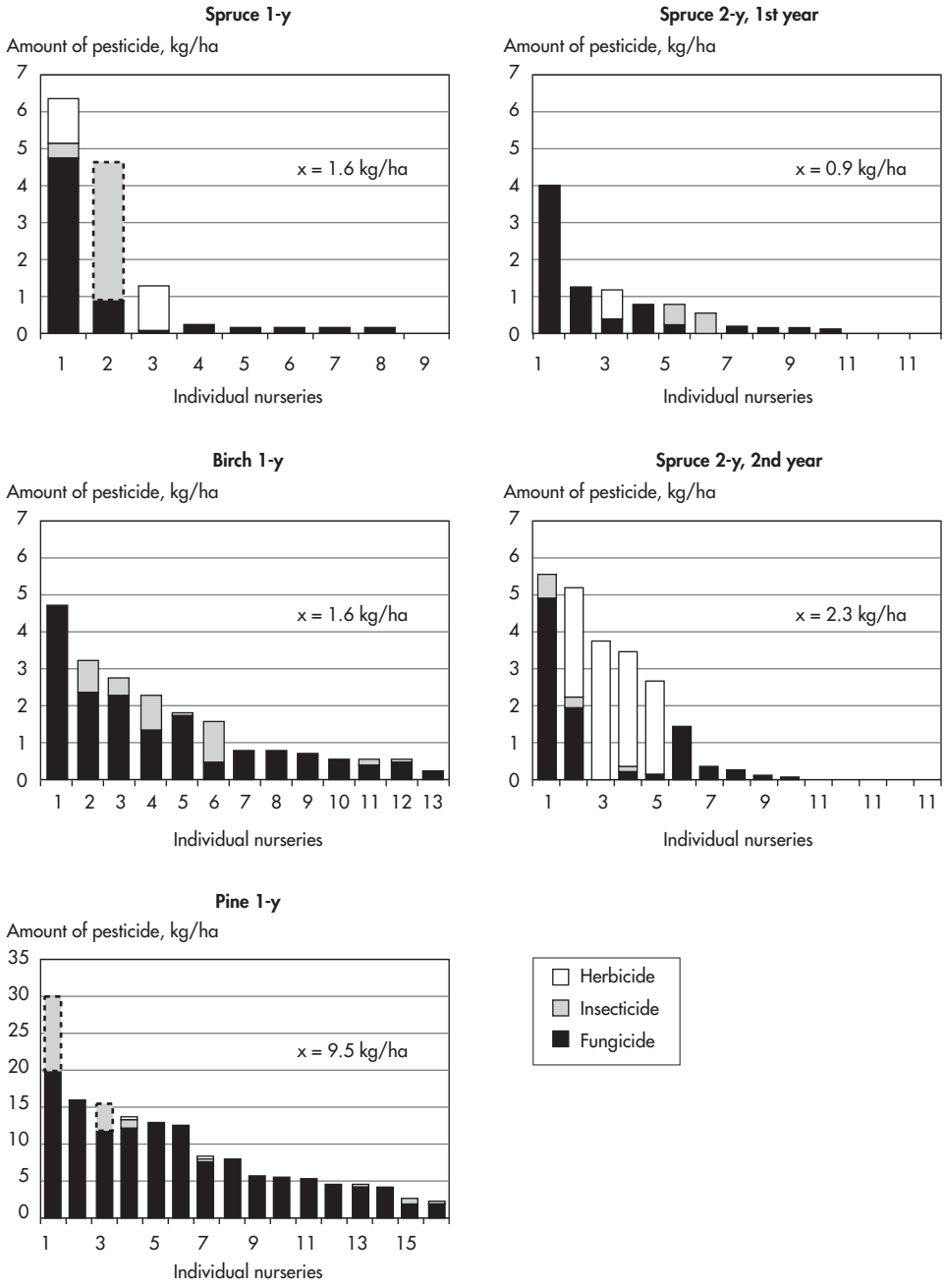

Fig. 1. Use of pesticides per unit area according to the detailed growing information. Zero values are not included in the mean. The nurseries are arranged in decreasing order according to amounts of pesticides, which means that number one does not represent the same nursery in all seedling lots. The amounts of permethrin applied by two nurseries in autumn are marked on the bars with a dotted line.

Table 6. Comparison of pesticide use in production of container and bareroot seedlings. The means, which were weighted by amount of production of the nurseries, were calculated as grams of active ingredient per 1000 seedlings produced.

	Container	Bareroot
	grams/1000 seedlings	grams/1000 seedlings
Herbicides to seedlings	0.3	5.6
Herbicides to outdoor areas	0.6	
Herbicides to fallow fields		2.3
Fungicides to seedlings	1.6	5.6
Insecticides to seedlings	0.9	1.2
Total	3.4	14.7

Table 7. Mean use of pecticides per 1000 container seedlings in different seedling stocks during the 1996 growing season. These results are based on the detailed growing information. When mean values were calculated, they were weighted by the number of seedling produced by the nursery, and zero values are also included.

	Active ingredient grams per 1000 seedlings				
	Number of nurseries	Use of fungicides	Use of insecticides	Use of herbicides	Total
Birch 1-y	13	1.39	0.19	0.00	1.58
Pine 1-y	16	1.40	0.30	0.002	1.70
Spruce 1-y	9	0.19	0.27	0.05	0.51
Spruce 2-y, 1st year	13	0.12	0.01	0.01	0.14
Spruce 2-y, 2nd year	15	0.13	0.01	0.11	0.25
Seedling[a], on average	25	1.23	0.65	0.28	2.16

[a] Based on total number of seedlings and on total use of pesticides (from annual inventories).

and bareroot seedlings (Table 6). The nurseries used about four times more pesticides for growing bareroot seedlings than for growing container seedlings.

The seedling-based values for different tree species were obtained from the detailed growing information (Table 7). In birch production the nurseries separate containers from each other so that there are about 20 centimeters of free space between containers. The free spaces increase the flow of air between containers and prevent diseases. This separation increases the required growing area about twofold. Although the nurseries separated the containers on very different dates during the summer, only 15% of all applications were made before separation. In our calculations the pesticide values for 1000 seedlings were therefore not twofold but 1.85 fold.

The difference between values calculated on the basis of detailed growing information and those calculated from the total use of pesticide is large (Table 7). Evidently the values obtained from detailed growing information underestimate the actual use.

4 Discussion

The nurseries included in this study used a total of 662 kg of pesticides (a.i.) during the 1996 growing season. If it is estimated that the rest of the nurseries in Finland used the mean amount of pesticide, the total use of pesticides in the whole country that year was about 1000 kilograms. If this amount is compared with the estimation of 18 000 kilograms made at the end of the 1970s (Kangas et al. 1980), pesticide use has decreased tremendously. The main reasons for the decrease in the use of pesticides are the increased proportion of container-seedling production, shorter growing time and the decrease in total production area.

In Finland the number of seedlings produced has also decreased since the 1980s, from 210–250 million seedlings to 150–180 million seedlings. In particular, the production of pine has decreased. According to the survey, the largest amounts of pesticides were used in pine production. The change in pesticide products may also have decreased their use. To obtain the desired effect with new active ingredients, the doses required are usually lower than with the old ingredients.

In 1996 a total of 956 metric tons of pesticides (a.i.) were sold in Finland. Of this amount, 21 metric tons were for forest protection (Hynninen and Blomqvist 1997). Forest nurseries are using

about 5% of the amount used in the forest sector and about 0.1% of the total amount of pesticide used in Finland. Although in terms of environmental effects, the nurseries are only a small point source of pesticides, they may be important locally, because some nurseries are located on ground water areas.

In Sweden, Persson (1992) examined the pesticide use of 15 nurseries in 1991 and found that use of pesticides depended on the size of the nursery. The large nurseries (production over 20 mill. seedlings) used, on average, 2.5 grams pesticide (a.i.) per 1000 seedlings and small ones (production less than 5 mill.) used 5.1 grams per 1000 seedlings. In Finland small, family-owned nurseries carried out fewer applications and used fewer products in production of seedlings than large enterprise-owned nurseries did. The small assortment of seedling types, growing of spruce and the young age of the nurseries may be possible explanations for the modest use of pesticides among family-owned nurseries.

In both Sweden and Finland the variation in pesticide use between individual nurseries was great. The mean values in Persson's (1992) and this study were, however, very similar. The use of pesticides per 1000 grown seedlings varied depending on seedling type and tree species. The magnitude of the values is, however, the same for all species of container seedlings, and this information is important when life-cycle analysis is made for wood-based products (Aldentun 1999).

The bareroot nurseries in the southern United States had applied, on average, about 2.0, 2.9 and 1.7 kg a.i./ha/crop of herbicides, fungicides and insecticides, respectively (South and Zwolinski 1996). On the basis of these values, the average use of pesticides per unit area in these nurseries was about twice the amount used on Finnish bareroot fields.

On the basis of the total area of nurseries and their use of pesticides, the nurseries applied, on average, 1.7 kg pesticides (a.i.)/ha annually. In Finland the use of pesticides on agricultural areas is also calculated by the same method. From 1990–1994 the estimated value was found to vary between 0.7 and 1.0 kg pesticides (a.i.)/ha (Laitinen et al. 1996). In Europe the highest mean use has been 10–17 kg/ha annually in Belgium and the Netherlands; in many countries the smallest mean use has been about two kilograms per hectare (Brouwer et al. 1994)

The mean amounts of pesticide use were greatest for pine seedlings (9.5 kg/ha) and smallest for spruce seedlings (0.9 kg/ha). Also in agricultural use, the species grown affects the use of pesticides. For cereals the annual rate is estimated to be about 2.6 kg/ha (Laitinen et al. 1996). According to Eronen (1998), during 1990–1997 the mean annual rates of pesticides (a.i.) used in sugarbeet fields has been 3.5–5.5 kg/ha. The use of pesticides varied considerably among 400 farms in four different catchment areas in Finland (Seppälä 1999). In one area the mean annual rate, 1.5 kg/ha, was greater than in other areas, 0.4–0.6 kg/ha. In forest nurseries the amounts used were at the same level as those used for some agricultural crops in Finland.

The use of pesticides was asked in two ways: total use during the 1996 growing season and use in growing certain seedling lots. These two ways gave different results. Apparently, it is not possible to calculate the total use of pesticides on the basis of values obtained from detailed information. The timing of permethrin applications explains some of the difference. Two nurseries reported that they sprayed the monitored seedling lot in autumn, and only this use of pesticides was included in the calculations based on detailed information. One explanation could be that nurseries had to use more chemical control in growing of seedling lots other than the monitored one. Another explanation could be that the amounts which nurseries sprayed near the containers (paths and edges) and areas without seedlings were not included in the detailed information.

The use of pesticides varied, not only between nurseries, but also within the same nursery. Some nurseries grew spruce seedlings without chemical control, which meant that there was no pesticide load on the environment from these areas. At many nurseries the largest area was used for growing spruce (Juntunen and Rikala 2001). The highest mean amounts of pesticide were used in production of pine seedlings. In bareroot production, the area for pine was very small; and in container production, the high growing density of pine decreased the area needed.

It should be noted that production of container

seedlings is more similar to horticultural production than to agricultural production. Seedlings are started in greenhouses and, depending on seedling type, are raised in greenhouses from two to six months with peat as the growing media. When container seedlings are sprayed with pesticides, most of the pesticide is sprayed on the very densely growing seedlings. In production of container seedlings the pesticides leaching to the ground include both pesticides leaching from the growth medium and pesticides applied directly to aisles and other empty space around the container blocks.

Timing of application may influence leaching. In greenhouses, leaching depends on how well nurseries arrange irrigation (Dumroese et al. 1995). On outdoor areas, leaching depends more on weather conditions, in particular, on the amount of precipitation**.** Evidently, the application method and skills of the sprayer influence the amount of pesticides sprayed outside containers, i.e. not on seedlings. In most Finnish nurseries, one or two persons are responsible for pesticide application.

For production of bareroot seedlings the situation is similar to that on agricultural fields. On bareroot fields, seedlings grow at much lower density than in containers, and there are empty areas between seedling rows and beds. Much more of the pesticide suspension is applied directly on the ground than in container production. In Finland the soil of bareroot fields is, however, improved with peat, which increases the organic matter content of fields and may prevent leaching of some pesticides.

Places where the risk of herbicide leaching may be high are outdoor areas and edges. These areas are often, at least in Finland, sandy soils with little organic matter. Nor do the sand and stone chips that most nurseries used as material covering outdoor areas prevent possible leaching. Although the nurseries already used textiles to cover the empty spaces between containers, solutions other than chemical control for preventing the growth of weeds on sites without seedlings would be most welcome.

The results presented in this article are based on values given by nurseries concerning their use of pesticides. The coverage of the survey was good, over 80% of the total seedling production in Finland; but the results are based on pesticide use during only one growing season. The pest situation and the need for chemical control at the nurseries vary from year to year depending, for example, on weather conditions (Lilja et al. 1997). In June and July 1996 the weather was favorable for diseases. Both months were rainy and the mean daily temperature was lower than normal. On the other hand, the autumn was warm and dry.

One problem with pesticides is that they are not a homogeneous group, and leaching depends on the characteristics of individual active ingredients. Today, however, forest nurseries in Scandinavia are allowed to use only a very few products. For example, only three herbicides, namely hexazinone (Velpar L®), terbutylazine and glysophate, of the 17 herbicides that nurseries applied during the 1996 growing season, were registered for use in forest nurseries. The nurseries tried, by using other herbicides, to find new solutions for chemical control of weeds, because it was known that terbutylazine (Gardoprim-Neste®) would soon disappear from the market. New products that can be used by nurseries are becoming available less and less often. In reality, there are so few registered products available that nurseries can rarely choose from among several products the one that is least harmful to the environment.

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Total of 18 references