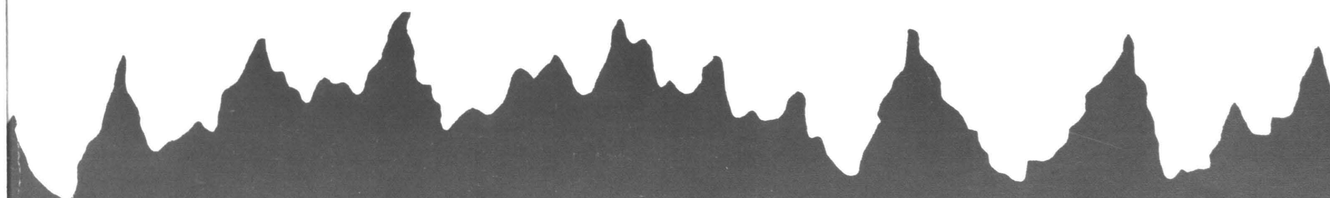
SILVA FENNICA

1991 · Vol. 25 N:o 2



SUOMEN METSÄTIETEELLINEN SEURA
SOCIETY OF FORESTRY IN FINLAND

SILVA FENNICA

A quarterly journal of forest science

PUBLISHER – JULKAISIJA

The Society of Forestry in Finland
Suomen Metsätieteellinen Seura r.y.

AIM AND SCOPE – TAVOITTEET JA TARKOITUS

Silva Fennica publishes papers relevant to Finnish forestry and forest research. The journal aims to cover all aspects of forest research, ranging from basic to applied subjects. Besides research articles, the journal accepts research notes, scientific correspondence, and reviews.

Silva Fennicassa julkaistaan artikkeleita, joilla on merkitystä Suomen metsätalouden ja metsäntutkimuksen kannalta. Sarja kattaa metsätalouden kaikki osa-alueet ja julkaisee sekä metsätieteen perusteita käsitteleviä että sovellutuksiin tähtääviä kirjoituksia. Tutkimusraporttien lisäksi julkaistaan tiedonantoja, keskusteluartikkeleita ja katsauksia.

SUBSCRIPTIONS – TILAUKSET

Subscriptions and orders for back issues should be addressed to Academic Bookstore, P.O. Box 128, SF-00101 Helsinki, Finland, Annual subscription price is FIM 250. Exchange inquiries can be addressed to the editorial office.

Tilaukset ja tiedustelut pyydetään osoittamaan toimitukselle. Silva Fennican tilaushinta kotimaahan on 180 mk, ulkomaille 250 mk. Seuran jäsenille lehti jaetaan jäsenmaksua vastaan.

This journal is indexed in Agrindex, Biological Abstracts, Current Advances in Ecological Sciences, Current Advances in Plant Science, Ecological Abstracts, Forest Products Journal, Forestry Abstracts, International Bibliography of Periodical Literature, Life Sciences Collection.

Chemical control of cone pests in a Norway spruce seed orchard

Erkki Annila & Kari Heliövaara

TIIVISTELMÄ: KUUSEN KÄPYTUHOJEN KEMIALLISESTA TORJUNNASTA SIEMENVILJELYKSILLÄ

Annila, E. & Heliövaara, K. 1991. Chemical control of cone pests in a Norway spruce seed orchard. Tiivistelmä: Kuusen käpytuhojen kemiallisesta torjunnasta siemenviljelyksillä. Silva Fennica 25(2): 59–67.

The effect of three pesticides containing either dimethoate (0.5 % a.i.), permethrin (0.05 %) or triadimephon (0.05 %) on the cone pests and flowering biology of Norway spruce was tested in a seed orchard in southern Finland. The developing cones were treated in mid May or in the beginning of June. The pesticide treatments significantly reduced infestation by *Laspeyresia strobilella* and *Kaltenbachiella strobi* only. Variation in the number of cones infested by both insects and cone rusts was high between the spruce clones. Generally, the pesticides did not affect flower viability, seed quality or seed germination, but reduced drastically the germinating capacity of the pollen *in vitro*. In practice, sufficient control cannot be achieved with the concentrations or methods used in the present study.

Hyönteisten ja käpyruosteiden aiheuttamien käpy- ja siementuhojen torjumista tutkittiin eteläsuomalaisella kuusen siemenviljelyksellä. Kehittyviä käpyjä käsiteltiin dimetoaattia (0,5 %), permetriiniä (0,05 %) tai triadimefonia (0,05 %) tehoaineena sisältävillä torjunta-aineilla. Osa kävyistä käsiteltiin toukokuun puolivälissä, osa kesäkuun alussa. Vain käpykääriäisen ja kuusenkäpysääsken esiintymistä voitiin merkitsevästi vähentää käsittelyillä. Sekä hyönteisten että ruostesienien määrissä esiintyi suurta vaihtelua kloonien välillä. Torjunta-aineet eivät vaikuttaneet olennaisesti käpyjen määrään, siemenen laatuun tai siemenen itävyyteen, mutta vähensivät huomattavasti siitepölyn itävyyttä laboratoriokokeissa. Käytännön kannalta käytetyt torjunta-aineväkevyydet tai käsittelyjen määrä eivät osoittautuneet riittäviksi tuholaisten torjunnassa.

Keywords: *Picea abies*, chemical control, cone pests, pollen, seed quality.
FDC 414 + 232.3 + 174.7 *Picea abies*

Authors' address: Finnish Forest Research Institute, P.O. Box 18, SF-01301 Vantaa, Finland.

Accepted September 5, 1991

1 Introduction

Insects and fungal diseases destroy a considerable proportion of the seeds in the cones of Norway spruce (*Picea abies* (L.) Karsten), especially when the trees have produced cones also in the previous year. Insect pests affect seed yield either by feeding on the seeds or indirectly by preventing the cones from opening during seed extraction. Rust fungi disturb seed development by utilizing the assimilation products allocated for seed production.

The most destructive insect species are *Cydia strobilella* (L.), (Lepidoptera, Tortricidae), *Di-*

oryctria abietella (Denis & Schiffermüller) (Lepidoptera, Pyralidae), and *Lasiomma anthracinum* (Czerny) (Diptera, Anthomyiidae) in cones, and *Plemeliella abietina* Seitner (Diptera, Cecidomyiidae) and *Megastigmus strobilobius* (Ratzeburg) (Hymenoptera, Torymidae) in seeds. *Kaltenbachiella strobi* (Winnertz) (Diptera, Cecidomyiidae) is often abundantly present in the cones without causing any marked damage. Two cone rust diseases, *Pucciniastrum areolatum* (Fr.) Otth and *Chrysomyxa pirolata* Winter infest cone scales resulting in seed losses.

When cones are collected for seed extraction in forest stands the effect of damaging agents can often be compensated by collecting a larger number of cones. In seed orchards, however, the number of cones is limited and every cone should be productive. In practice, pest control is often considered necessary to ensure the quality of the cone crop in seed orchards.

Several studies dealing with the control of cone and seed insects with chemicals have been published since the beginning of the 1960's (Merkel 1976). Systemic insecticides (e.g. dimethoate, oxydemetonmethyl) have proved to be rather effective (Hedlin 1962, 1964, 1966, Johnson 1962, 1963, Annila 1973, Summers and Miller 1986). Contact insecticides, pyrethroids, have recently also been tested in the control of cone worms (*Dioryctria* spp.) and seed bugs (Heteroptera, *Leptoglossus*, *Tetyra*) in seed orchards in North America (Overgaard 1981, Nord et al. 1984, 1985, Summers and Ruth 1987). Pyrethroids have two advantages, low mammalian toxicity and a longer-lasting effect.

While numerous insecticides have been tested to protect the cone crop, only a few attempts have been made to control cone rusts. Summers et al. (1986) demonstrated that *Chrysomyxa pirolata* infestation in the cones of *Picea glauca* (Moench) Voss can be markedly reduced by spraying the cones with ferric dimethyldithiocarbamate.

The aims of the present study were 1) to test the efficacy of permethrin (a pyrethroid) for insect control compared with dimethoate (a systemic organophosphate), and triadimephon (a systemic organic fungicide) for fungi control in a Norway spruce seed orchard, and 2) to study the possible phytotoxic effects of these pesticides on pollen, female flowers and seeds.

Our warmest thanks are due to A. Pasanen and J. Järvenpää from the National Board of Forestry for carrying out the field work, to A. Immonen, E. Kemppi, M. Nieminen for their help in the laboratory, to S. Lilja for performing the pollen analyses, to I. Mannerkoski for commenting on the manuscript, and to J. Derome for checking the English.

2 Material and methods

2.1 Study area and pesticide treatments

The field work was carried out in a Norway spruce seed orchard (No. 365) located in Joutsa, southern Finland (61° 40'N, 26° 15'E) in 1989. The orchard was established in 1970–72, the height of trees ranging now from four to eight metres. All trees (grafts) of the same clone have been planted in a single row.

The material consisted of 300 trees, belonging to 16 different clones. The five treatments consisted of an untreated control, permethrin (0.05 % a.i.) (Ambush®), dimethoate (0.5 % a.i.) (Roxion®), triadimephon (0.05 % a.i.) (Bayleton 25®), and a combination of dimethoate (0.5 %) and triadimephon (0.05 %). Three successive trees belonging to the same clone in each row were sprayed once with the same pesticide. One tree was left untreated in between treatments, and one row of untreated trees was left between the treated ones. Tree crowns carrying cones were sprayed with backpack pumps driven by a forest tractor. Each tree was treated with the pesticide until cones and twigs were fully saturated.

150 trees were sprayed on May 15–16 during of the flowering period when the female flowers were open and erect (temperature sum of 99 degree days). In southern Finland, the temperature sum for anthesis in Norway spruce is ca. 140 d.d. (Sarvas 1967). Another 150 trees were sprayed on June 1 (248 d.d.), when the cones had already turned down. Both sets of treatments were repeated in ten different clones. Three of the clones were included in both applications, thus making it possible to compare the effect of pesticides sprayed at two different times. The weather was warm (+20 °C) and slightly windy during both applications.

2.2 Cone analysis

The first cone samples were collected at the end of August. All the cones from one branch (at least 10 cones) on each tree were included in the sample. The cones were stored in plastic bags at –18 °C for detailed analyses. After visual examination for the aecidia of fungal diseases, the cones were dissected longitudinally and all the seeds along on both sides of the cut surfaces were picked out. The seeds were opened under a stereomicroscope to determine the percentage of filled and insect-damaged seeds. Both halves of each cone were inspected scale by scale in order to detect the number and species of insect larvae. Altogether 38542 seeds and 2855 cones were analysed.

The rest of the cones from the treated trees were collected in late September. The seeds were extracted from the cones in a commercial seed extractory for X-raying and germination tests.

2.3 Flower, seed and pollen viability analyses

The number of withered female flowers was counted June 14 in order to determine the possible phytotoxic effects of the chemicals. All the cones from one branch pointing along the row were counted in each clone.

Seed quality was initially examined by X-raying 200 seeds of each clone per each treatment (20000 seeds in total). The seeds were classified into eight different categories primarily on the basis of embryonic development (see Table 3). A sample of 1000 seeds was weighed for each clone per each treatment. Seed germination was determined using 200 seeds of each clone per each treatment in standardized germination conditions at 21 °C. Germination was checked after 10, 15 and 21 days, and the proportion of germinated seeds calculated.

The tolerance of spruce pollen against the pesticides was tested *in vitro*. Pollen sets of three different origins were distributed on a water-agar dilution in Petri dishes. The three pesticides were dissolved in agar using the same final concentration of active ingredients as in the field trials. The germination capacity of about 600 randomly selected pollen grains was analysed under a microscope after three days. A pollen grain was interpreted as having germinated when the length of the germ was longer than the diameter of the pollen grain.

Traditional parametric (ANOVA) and non-parametric statistical analyses (Chi square, Kruskal-Wallis and Wilcoxon matched-pairs signed-ranks test) were used to test the differences between different treatments.

3 Results

3.1 Pest control

The first application did not have any marked effect on the proportion of cones infested by *Dioryctria abietella* ($X^2 = 3.92$, NS, df = 4, Fig. 1). After the second application, the lowest proportion of infested cones was recorded in the rows treated with dimethoate or permethrin, the difference between the treatments being significant ($X^2 = 11.41$, $p = 0.022$, df = 4).

Variation in the proportion of infested cones between the clones was high. The differences between the clones were significant in seven cases out of ten ($0.01 < p < 0.001$).

The proportion of infested cones within a clone was smaller after the first application in eight cases out of 12 (untreated excluded) than after the second one. In four cases the difference was statistically significant ($0.05 < p < 0.001$). However, the effect of random variation is high because significant differences were also observed between the untreated cones.

Lasiomma anthracinum occurred in rather low numbers in the study material. Only 36 cones (1.3 %) were infested by the species. Neither the first ($X^2 = 1.01$, NS, df = 4) nor the second application ($X^2 = 1.87$, NS, df = 4) affected the abundance of the pest in the cones. Possible clonal variation was not investigated due to the limited material.

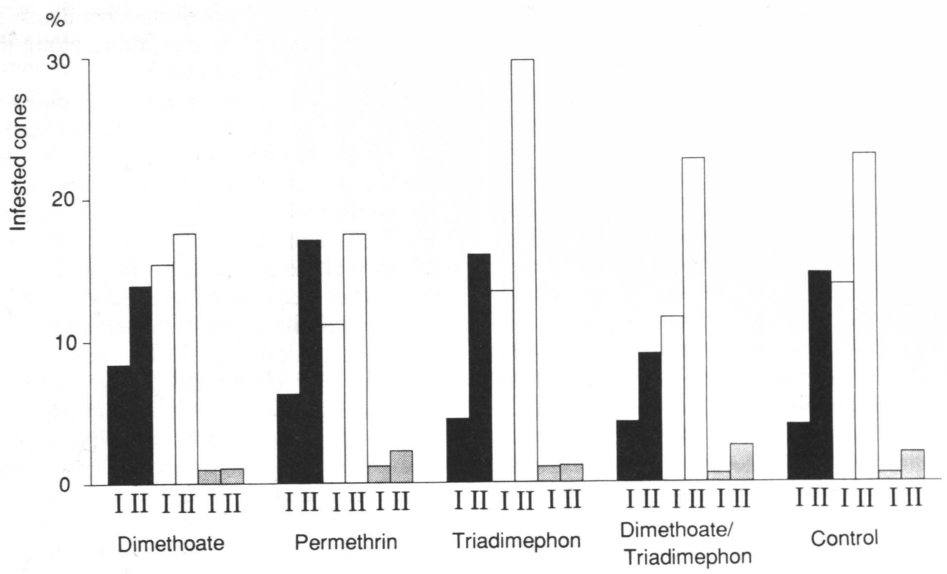


Fig. 1. Proportions of cones infested by *Pucciniastrum aerolatum* (dark), *Dioryctria abietella* (white) and *Lasiomma anthracinum* (grey) in the different treatments. Application time: I = May 15–16, II = June 1.
Kuva 1. Kuusentuomiruosteen (tumma), käpykoisan (valkoinen) ja kuusenkäpykärpäsen (harmaa) vioittamien käpyjen osuudet eri torjunta-ainekäsittelyissä. Käsittelyajankohta: I = toukokuun 15–16., II = kesäkuun 1.

The number of *Laspeyresia strobilella* larvae recorded inside the cones varied from 0 to 8, and was highest in the untreated cones (Fig. 2). The lowest number of larvae was observed in cones treated with dimethoate. Both insecticides reduced infestation after the first ($H = 65.37$, $p < 0.001$, $df = 4$) and the second application ($H = 51.60$, $p < 0.001$, $df = 4$). The variation between the clones was also very high for both applications (in all H values $p < 0.001$).

Within the clones, the first treatment reduced the number of larvae more effectively than the second one. The difference was statistically significant in eight cases out of 12 (untreated excluded) ($0.05 < p < 0.001$).

The number of *Kaltenbachiella strobi* larvae in the cones varied between 0 and 8. As was the case for *Laspeyresia*, the lowest numbers were recorded in the cones treated with dimethoate and the highest in the untreated cones (Fig. 2). The variation between the clones was also high; in all cases except one the difference was statistically significant. No clear trend was revealed between the timing of treatments within the clones.

No seed-destroying insects were found in the seed material. Dissection of the seeds did not reveal any larvae of *Megastigmus strobilobius* nor of *Plemeliella abietina*. This observation was confirmed by X-raying.

The cone rust, *Pucciniastrum areolatum*, occurred in 9.0 % of the cones in the pooled material (Fig. 1). A related cone rust, *Chrysomyxa pirolata*, was observed in only one cone. Triadimephon treatment did not affect the abundance of rusts after the first application. The highest number of infested cones was observed in trees treated with insecticides, the difference being statistically significant between all the treatments ($X^2 = 10.03$, $p < 0.040$, $df = 4$). After the second spraying, the lowest proportion of infested cones was recorded in the trees treated with a combination of triadimephon and dimethoate ($X^2 = 11.41$, $p = 0.022$, $df = 4$).

3.2 Flower development

Altogether 3.6 % of the female flowers had withered after the first application and 4.9 % after the second (Table 1). Differences in flower viability were small between treatments. None of the pesticides significantly increased flower withering compared with the untreated trees.

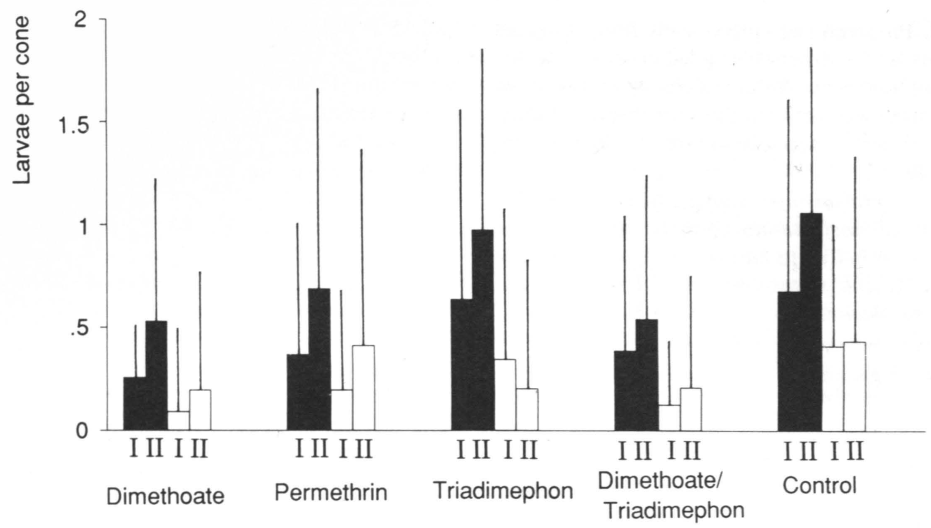


Fig. 2. Number of *Laspeyresia strobilella* (dark) and *Kaltenbachiella strobi* (white) larvae (mean, standard deviation) per cone in the different pesticide treatments. Application time: I = May 15–16, II = June 1.
Kuva 2. Käpykääriäisen (tumma) ja kuusenkäpysääsken (valkoinen) toukkien lukumäärät (keskiarvo, keskihajonta) kävyissä eri torjunta-ainekäsittelyissä. Käsittelyajankohta: I = toukokuun 15–16., II = kesäkuun 1.

The proportion of withered flowers varied between the clones in both applications (May 15–16: $H = 26.12$, $p = 0.002$, $df = 9$; June 1: $H = 24.92$, $p = 0.002$, $df = 8$, Kruskal-Wallis test). The effect of the clone on flower viability was thus greater than that of the pesticide. Those clones where the proportion of withered flowers was high in the treated trees were also associated with high level of flower withering in the untreated trees. This was true for both the first ($T = 14$, NS, $n = 7$, Wilcoxon test) and the second applications ($T = 4$, NS, $n = 7$).

3.3 Seed quality

On an average, 48.6 % of the seeds from the dissected cones were empty, indicating unsuccessful pollination or fertilization. In general, the pesticides did not have any marked effect on seed quality as indicated by the percentage of empty seeds (Table 2). However, the proportion of empty seeds in both treatments with permethrin was significantly lower than that for the untreated trees.

The proportion of empty seeds varied considerably between the clones. As with flower via-

Table 1. Percentages of withered female flowers in the different treatments. Values of the chi-square test show the difference between the treated and untreated material. Application time: I = May 15–16, II = June 1.
Taulukko 1. Surkastuneiden emikukkien osuudet eri torjunta-ainekäsittelyissä. Testisuure kuvaa käsitellyn ja käsittelemättömän aineiston eroa. Käsittelyajankohta: I = toukokuun 15–16., II = kesäkuun 1.

Treatment *Käsittely*	Application *Ajankohta*	Female flowers *Emikukkia* no. *kpl*	withered % *surkastuneita, %*	X^2	p
Dimethoate	I	363	4.1	0.06	0.813
	II	287	4.2	0.02	0.903
Permethrin	I	378	1.9	1.64	0.200
	II	189	4.8	0.12	0.726
Triadimephon	I	351	4.8	0.52	0.469
	II	179	6.1	0.89	0.344
Dimethoate/	I	302	2.0	1.07	0.300
Triadimephon	II	150	6.7	1.19	0.255

Table 2. Proportion of empty seeds from dissected cones (endosperm not recorded inside) in the different treatments. Values of chi-square test show the difference between the treated and untreated seed material. Application time: I = May 15–16, II = June 1.

Taulukko 2. Halkaistujen käpyjen tyhjien siementen osuus eri torjunta-ainekäsittelyissä. Testisuure kuvaa käsitellyn ja käsittelemättömän aineiston eroa. Käsittelyajankohta: I = toukokuun 15–16., II = kesäkuun 1.

Treatment *Käsittely*	Application *Ajankohta*	No. of seeds *Siemeniä, kpl*	Empty seeds, % *Tyhjiä, %*	X^2	p
Dimethoate	I	5975	45.3	0	0.990
	II	3862	52.4	20.61	<0.001
Permethrin	I	4486	39.1	39.13	<0.001
	II	2973	50.9	29.24	<0.001
Triadimephon	I	4634	44.6	0.44	0.507
	II	1999	60.0	2.29	0.131
Dimethoate/	I	3254	50.3	21.19	<0.001
Triadimephon	II	2535	56.6	0.84	0.361
Untreated	I	5665	45.3		
Käsittelemätön	II	3150	57.8		

bility, the high proportion of empty seeds was associated with certain clones (T_I = 27, NS, n = 10; T_{II} = 16, NS, n = 8), thus masking the effect of pesticide treatments.

The differences in the quality of the extracted seeds between the treatments were also small. The proportion of seeds with a fully developed embryo and endosperm (category a, Table 3) was 5...10 % higher in the first group than in the second one. The difference was, however, related to clonal variation, since the difference between untreated seeds was similar. Statistical analysis was not performed between the two applications because different clones were used in the treatments. The proportion of seeds with an endosperm but no embryo (category f) was higher in the former application than in the latter (H = 14.72, p = 0.005, df = 4, Table 3).

3.4 Seed germination

The difference in seed weight between the pesticides was not significant in either the first application (F = 0.54, p = 0.709, df = 4, 45) or the second one (F = 0.39, p = 0.812, df = 4, 43) (Table 3). On an average, 68.5 % of the seeds germinated in the first group, and 60.6 % in the second one. However, no differences were observed between the pesticides in either case (F_I = 0.21, p = 0.929, df = 4, 45; F_{II} = 0.42, p = 0.791, df = 4, 42). The latter application, except for permethrin, increased seed germination (i.e. decreased the proportion of unviable seeds) compared with the untreated seeds (Table 3).

3.5 Tolerance of pollen to pesticides

Approximately one half of the untreated spruce pollen grains germinated on water-agar in Petri dishes (Table 4). The pesticides clearly reduced the germinating capacity of the pollen. No pollen grains germinated within three days in dishes treated with dimethoate or triadimephon. After 7 days, some development but no true germination of the pollen grains was observed in the triadimephon-treated dishes.

4 Discussion

The results show that infestation of *Laspeyresia strobinella* and *Kaltenbachiella strobi* only can be significantly reduced with these treatments. Dimethoate, a systematic insecticide, appeared to be more effective than a contact permethrin. However, the efficacy of dimethoate even was only moderate.

Control of *L. strobilella* and *K. strobi* was expected since these species lay their eggs in the female strobili during the flowering period. The cone worm, *Dioryctria abietella*, infests cones later on when they have already closed and turned down. The first application probably no longer had any effect when the cone worm larvae started to bore into the cones. In the second application penetration of the insecti-

Table 3. Proportion of X-rayed seeds in different quality categories and 1000-seed weight (mean, S.D.), and seed germination in the different pesticide treatments. a) embryo over 50 % of the length of the embryo cavity, fully developed endosperm, b) embryo over 50 %, scanty endosperm, c) embryo 25–50 %, full endosperm, d) embryo 25–50 %, scanty endosperm, e) embryo less than 25 %, f) no embryo, endosperm more or less developed, g) insect damage, and h) empty seed. Values of chi-square test show the difference in seed germination between the treated and untreated seeds. Application time: I = May 15–16, II = June 1.

Taulukko 3. Röntgenkuvauksella analysoitujen siementen jakaantuminen laatuluokkiin eri torjunta-ainekäsittelyissä sekä 1000 siemenen paino (keskiarvo, keskihajonta). a) alkion pituus yli 50 % alkio-ontelon pituudesta, täysi siemenvalkuainen, b) alkio yli 50 %, vajaa siemenvalkuainen, c) alkio 35–50 %, täysi siemenvalkuainen, d) alkio 25–50 %, vajaa siemenvalkuainen, e) alkio pienempi kuin 25 %, f) ei alkiota, siemenvalkuainen heikosti kehittynyt, g) hyönteisvioitus, ja h) tyhjä siemen. Testisuure kuvaa käsitellyn ja käsittelemättömäm aineiston eroa. Käsittelyajankohta: I = toukokuun 15–16., II = kesäkuun 1.

Treatment *Käsittely*		a	b	c	d	e	f	g	h, %	Weight, g *Paino, g* x̄	S.D.	Germ. % *Itäv. %*	X^2	p
Dimethoate	I	67.7	0.10	0.20	0.25	0.60	3.05	1.05	25.8	4.15	0.71	68.1	0.51	0.474
	II	62.5	0.35	0.10	0.60	0.45	0.20	1.35	34.2	4.24	0.91	67.6	56.52	<0.001
Permethrin	I	70.1	0.25	0.30	0.40	0.55	1.70	3.60	23.1	4.33	0.67	69.8	0.12	0.731
	II	57.2	1.28	0.06	1.06	0.72	0.78	1.11	38.3	4.17	1.34	57.7	1.97	0.161
Triadimephon	I	61.8	0.90	0.70	0.70	0.70	2.15	2.00	31.2	4.22	0.52	69.7	0.10	0.757
	II	51.0	0.50	0.00	0.00	0.31	0.50	1.50	46.2	3.97	1.17	60.8	53.26	<0.001
Dimethoate/	I	66.1	0.05	0.30	0.05	0.65	3.95	1.75	27.2	3.95	0.85	65.5	6.06	0.014
Triameophon	II	54.1	1.05	0.20	0.15	1.10	0.20	3.35	39.8	4.13	1.17	60.5	50.30	<0.001
Untreated	I	69.1	0.50	0.15	0.60	0.35	0.65	1.15	27.4	4.01	0.51	69.7		
Käsittelemätön	II	60.2	0.31	0.12	0.06	0.19	0.43	0.81	37.9	3.86	0.82	55.3		

cides, especially permethrin, into the cones, was evidently low.

Higher concentrations could have given better results. On the other hand, earlier studies (Annila 1973) have shown that good protection against insect damage in Norway spruce can be obtained with dimethoate at a concentration of 0.1–0.2 % active ingredient when the cones are carefully treated with a hand-sprayer. Pyrethroids such as fenvalerate (from 0.025 to 0.2 % a.i.), permethrin (from 0.025 to 0.15 % a.i.), and esfenvalerate (0.006 % a.i.), have been found to effectively reduce insect damage (*Dioryctria, Leptoglossus*) in Douglas-fir (Overhulser 1981) and in southern pine species (Nord et al. 1984, 1985, Cameron 1989) in the United States when the cones were treated several times during the summer.

Spraying had no marked effect on the occurrence of cone rusts. The infestation of *Pucciniastrum areolatum* was not reduced with tri-

Table 4. Germinating capacity in three different sets of spruce pollen grains treated with pesticides in vitro. Values of chi-square test show the difference between the treated and untreated pollen grains.

Taulukko 4. Kolmen siitepölyerän itävyys eri torjunta-ainekäsittelyissä vesiagarilla. Testisuure kuvaa eroa käsitellyn ja käsittelemättömän aineiston välillä.

Treatment *Käsittely*	No. of pollen grains *Siitepöly-hiukkasia, kpl*	Germinated % *Itävyys, %*	X^2	p
Dimethoate	600	0	147.08	<0.001
Permethrin	400	27.3	41.29	<0.001
Triadimephon	600	0	147.08	<0.001
Untreated *Käsittelemätön*	727	47.0		

adimephon. The fungicide is widely used to control different species of rust fungi (Worthing 1987). In British Columbia, ferric dimethyldithiocarbamate (ferbem) has been found to be effective in the control of cone rusts when spruce cones have been sprayed during the pollination period (Summers et al. 1986). Cone rusts infest cones within a short space of time during flowering. Insecticide spraying during the flowering period may promote rust infestation because rainy weather has been observed to advance infestation (Rummukainen 1960).

The chemicals used in the study appeared to have no clear phytotoxic effects on the female flowers since no significant differences in cone abortion were found between the treatments. Generally, insecticides at low concentrations do not seem to be especially phytotoxic to young conifer cones or seeds. Overhulser (1981) and Overgaard (1981) did not find any negative effects of fenvalerate (concentrations of 0.05 to 0.2 %) on cones or seeds of Douglas-fir. Instead, it would appear that the treatment reduces ovule abortion, conelet mortality or the percentage of empty seeds (Nord et al. 1984, Summers et al. 1986). In the present study, too, the lowest proportion of empty seeds was found in cones treated with permethrin. The proportion of empty seeds in the dissected cones was considerably higher than that in the extracted cones. Some of the empty seeds may have been lost during mechanical seed extraction and the difference is actually spurious.

Pollen germination seems to be totally inhibited by dimethoate and triadimephon when these chemicals come into contact with pollen grains. Permethrin also significantly reduced germination. Because no increase in the proportion of empty seeds was observed, it can be concluded that the chemicals did not reach the pollen chamber in the ovule. Neither seed weight nor germination were substantially affected by the treatments.

It would appear that sufficient control cannot be achieved in practice with the concentrations used in the present study. Furthermore, the application method, spraying with a backpack pump from a tractor, was probably not very successful. Additional tests should be done, especially with fungicides. Phytotoxicity tests at higher concentrations should be performed simultaneously. Because clones seem to exhibit high variation with regards to their susceptibility to pests, as well as to seed quality, different kinds of tests should be done on the same clones.

References

Annila, E. 1973. Chemical control of spruce cone insects in seed orchards. Communicationes Instituti Forestalis Fenniae 78(8). 23 p.

Cameron, R. S. 1989. Promising new pesticides for cone and seed insect control in the southern United States. Proc. 3rd Cone and Seed Insects Working Party Conference, 1988. Victoria, B. C., Canada. p. 193–202.

Hedlin, A. F. 1962. Two systemic insecticides, phosphamidon and systox, used against the douglas-fir cone midge, Contarinia oregonensis Foote. Canadian Department of Forestry, Forest Entomology and Pathology Branch, Bi-monthly Program Reports 18: 3–4.

— 1964. Five systemic insecticides used against douglas-fir cone insects. Canadian Department of Forestry, Forest Entomology and Pathology Branch, Bi-monthly Program Reports 20: 4.

— 1966. Preventation of insect-caused seed loss in douglas-fir with systemic insecticides. Forestry Chronicle 42: 76–82.

Johnson, N. E. 1962. Test of guthion for the control of the douglas-fir midge. Journal of Economic Entomology 55: 615–616.

— 1963. Insecticides tested for control of the douglas-fir cone midge. Journal of Economic Entomology 56: 236–237.

Merkel, E. 1976. Control of seed destroying insects in the southern USA with insecticides and behavioral chemicals. 16 IUFRO World Congress Div. II. Norway 1976. p. 362–368.

Nord, J. C., DeBarr, G. L., Overgaard, N. A., Neel, W. W., Cameron, R. S. & Godbee, J. F. 1984. High-volume applications of azinphosmethyl, fenvalerate, permethrin, and phosmet for control of coneworms (Lepidoptera: Pyralidae) and seed bugs (Hemiptera: Coreidae and Pentatomidae) in southern pine seed orchards. Journal of Economic Entomology 77: 1589–1595.

— , DeBarr, G. L., Barber, L. R., Weatherby, J. C. & Overgaard, N. A. 1985. Low-volume applications of azinphosmethyl, fenvalerate, and permethrin for control of coneworms (Lepidoptera: Pyralidae) and seed bugs (Hemiptera: Coreidae and Pentatomidae) in southern pine seed orchards. Journal of Economic Entomology 78: 445–450.

— & Overgaard, N. A. 1981. Pilot test for controlling coneworms and seedbugs by aerial application of pydrin and guthion at the Beauregard seed orchard, Louisiana. Report 81-2-16. USDA Forest Service, Southeastern Area, State and Private Forests. Atlanta, Ga. 15 p.

Overhulser, D. L. 1981. Cooperative test of pydrin for coneworm control. Weyerhaeuser Interoffice Communications. 7 p. (mimeographed).

Rummukainen, U. 1960. Kuusen siementuhojen runsaudesta ja laadusta. Zusammenfassung: Über Reichlichkeit und Art der Samenschäden bei der Fichte. Communicationes Instituti Forestalis Fenniae 52(3). 83 p.

Sarvas, R. 1967: The annual period of development of forest trees. Proceedings of the Finnish Academy of Science and Letters 1965: 211–231.

Summers, D. & Miller, G. E. 1986. Experience with systemic insecticides for control of cone and seed insects in Douglas-fir seed orchards in coastal British Columbia, Canada. Proc. 2nd Conference of Cone and Seed Insects Working Party S2.07-01. Briancon, France. p. 267–283.

— & Ruth, D. S. 1987. Effect of diatomaceous earth, malathion, dimethoate and permethrin on Leptoglossus occidentalis (Hemiptera: Coreidae): a pest of conifer seed. Journal of Entomological Society in British Columbia 84: 33–38.

— , Sutherland, J. R. & Woods, T. A. D. 1986. Inland spruce cone rust (Chrysomyxa pirolata) control: relation of ferbam application to basidiospore production, rainfall, and cone phenology. Canadian Journal of Forest Research 16: 360–362.

Worthing, C. R. (ed.). 1987. Pesticide manual. British Crop Protection Council. Lavenham, Suffolk, 1081 p.

Total of 18 references