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Lygus bugs as agents of growth disorders in permethrin-treated pine seedlings in regeneration areas

Maarit Kytö

TIIVISTELMÄ: NIITTYLUTEIDEN MERKITYS PERMETRIINILLÄ KÄSITELTYJEN MÄNNYNTAIMIEN KASVUHÄIRIÖIDEN AIHEUTTAJANA UUDISTUSALOILLA

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The ability of *Lygus* bugs to cause growth disorders in permethrin-treated pine seedlings after planting was studied experimentally in two regeneration areas. There were three treatments: exposure of the seedlings to *Lygus*, mechanical protection of the seedlings from insects, and control seedlings. There were no significant differences in the rate of growth disorders between the treatments. The permethrin application protected the seedlings against *Lygus* bugs in the early summer, as well as when the bug abundance was low. The development of these seedlings, as well as the multiple-leadered and bushy seedlings on a third regeneration area, was followed for two years. Multiple leadering reduced height growth and bud number, but caused marked losses in growth only when the seedlings were still multiple leadered the following year, or when they formed several, equally developed stems.

Niittyluteiden kykyä aiheuttaa kasvuhäiriöitä permetriinillä käsitellyissä männyntaimissa istutuksen jälkeen selvitettiin kokeellisesti kahdella uudistusalalla. Koekäsittelyjä oli kolme: altistus luteille, mekaaninen suojaus hyönteisiltä ja vertailu. Silmuhäiriöiden määrässä ei ollut merkitseviä eroja käsittelyjen välillä, ja permetriinikäsittelyn todettiin suojaavan taimia ludevioituksilta kasvukauden alussa ja ludetiheyden ollessa alhainen. Koetaimien, kuten myös erillisen kolmannen uudistusalan monilatvaisten ja pensastuneiden taimien kehitystä seurattiin kahden kasvukauden ajan. Monilatvaisuus vähensi pituuskasvua ja silmulukumäärää, mutta merkittävää haittaa aiheutui vasta, kun taimi pysyi monilatvaisena toisenakin kasvukautena tai kehittyi monirunkoiseksi pensaaksi.

Keywords: *Lygus*, permethrin, growth disorders, bud disorder, *Pinus sylvestris*, seedlings.
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1 Introduction

Growth disorders of pine seedlings were especially common in Finnish forest nurseries during the early 1980's (Raitio 1985). Nutrient and water imbalances, insects, viruses and frost were among the factors suspected of causing the disorders (Holopainen and Rikala 1991). One important agent causing deformation on young pine seedlings was found to be *Lygus* bugs, especially *L. rugulipennis* Popp., which are common in Finnish nurseries (Holopainen 1986, Poteri et al. 1987). Typical symptoms on the pine seedlings were various deformations and bud disorders (Raitio 1985). Bud disorders that lead to the loss of apical dominance and multiple leadering have also occasionally been abundant in planted pine seedlings in regeneration areas.

In some cases it has been suspected that the disorders of seedlings which, after planting, develop a bushlike form and suffer from bud deformations, originate in the nursery. However, it is usually difficult to determine the cause and time of occurrence of the disturbances by the time the symptoms become visible. In controlled experiments on pine seedlings, *Lygus* bugs have been shown to cause latent bud damage that first becomes visible when the following year's buds are formed (Kytö 1992). The marketing of damaged seedlings is prohibited, but latent damage cannot be visually detected when the seedlings are sorted in the spring. On the other hand, the abundance of *Lygus* bugs can be high even in regeneration areas, and the seedlings may be damaged by *Lygus* after planting. There are also several other insect species, voles and tetraonids that can damage the buds and shoots of the seedlings in the regeneration areas.

A range of bud disorders and leader shoot damage often cause the seedlings to become bushy-topped. Multiple leadering is usually not persistent, and one of the top shoots rapidly becomes dominant. However, the first years after planting are critical for the future development of the seedling. Owing to their inferior height growth, bushy seedlings suffer more than normal seedlings from competition with the ground vegetation, and can also be more susceptible to fungal diseases (Rikala 1985). The aim of this study was to determine whether *Lygus* bugs can cause growth disorders on permethrin-treated pine seedlings after planting, and to follow the development of seedlings with growth disorders.

2 Materials and methods

2.1 *Lygus* exposure experiments

Field experiments were established in two regeneration areas in southern Finland (Table 1) to determine whether *Lygus* bugs are capable of causing growth disorders on planted, permethrine-treated, bare-rooted pine seedlings. All the seedlings had been dipped into insecticide solution (0.5 % permethrin) in the nursery in May prior to transportation to the field. The seedlings within each experiment were of the same origin. There were three treatments in the study: 1) mechanical protection of the seedlings from insects by enclosing them in gauze bags (Fig. 1), 2) exposure of the seedlings to *Lygus* by enclosing them in gauze bags and adding an adult *Lygus* bug to each bag, and 3) control seedlings without gauze enclosure. In the Tuusula experiment a split-plot design was used, there being four replicates of 20 seedlings in each treatment. In the Luumäki experiment, 180 seedlings in the centre of the regeneration area were randomly divided between the three treatments. The seedlings were enclosed in the bags one day after planting, and the bags were removed at the end of the summer. In order to determine the abundance of *Lygus* bugs in the experimental areas, samples were collected with a sweep net at the times when the bugs were expected to be swarming, and when nymph abundance was expected to be at its height.

The seedlings were examined and measured at the beginning of the experiment, and at the end of the first and second growing seasons. A bud or shoot was classified as dominant if it appeared to be bigger and stronger than its competitors. The shoot angle was also taken into account when classifying the shoots. If a seedling lacked a dominant top shoot, it was classified as multiple leadered. In the case of multiple-leadered seedlings, the growth was measured on the longest shoot and the bud number counted on the shoot with the highest number of buds. If a branch or shoot that had emerged from a lateral bud had become dominant and replaced the normal leader shoot, it was classified as a leader substitute.

Table 1. Details of the two *Lygus* exposure experiments.

	Tuusula	Luumäki
Location	N 60°21' E 25°	N 60°55' E 27°30'
Area	< 1 ha	1 ha
Site type	*Myrtillus* type	*Myrtillus* type
Site preparation	Manual	Mechanical scarification
Planting date	8. or 15. May 1989	2. May 1990
Number of seedlings	240	180
Start of *Lygus* exposure	16. June 1989	16. or 28. May 1990
Seedling inventories	May and Sept. 1989, Sept. 1990	May and Aug. 1990, Aug. 1991
Sweep samples	June, July and Aug. 1989	May and July 1990

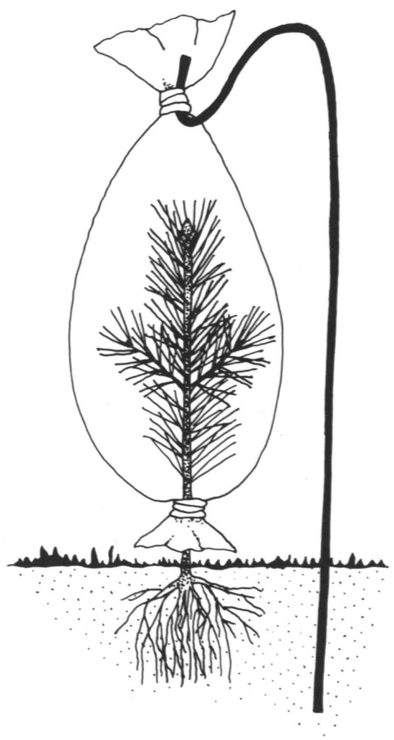

Fig. 1. A seedling enclosed in a gauze bag supported by a piece of wire.

2.2 Seedling stand inventory

A seedling stand where most of the seedlings had multiple leaders or bud disorders one year after planting was surveyed in Luumäki, close to the *Lygus* exposure experiment site. This mechanically scarified regeneration area was about 2 ha in size, of the relatively fertile Myrtillus site type, and had been planted with permethrin-treated pine seedlings in May, 1988. The area had become overgrown with herbs and grasses one year after planting. The seedlings were sampled systematically on 4 m^2 circular plots at 15 m intervals along parallel lines running at a spacing of 15 m. The number of sample plots was 74. 68 planted pine seedlings were identified and marked for the follow-up study. The size and growth of the sample seedlings were measured, and the dominance and number of buds and leader shoots determined and counted in August 1989 and 1990 according to the same principles as in the *Lygus* experiments. Sweep net samples were collected systematically between the sampling lines in connection with the seedling inventories in order to determine the abundance of *Lygus* bugs in the area.

3 Results

3.1 *Lygus* exposure experiments

Lygus abundance was low in the studied regeneration areas during the experiment. In Tuusula no *Lygus* were found in summer 1989. The Luumäki sweeping samples contained no *Lygus* one day after planting, although they were found on the same day already at a nearby nursery. Even in the mid May samples there were no *Lygus*, but in July a number of nymphs were found. An average of 4.6 nymphs were found per 30 sweeps from among the grasses and shrubs growing along the edges of the area, and 2.5 nymphs per 30 sweeps from among the shrubs in the actual regeneration area. An average of one nymph per 20 seedlings was found on the planted pine seedlings.

The mortality of the seedlings was low in the experiments, especially at Luumäki where only five seedlings died during the first two years. In Tuusula more than 90 % of the seedlings were alive at the end of the first, and 85 % at the end of the second growing season. The causes of death were drought, dense ground vegetation, *Hylobius abietis* L., fungal diseases, and interactions between these causes. There were no statistically significant differences in either of the experiments between the treatments as regards height, growth, bud formation, or bud or shoot dominance of the seedlings (Tables 2, 3, and 4). Enclosing the seedlings in gauze bags and exposing them to *Lygus* thus did not affect the development of the seedlings.

Because the treatments did not affect the growth, bud disorders or multiple leadering of the seedlings, all the treatments were pooled when comparing the development of normal and multiple-leadered seedlings. In Tuusula, ca. 80 % of the seedlings had a normal dominating apical bud at planting; in the rest of the seedlings the terminal bud was either slightly deformed or replaced by a lateral bud. A significantly higher proportion of the seedlings that lacked a dominating terminal bud became multiple leadered than of the normal seedlings (Pearson $\chi^2 = 37.4$, df = 1, p < 0.01). Almost one third of the seedlings without a dominating bud at planting were multiple leadered at the end of the summer, while only 1.5 % of the seedlings with normal buds became multiple leadered. In Luumäki only 53 % of the seedlings had a normal terminal bud at planting. One lateral or axillary bud was dominant in 13 % of the seedlings, and in 34 % there were several equally viable lateral and axillary buds. 72 % of the seedlings that lacked a dominating bud became multiple leadered, and the difference compared to the other seedlings was significant (Pearson $\chi^2 = 79.3$, df = 2, p < 0.01). 13 % of the seedlings with a dominating lateral bud became multiple leadered. However, they did not differ significantly from the normal seedlings, of which 6 % became multiple leadered.

The height growth of the multiple-leadered seedlings was lower in both experiments, even though there was no significant difference in the mean heights at planting (Fig. 2, Table 5). At the end of the summer in the planting year the multiple-leadered seedlings had a slightly larger root-collar diameter than the normal seedlings. However, the difference was significant only in the Luumäki experiment where the seedlings with a leader shoot substitute also had a larger root collar than the normal seedlings (Table 5). In the first growing season the multiple-leadered seedlings formed, on the average, one bud less than the seedlings with one leader shoot. However, actual bud deformations did not occur more often in multiple-leadered than in normal seedlings. In Tuusula 6 % of the seedlings lacked a dominating terminal bud. Two thirds of these became multiple leadered during the following growing season, when only one sixth of the seedlings with normal buds became multiple leadered. In Luumäki 7 % of the seedlings lacked a dominating terminal bud, and 42 % of them became multiple leadered the following year, the proportion for the seedlings with normal buds being 15 %.

In Tuusula 33 % and in Luumäki 41 % of the first year's multiple-leadered seedlings still lacked a dominating leader shoot or stem at the end of the second growing season. 19 % of the seedlings with a dominating leader in Tuusula and 7 % in Luumäki had become multiple leadered by the end of the second summer. The height growth of the multiple-leadered seedlings was less, and the total height lower, than that of the normal seedlings also in the second growing season (Fig. 2, Table 6). When the single-leadered and multiple-leadered seedlings are divided into subgroups

Table 2. The mean size, growth, bud number, and proportion of multiple-leadered seedlings in the Tuusula *Lygus* exposure experiment. The differences between the treatments are not statistically significant according to analysis of variance.

Treatment	Number of seedlings	Height at planting	Height growth 1989	Height growth 1990	Root-collar diameter 1989	Root-collar diameter 1990	Number of buds 1988	Number of buds 1989	Number of buds 1990	Multiple leadered 1989	Multiple leadered 1990
		mm	mm	mm	mm	mm				%	%
Lygus exposure	66	198	70	142	4.6	8.7	4.8	3.8	4.4	4.2	20.2
Mech. protection	68	179	72	135	4.2	7.9	4.5	3.9	4.4	4.5	22.2
Control	69	185	67	136	4.3	8.0	4.1	4.0	4.4	4.2	13.2

Table 3. The mean size, growth, and bud number in the Luumäki *Lygus* exposure experiment. The differences between the treatments are not statistically significant according to analysis of variance.

Treatment	Number of seedlings	Height at planting	Height growth 1990	Height growth 1991	Height 1991	Root-collar 1990	Number of buds 1989	Number of buds 1990
		mm	mm	mm	mm	mm		
Lygus exposure	60	125	84	147	356	4.8	3.9	3.7
Mech. protection	58	119	76	160	355	4.4	3.7	3.4
Control	57	126	81	152	359	4.9	3.6	3.6

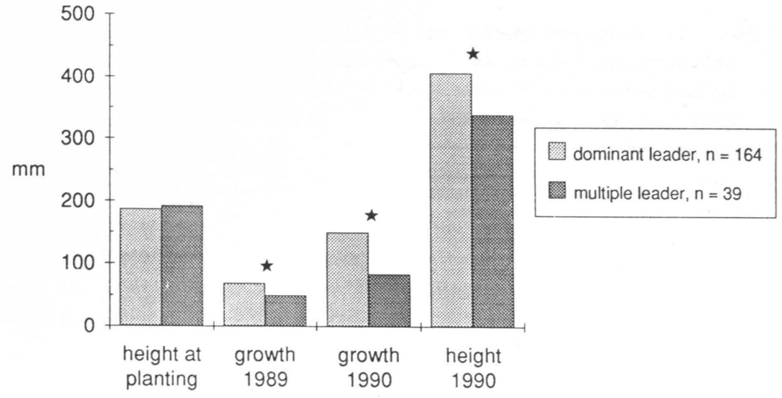

Fig. 2. The mean height and growth of the normal and multiple-leadered seedlings in the Tuusula *Lygus* exposure experiment. The means marked with an asterisk differ significantly (P < 0.01, df = 1) from each other according to analysis of variance.

Table 4. The proportion (%) of seedlings with a normal leader shoot, seedlings with a dominating leader shoot substitute, and multiple leadered seedlings in the Luumäki *Lygus* exposure experiment. The differences between the treatments were not statistically significant according to Pearson χ^2 test.

Treatment	Normal 1990	Normal 1991	Substitute 1990	Substitute 1991	Multiple 1990	Multiple 1991
	%	%	%	%	%	%
Lygus exposure	48	46	22	32	30	22
Mech. protection	40	38	29	48	31	14
Control	37	35	35	51	28	14

Table 5. The mean size, growth, and bud number of seedlings with different stem forms in 1990 in the Luumäki *Lygus* exposure experiments. The means marked with the same letter do not differ significantly from each other according to Tukey's test.

Stem form 1990	Number of seedlings	Height at planting mm	Height growth mm	Root-collar diameter mm	Number of buds
Normal	69	118 a	84 a	4.4 a	3.8 a
Leader substitute	50	127 a	90 a	5.0 b	4.1 a
Multiple leader	51	128 a	67 b	4.9 b	2.9 b

Table 6. The mean height and growth of seedlings with one dominating leader shoot, and multiple-leadered seedlings in 1991, in the Luumäki *Lygus* exposure experiments. The means marked as in Table 5.

Stem form 1991	Number of seedlings	Height at planting mm	Height growth mm	Height mm
Dominating leader	146	121 a	160 a	364 a
Multiple leader	29	132 a	116 b	320 b

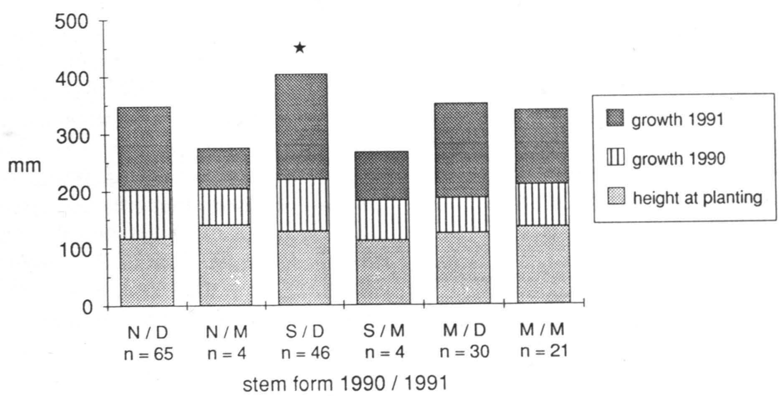

Fig. 3. The mean height and growth of the seedlings in the Luumäki *Lygus* exposure experiment. The seedlings are grouped according to their stem form in the 1990 and 1991 growing seasons. N = normal leader shoot, S = leader shoot substitute, M = multiple leadered, D = dominating leader shoot. The group marked with an asterisk differs significantly ($p < 0.01$, df = 5.164) from the normal seedling group according to the Dunnett test.

according to their shoot dominance during the first growing season, the decline in height growth is especially notable in the multiple-leadered seedlings that had only recently lost their dominating leader shoot (Fig. 3). However, the difference between these and the normal seedlings was not statistically significant. 76 % of the seedlings that remained multiple leadered even in the second year had developed two or three equally strong stems with a dominating leader shoot on each stem. As in the first year, the multiple-leadered seedlings produced a lower number of buds even in the second summer, but there were no differences in the occurrence of bud deformations.

3.2 Seedling stand inventory

The sweep samples taken in the Luumäki seedling stand in August 24, 1989 contained both *L. rugulipennis* and *L. punctatus* (Zett.), the former being somewhat more numerous. The average number of bugs was 4.3 per 30 sweeps. Most of them were teneral adults, but even first-instar nymphs were caught, which might indicate that a second generation was under development. In August 1990 no *Lygus* were found in the area. About 20 % of the sample seedlings had a normal stem form in 1989, over 40 % had lost their original stem because of bud or stem damage and it had been replaced by a substitute, and the rest of the seedlings were multiple leadered and bushy. Damaged seedlings were more or less evenly distributed over the area. Part of the damage was probably caused by voles and moose, but in most cases it was not possible to make a definite identification. The mean height of seedlings with defective stems in 1989 did not differ from the normal seedlings in the previous year, but in 1989 the height growth of the normal seedlings was highest and of the multiple leadered seedlings lowest (Table 7). The mean height of the multiple-leadered seedlings in 1989 was also significantly lower than that of the single-leadered seedlings. 16 % of the sample seedlings had died between August 1989 and August 1990. There was no significant difference in mortality between the stem form classes. 36 % of the normal seedlings, and 52 % of the seedlings with a leader substitute had become multiple leadered. 52 % of the multiple leadered seedlings had remained multiple leadered or bushy. On the average, the multiple-leadered seedlings were shorter than the others (Table 8), but there was no significant difference in the 1990 height growth between the stem form classes. When the seedlings were divided into subgroups according to their previous year's stem form, and tested pairwise with the normal seedlings, only the 1990 multiple-leadered seedlings differed significantly from the normal ones (Fig. 4). The earlier multiple-leadered seedlings that had developed a new dominating leader shoot had grown especially well.

Table 7. The mean size and growth of the seedlings with different stem forms in 1989 in the Luumäki seedling stand inventory. The means are marked as in Table 5.

Stem form 1989	Number of seedlings	Height mm	Height growth %	Root-collar diameter mm
Normal	14	290 a	62.92 a	7.6 a
Leader substitute	29	261 a	40.32 b	7.4 a
Multiple leader	25	221 b	22.10 c	7.3 a

Table 8. The mean size and growth of the seedlings with different stem forms in 1990 in the Luumäki seedling stand inventory. The means are marked as in Table 5.

Stem form 1990	Number of seedlings	Height mm	Height growth %	Root-collar diameter mm
Normal	7	461 a	51.64 a	10.9 a
Leader substitute	17	383 a	61.60 a	10.8 a
Multiple leader	33	323 b	49.54 a	11.2 a

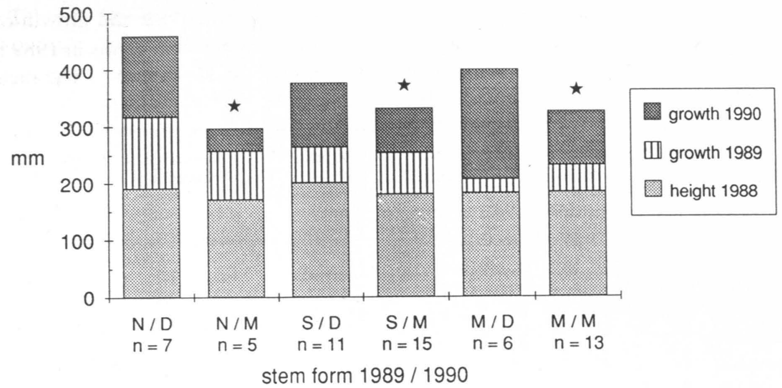

Fig. 4. The mean height and growth in the different seedling groups in the Luumäki seedling stand survey. The seedlings are grouped according to their stem form in the 1989 and 1990 growing seasons. Symbols as in Fig. 3. The groups marked with an asterisk differ significantly ($p < 0.05$) from the normal seedling group in two-group t tests.

4 Discussion

Although permethrin is primarily applied to seedlings to protect them against *Hylobius*, it apparently also protects them against plant bugs, since the number of bud disorders on the seedlings exposed to *Lygus* was similar to that on the seedlings mechanically protected from insects. In a previous greenhouse experiment with 2–3-year-old pine seedlings not treated with insecticides, about half of the seedlings exposed to *Lygus* showed damage symptoms, but the proportion was only 5 % in the case of the mechanically protected control seedling group (Kytö 1992). Information about the length of their survival after enclosure is not available, because a close follow-up of the *Lygus* in the present exposure experiments was not possible. According to sporadic observations in the Tuusula experiment, at least some of the bugs were still alive one day after enclosure. Permethrin products are synthetic pyrethroids, they act intestinally and through skin contact, and also have a repellant effect on insects. In the present experiment permethrin probably entered the bugs through the skin between the tarsal segments.

Pyrethroids have been found to be fairly effective in controlling *Lygus* bugs (Pree 1985, Martel et al. 1986, Holopainen 1989a). In laboratory experiments permethrin was toxic to *Lygus lineolaris* (Palisot de Beauvois) at concentrations of 0.01–0.001 % (Martel et al. 1986). Since the seedlings had been treated with permethrin already in the nursery, and the *Lygus* exposure was not performed until 2–5 weeks after planting, it is difficult to estimate whether the application still had any effect at that time. In the experiments of Pree (1985), the toxic effect of permethrin applied on peach leaves was considerably reduced already after three days, but the concentration used was very low (6.3 g AI/100 l) compared to the concentration (ca. 500 g AI/100 l) used for pine seedlings in Finland. The larvae of *Acantholyda* seemed to thrive on the seedlings, which indicates that the toxicity of the needles was no longer very high by the middle of summer. In any case, the growth disorders that occurred in the seedlings in the present study were not caused by *Lygus* after planting. However, the possibility of latent *Lygus* damage, originating in the nursery, cannot be completely ruled out.

Shoot elongation had already begun by the time the *Lygus* exposure was started, and the emerging shoots were free from permethrin. *Lygus* bugs prefer to feed on the apical meristems which, together with the repellent effect of permethrin on the lower parts of the seedlings,

may have directed the bugs to feed on the shoot apices. In the feeding process, plant tissue is destroyed both directly as a result of mechanical damage, and indirectly as a result of enzymatic activity (Strong 1970, Holopainen 1986). Because no malformations or damage were detected on the new shoots or buds of most of the seedlings, the *Lygus* bugs had not caused much damage. The tissues that were in a very active growth phase (Sucoff 1971, Kanninen 1990) had apparently been able to compensate for the destroyed cells, if feeding damage had occurred.

According to host preference studies, pine is not among the primary choices of *Lygus rugulipennis*, but they can manage their complete life cycle on pine seedlings alone (Varis 1972, Holopainen 1989b). In the Luumäki *Lygus* exposure experiment where the *Lygus* abundance was low, feeding damage in the control seedlings was not greater than in the seedlings that were mechanically protected with gauze bags. Obviously the bug abundance would have to be considerably higher before noticeable damage could occur, especially when a wide selection of herbs and grasses is present in the area. Bud disorders were more numerous in the Luumäki seedling stand inventory, but most of the disorders were attributed to damage caused by voles or moose, even in the year when *Lygus* bugs were found in the area.

According to the official regulations, marketable pine seedlings must have a dominating terminal bud, which can also be a lateral or axillary bud (Päätös metsänviljelyaineiston kaupasta 1988). The results of the present study support the necessity of this criterion, especially if rapid initial development of the planted seedlings is the objective. If a seedling, like many of the seedlings included in this study, lacks a dominating terminal bud, then the seedling easily develops into a multiple-leadered plant for one growing season at least. As in Rikala's (1985) experiment, in this study multiple leadering was also found to be a temporary phase that only causes problems if it leads to forking of the stem. Raising pine seedlings that remain bushy does not appear to be a worthwhile undertaking. The bud disorders of planted seedlings are not necessarily fatal, since the disorders as such do not increase seedling mortality. On the other hand, the height growth declines, as is probably also the case for the amount of photosynthesizing biomass. In the present study at least, the multiple-leadered seedlings formed fewer lateral buds that develop into lateral branches. Slow height growth reduces the seedlings' ability to compete with the ground vegetation, and the decrease in photosynthesis, bad lighting conditions and insufficient ventilation might make the seedlings susceptible to fungal diseases during damp and cool summers or under the snow cover in the winter.

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