Silva Fennica 1989, Vol. 23 N:o 4:279–286

Effect of forest fertilization on pine needle-feeding Coleoptera

Kari Heliövaara & Kari Löyttyniemi

TIIVISTELMÄ: LANNOITUKSEN VAIKUTUS MÄNNYN NEULASILLA ELÄVIIN KOVAKUORIAISIIN

Heliövaara, K. & Löyttyniemi, K. 1989. Effect of forest fertilization on pine needle-feeding Coleoptera. Tiivistelmä: Lannoituksen vaikutus männyn neulasilla eläviin kovakuoriaisiin. Silva Fennica 23 (4): 279–286.

The effects of forest fertilizers on the intensity of damage caused by two curculionid (*Brachyderes incanus, Brachonyx pineti*) and two chrysomelid (*Calomicrus pinicola, Cryptocephalus pini*) species feeding as adults on Scots pine needles were investigated in two pine stands growing on dry (*Calluna* type) sites in South-West Finland. There was much variation in the abundance of the insect species both between the trials and the sample plots. Nitrogen fertilization increased both the height and radial growth of the pines. The curculionids were slightly more abundant on the nitrogen-treated plots. Potassium application seemed to decrease the feeding intensity of the chrysomelids especially. The overall effects were so small that forest fertilization cannot be considered as an efficient control method against needle-feeding beetles.

Kahdella Lounais-Suomessa kuivalla kankaalla sijaitsevalla lannoituskoesarjalla tutkittiin typpilannoitteiden vaikutusta kahden männynneulasilla elävän kärsäkäs- ja kahden lehtikuoriaislajin neulasvioitusten määrään. Hyönteisten runsaudessa todettiin huomattavaa vaihtelua koealojen välillä. Typpilannoitus lisäsi sekä mäntyjen pituus- että paksuuskasvua.Kärsäkkäiden aiheuttamat vioitukset olivat hieman runsaampia typellä käsitellyillä aloilla. Kalium vähensi erityisesti lehtikuoriaisten vioitusten määrää. Kokonaisuutena vaikutukset olivat niin vähäisiä, että typpilannoituksella ei näytä olevan käyttöä neulasilla elävien kovakuoriaisten torjunnassa.

Keywords: *Pinus sylvestris*, Chrysomelidae, Curculionidae, herbivores, fertilization.
ODC 145.7+237.4

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

Accepted September 20, 1989

1. Introduction

If the growth response of tree stands to fertilizer application is positive, then tree resistance to insect pests usually increases as well. Nitrogen fertilization especially has been found to increase larval mortality in pine needle feeding moths and diprionid sawflies, thus decreasing the actual damage caused to the trees (Merker 1958, Oldiges 1958, Schwenke 1960, Smirnoff & Bernier 1973). This is believed to be mainly due to the mechanical effect of robust needles, and to the mechanical and chemotoxic effect of increased resin content and flow, which discourage feeding (e.g. Büttner 1961, Smeljanez 1969, Otto 1964, Otto & Geyer 1970, Hiltunen et al. 1975). Recent studies also suggest that trees with enhanced nutritional quality brought about by fertilization are able to produce greater amounts of defensive chemicals, which results in lower populations of larval defoliators in fertilized stands (Larsson & Tenow 1984). In contrast, nitrogen-fertilized trees have been shown in some cases to maintain a higher insect herbivore biomass than untreated trees. However, this resulted in a smaller proportion of defoliation due to the increased foliar biomass (Wickman & Mason 1988).

On the other hand, little is known about the effect of forest fertilization on the injuriousness of adult insect herbivores which are more freely able to choose between the host trees. The aim of the present study is to investigate the effect of forest fertilization on the feeding intensity of some beetle species that feed on the needles of Scots pine (*Pinus sylvestris L.*). Attention is paid to *Brachyderes incanus* (L.) and *Brachonyx pineti* (Paykull) (Curculionidae), and *Calomicrus pinicola* (Duftschmid) and *Cryptocephalus pini* (L.) (Chrysomelidae). These beetles are usually of minor forest economic importance, except locally when occurring in high numbers (Saalas 1949, Schwenke 1974).

The authors are grateful to Mrs. Tuula Hiltunen for inspecting the needle material, to Mr. E. Kemppi for help in the computations. Prof. E. Annila and Dr. E. Lipas, Dr. P. Niemelä and Dr. R. Väisänen are thanked for commenting on the manuscript. The fertilization trials have been established by the Department of Soil Science, the Finnish Forest Research Institute.

2. Material and methods

The study was carried out in Alastaro, South-West Finland (60°55'N, 22°40'E). The study consisted of two fertilization experiments, A and B, about 800 m apart, comprising eight sample plots (30 x 30 m) each (N - P - K factorial experiment, see Viro 1967, 1972) established in a naturally regenerated, uniform Scots pine stand growing on a site of the *Calluna* type (CT). This site type is a favourable biotope for the needle-feeding species of Coleoptera in Finland (Kangas 1937, Saalas 1949). The plots were fertilized for the first time in 1959 when the dominating trees were 20 years old (Table 1). Finely-ground limestone (Ca) 2000 kg/ha, ammonium sulphate (21 % N) 400 kg/ha and finely-ground rock phosphate (14.4 % P) 200 kg/ha were applied in 1959. Nitrogen-treated plots were refertilized with 200 kg urea (46 % N) per hectare in both 1964 and 1969. In addition, 577 kg/ha of ammonium nitrate with lime (26 % N), 500 kg/ha of superphosphate (8.7 % P), and 125 kg/ha of potassium chloride (59 % K) were added per hectare to certain plots in 1973.

In 1974, 20 pines were chosen randomly on each sample plot, i.e. a total of 320 pines. One branch in the third branch whorl from the top, facing south, was cut from each tree in October. The branches were transferred to the laboratory where damage caused by the needle-feeding species of Coleoptera was identified. The feeding scars were recorded in two ways: 1) as the number of damaged

needles per shoot, which depicts the abundance of the beetles on the plots, and 2) as the number of damaged needles per unit shoot length, which takes into account the possible 'dilution' of herbivory as a consequence of shoot growth. The needle material was divided into new needles of the present summer (1974), and old needles of the preceding summer (1973). In addition, the height and diameter (DBH) of the trees were measured, as well as the height and radial growth for 1973 and 1974. The effects of the fertilizer nutrients were analysed by comparing nitrogen vs. non-nitrogen plots, phosphorus vs. non-phosphorus plots and potassium vs. non-potassium plots.

3. Results

31. Growth response of the study trees

The mean height of all the pines measured in 1974 was 5.6 m (SD 0.8). The tallest pines were usually growing on the sample plots treated with nitrogen fertilizers (Fig. 1). The height of the pines significantly differed between the sample plots ($F = 4.26$, $p < 0.001$, df = 15, 304, analysis of variance). The same tendency was also true for the diameter at breast height (mean 8.4 cm, SD 1.5). In 1973, the mean height growth of the trees was 34.8 cm (SD 6.2) and in 1974 27.7 cm (SD 6.1). The height growth was also usually the greatest on the nitrogen-treated sample plots in both 1973 and 1974. The difference betweeen all the sample plots was highly significant (for 1974, $F = 12.13$, $p < 0.001$, df = 15, 304). The mean height growth of the trees in 1973 was about 12.6 % greater and in 1974 22.6 % greater on the nitrogen-fertilized plots than on those without. The radial increments of the pines, especially, were significantly higher on the nitrogen-treated plots (mean for all trees 1974 2.7 mm, SD 0.8). Nitrogen fertilization had increased the radial growth by about 64.8 % in 1973 and by 32.7 % in 1974.

32. Insect damage

There was much variation in the abundance of all the insect species studied both between the two experiments and the sample plots. *Brachyderes pineti* and *Calomicrus pinicola* were more abundant on the new needles, while *Brachyderes incanus* and *Cryptocephalus pini* were more abundant on the old needles (Figs. 2 and 3). *B. incanus, C. pinicola* and *C. pini* were more abundant on experiment A.

Signs of *Brachyderes incanus* damage were recorded on every sample plot (Fig. 2). The total number of needles notched by *B. incanus* was 5,687, the preceding year's shoots having more (3,389) than the current ones (2,298). The number of feeding scars was slightly higher on both the nitrogen-treated plots and phosphorus-treated plots. The results are contradictory as regards the potassium treatment (Table 2).

Damage caused by *Brachonyx pineti* was also recorded on each sample plot (Fig. 2). The number of damaged needles totalled 10,613, the damage being concentrated on the current shoots. The number of feeding scars was higher on the new needles on the nitrogen-treated plots in experiment A, but this was not observed elsewhere. In experiment B, there was a tendency for decreased species abundance on the phosphorus and potassium-treated plots (Table 2).

C. pinicola had damaged more needles (12,534) than the other species (Fig. 3). Almost all of the damage was recorded on the current year's shoots. 40 % of this damage occurred on one sample plot given phosphorus fertilization. There were less damaged new needles on the sample plots treated with either nitrogen or potassium-containing fertilizers (Table 2). On the old needles, nitrogen treatment seemed to increase the damage, but this observation was based on a very limited material.

As far as the incidence of damage was concerned, *C. pini* was the least common species recorded. Altogether 2,949 damaged needles were recorded, and these were almost entirely concentrated on the preceding year's shoots (Fig 3). There was a tendency for this species to occur on the same plots as *C. pinicola* in experiment A ($r_s = 0.905$, $p<0.01$, n = 8). The lowest number of damaged needles was recorded on the sample plots treated with nitrogen or potassium (Table 2). The slightly higher incidence of damage on the new needles on the nitrogen-treated plots in experiment B is based on a very small material.

The overall effects of the main nutrients on insect damage were rather weak and slightly contradictory. Nitrogen application had the most masked effect, either negative or positive depending on the species (Table 2). Potassium application tended to decrease the damage rate. The effects of phosphorus remained small and obscure. The increased shoot growth brought about by nitrogen application was, however, so insignificant that statistical analyses gave rather similar results irrespective of whether shoot growth was taken into account or not. Six of the H-values in the Kruskal-Wallis test were more and one less significant when shoot growth was taken into account (Table 2).

4. Discussion

Fertilization can have both beneficial and adverse effects on insect pest populations. In many cases fertilization results in a reduction of pest populations through its effect on tree vigour and resistance (see Stark 1965). Recent studies show that the carbon-nutrient balance of plants strongly affects their palatability and response to herbivores. The carbon/nutrient hypothesis presented by Bryant et al. (1983) predicts that when the amount of plant nutrients is low, there is an excess of carbon to be used for the synthesis of carbon-based defensive compounds. This should increase the resistance of the plant to herbivores. For instance, nitrogen fertilization resulted in decreased concentrations of condensed tannin and phenolic clycosides in the leaves of aspen and an increase in their nitrogen concentrations and value as food for the large aspen tortrix *Choristoneura conflictana* (Walker), (Lepidoptera, Tortricidae). The carbon/nutrient balance positively influenced the quality of leaves for insects by increasing nitrogen levels, and negatively by decreasing harmful substances, e.g. carbon-based secondary metabolites in leaves (Bryant et al. 1987). Increased soluble nitrogen levels in a plant usually increase growth and reproduction of herbivorous insects, which has been clearly illustrated especially in the case of aphids (see Mattson 1980).

Investigations concerning the effects of fertilization on needle-feeding beetles are scarce and to a greater extent contradictory. Only *B. incanus* has been studied in this respect. Both nitrogen fertilization alone and in combination with other nutrient elements increased the damage in pine stands on mineral soils in Germany (Otto 1964). On the other hand, more damage and individuals of *B. incanus* were observed on nitrogen-free sample plots in dry heath stands, while the differences were smaller in a more fertile area (Bischoff 1967). As regards other Coleoptera, nitrogen fertilization did not affect the attractiveness of the breeding material during the swarming time of the pine shoot beetles *Tomicus* spp. (Scolytidae). In addition, fertilization was not found to affect the orientation of the beetles to the crown of pine (Löytyniemi 1978). Non-existent effects of nitrogen fertilization were also observed in *Strophosomus* spp. (Curculionidae) feeding on the leaves of deciduous trees. This was presumed to be due to mechanical factors which had a greater effect on the palatability of the leaves than chemical factors changed by fertilization (Zwölfer 1962).

In the present study, there was high variation in the abundance of feeding scars on needles between the sample plots. The curculionids *B. incanus* and *B. pineti* occurred

Table 1. Fertilization treatments in 1959, 1964, 1969 and 1973 on the different sample plots. Doses are given in the text.

Sample plot	Fertilization in May 1959	1964	1969	1973
Experiment A				
1	0			0
2	CaN	N	N	N
3	CaP			P
4	NP	N	N	NP
5	CaNP	N	N	NPK
6	P			PK
7	N	N	N	NK
8	Ca			K
Experiment B				
1	0			K
2	CaN	N	N	NK
3	CaP			PK
4	NP	N	N	NPK
5	CaNP	N	N	NP
6	P			P
7	N	N	N	N
8	Ca			0

Table 2. Differences in the number of damaged needles between nitrogen vs. non-nitrogen, phosphorus vs. non-phosphorus and potassium vs. non-potassium plots. +/- = $p<0.05$, ++/-- = $p<0.01$, +++/--- = $p<0.001$, Kruskal-Wallis test. Signs in parentheses indicate a very small material.

Species	Year	Experiment	Scars per cm N	P	K	Scars per shoot N	P	K
B. incanus	1973	A	+++		+	+++		++
		B		+++	-		++	--
	1974	A						+
		B	++			+++		
B. pineti	1973	A						
		B		--			---	
	1974	A	+++			+++		
		B			--			---
C. pinicola	1973	A						
		B	(++)			(++)		
	1974	A	---		---	---		---
		B	---			---		
C. pini	1973	A	---		---	---		---
		B						
	1974	A						
		B	(+)			(+)		

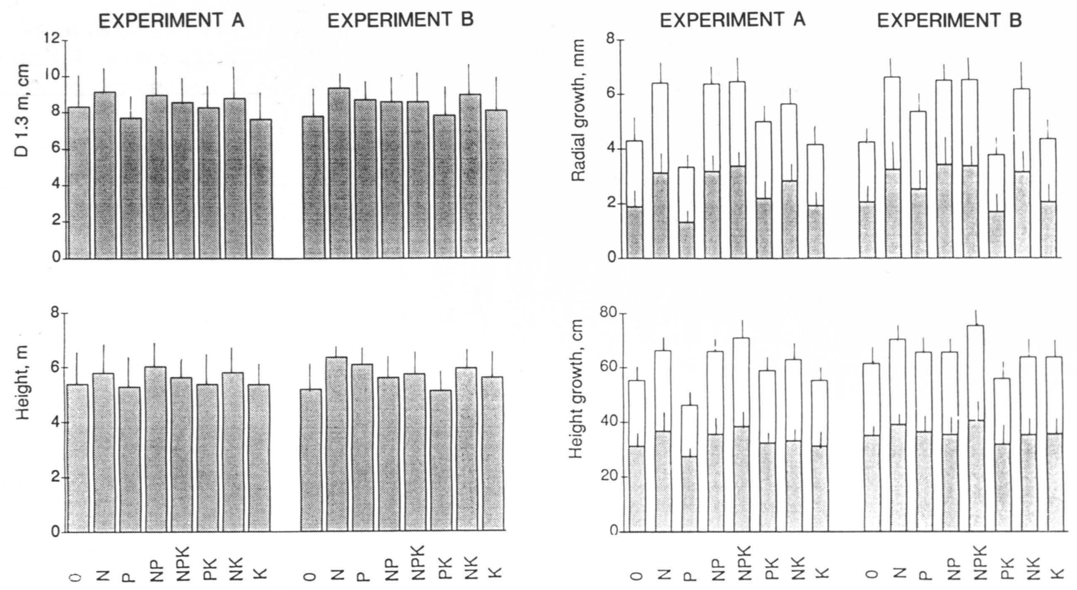

Fig. 1. Mean height, diameter at breast height and height growth in 1973 (dark columns) and in 1974 (white columns) of the pines. Vertical bars indicate standard deviations.

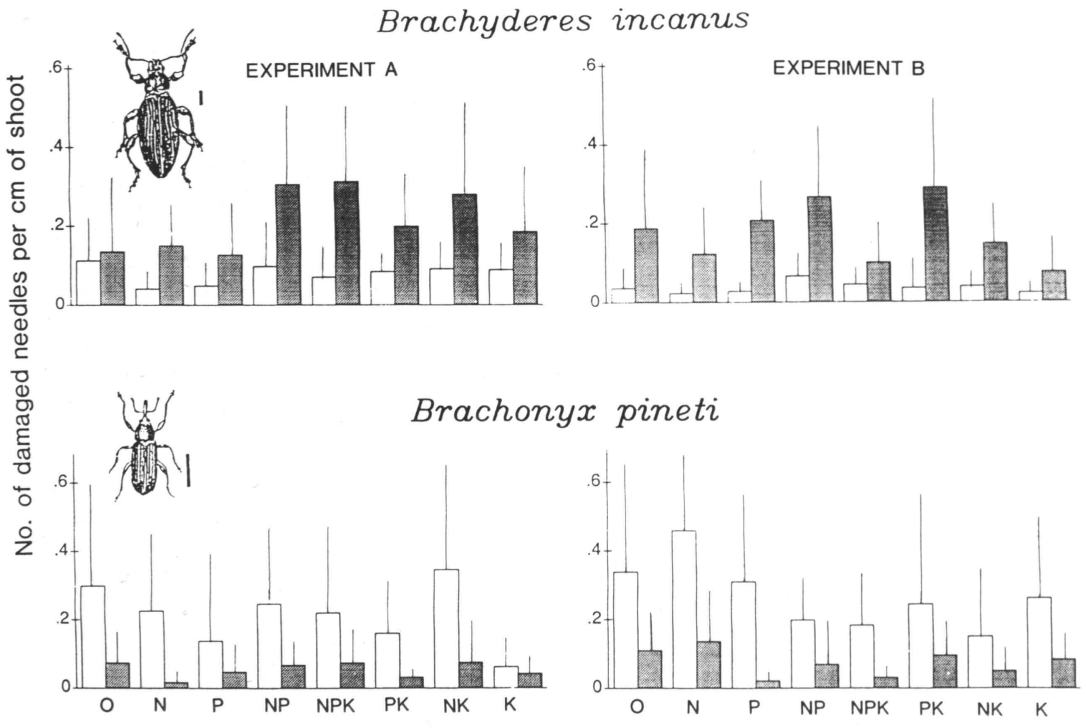

Fig. 2. Number of damaged needles per cm of shoot (mean, SD) caused by the curculionids *Brachyderes incanus* and *Brachonyx pineti* on different sample plots. White columns – damage to current year's needles (1974), dark columns – damage to previous year's needles (1973). Scale of the vignettes is 1 mm.

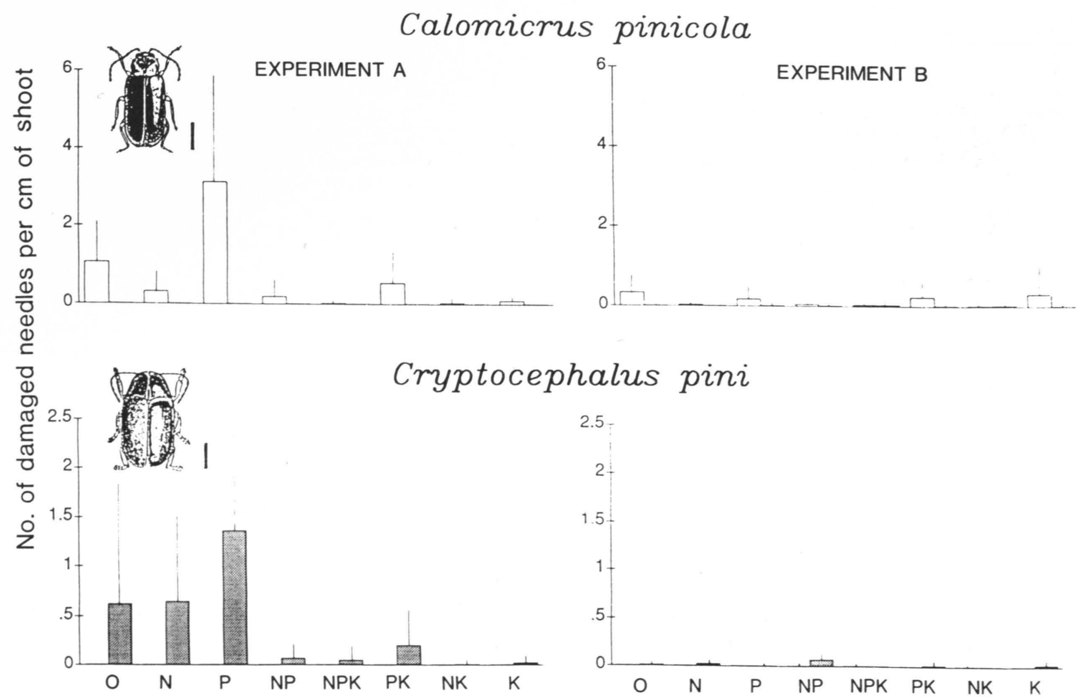

Fig 3. Number of damaged needles per cm of shoot (mean, SD) caused by the chrysomelids *Calomicrus pinicola* and *Cryptocephalus pini*. Explanations as in Fig. 2.

throughout the study area. Nitrogen application slightly favoured these species. In addition, *B. incanus* was most abundant on the plots treated with combinations of main nutrients especially in experiment A, thus supporting the previous findings of Otto (1964). In contrast, the chrysomelids *C. pinicola* and *C. pini* seemed to be slightly less abundant on the nitrogen-treated plots. Our results also provide some support for findings that overfertilization with potassium generally depresses forest pest populations (e.g. Merker 1961, 1962). High potassium, particularly in the presence of low urea, has also been shown to affect negatively by decreasing the pupal weight of the spruce budworm *Choristoneura fumiferana* (Clem) feeding on balsam fir (Shaw et al. 1978).

The factors controlling the abundance of the needle-feeding beetles and even their life-styles are poorly known. Larvae of *B. pineti* live in the needles, while larvae of the other species feed mostly on plant roots in the soil (e.g. Kangas 1937, Saalas 1949, Bakke 1958). Changes in undergrowth caused by fertilization could affect the abundance of larvae in the soil. However, nothing is known about these indirect effects. Patchy distribution within a stand is characteristic of *C. pinicola*, especially. It is possible that this species, which presumably has a good dispersal ability, can more easily move to the most suitable sites. The occurrence of the two chrysomelid species on the same plots in experiment A may be due to chance. The abundance of the studied species is apparently more affected by factors other than the change in nutritional quality brought about by fertilization.

The sample plots in our investigation had been treated for the first time with nitrogen fertilizer fifteen years earlier. The pines had clearly responded to the nitrogen application both in increased height and radial growth. Consequently, if fertilization had had a marked effect on the pest species in question, their response would have been clear as well. Despite some statistical significant differences in the number of damaged needles between the sample plots, the actual differences were rather small. This indicates that forest fertilization according to practical forest fertilization recommendations cannot be regarded as an efficient tool in the prophylactic control of needle-feeding beetles.

References

Bakke, A. 1958. Mass attack of Brachonyx pineti Payk. (Col., Curculionidae) on pine forests in Norway. Medd. Norske Skogforsoksv. 50: 124-142.

Bischoff, M. 1967. Untersuchungen von Frassschäden des Graurüsslers (Brachyderes incanus L.) auf Düngungs-Versuchsflächen. Forst- u. Holzwirt 22(7): 1-4.

Bryant, J. P., Chapin, F. S. III & Klein, D. R. 1983. Carbon/nutrient balance of boreal plants in relation to vertebrate herbivory. Oikos 40: 357-368.

– , Clausen, T. P., Reichardt, P. B., McCarthy, M. C. & Werner, R. A. 1987. Effect of nitrogen fertilization upon the secondary chemistry and nutritional value of quakin aspen (Populus tremuloides Michx.) leaves for the large aspen tortrix (Choristoneura conflictana (Walker). Oecologia 73: 513-517.

Büttner, H. 1961. Der Einfluss von Düngestoffen auf Mortalität und Entwicklung forstlicher Schadinsekten über deren Wirtspflanzen. Schriftenreihe der Landesforstverwaltung Baden-Württenberg 11: 1-69.

Hiltunen, R., Schantz, M. von & Löyttyniemi, K. 1975. The effect of nitrogen fertilization on the composition and the quantity of volatile oil in Scots pine (Pinus sylvestris L.). Commun. Inst. For. Fenn. 85(1): 1-14.

Kangas, E. 1937. Tutkimuksia mäntytaimistotuhoista ja niiden merkityksestä. Zusammenfassung: Untersuchungen über die in Kiefernpflanzbestände auftretenden Schäden und ihre Bedeutung. Commun. Inst. For. Fenn. 24(1): 1-304.

Larsson, S. & Tenow, O. 1984. Areal distribution of a Neodiprion sertifer (Hym., Diprionidae) outbreak on Scots pine as related to stand condition. Holarctic Ecol. 7: 81-90.

Löyttyniemi, K. 1978. Metsälannoituksen vaikutuksesta ytimennävertäjiin (Tomicus spp., Col., Scolytidae). Summary: Effect of forest fertilization on pine shoot beetles (Tomicus spp., Col., Scolytidae). Folia For. 348. 19 p.

Mattson, W. J. 1980. Herbivory in relation to plant nitrogen content. Ann. Rev. Ecol. Syst. 11: 119-161.

Merker, E. 1958. Forstschutz gegen Insekten durch Düngung der Baumbestände. Allg. Forstz. 13: 314-315.

— 1961. Welche Ursachen hat die Schädigung der Insekten durch Düngung im Walde? Allg. Forst Jagdz. 132: 73-82.

— 1962. Augenblickicher Stand der Untersuchungen über die Schädigende Wirkungweise von Düngestoffen auf Waldschädlinge. Allg. Forst Jagdz. 133: 81-83.

Oldiges, H. 1958. Waldbödendüngung und Scähdlingsfauna der Kronenraumes. Allg. Forstz. 13: 138-140.

Otto, D. 1964. Untersuchungen von Graurüssler-Frass (Brachyderes incanus L.) auf Kiefern-Düngungsflächen. Tagunsber. Nr. 75 der DAL Sympos. 'Probleme der Kiefernwirtschaft', Eberswalde 1964. p. 229-235.

— & Geyer, W. 1970. Zur Bedeutung des Kiefernnadelharzes und des Kiefernnadelöles für Entwicklung nadelfressender Insekten. Arch. Forstwesen 19: 151-167.

Saalas, U. 1949. Suomen metsähyönteiset. Porvoo. 719 p.

Shaw, G. G., Little, C. H. A. & Durzan, D. J. 1978. Effect of fertilization of balsam fir trees on spruce budworm nutrition and development. Can. J. Res. 8: 364-374.

Schwenke, W. 1960. Über die Wirkung der Waldüngung auf die Massenvermehrung der Kiefernbuschhornblattwespe (Diprion pini L.) in 1959 in Mittelfranken und die hieraus ableitbaren gradologischen Folgerungen. Zeitschr. Angew. Entomol. 46: 371-378.

— 1974. Die Forstschädlinge Europas. Zweiter Band. Hamburg. 500 p.

Smeljanez, W. P. 1969. Die Rolle der Terpenoide bei der Widerstandsfähigkeit gegen Schadinsekten. Anz. Schädlingskunde Pflanzenschutz 42: 33-37.

Smirnoff, W. A. & Bernier, B. 1973. Increased mortality of the Swaine jack-pine sawfly, and foliar nitrogen concentrations after urea fertlization. Can. J. For. Res. 3: 112-121.

Stark, R. W. 1965. Recent trends in forest entomology. Ann. Rev. Entomol. 10: 303-324.

Viro, P. J. 1967. Forest manuring on mineral soils. Medd. Norske Skogforsoksv. 85: 111-136.

— 1972. Die Walddüngung auf finnischen Mineralböden. Folia For. 138. 19 p.

Wickman, B. E. & Mason, R. R. 1988. The effects of thinning and fertilization on western spruce budworm, Choristoneura occidentalis Freeman (Lepidoptera: Tortricidae), and Grand fir growth. Proc. XVIII Int. Congr. Entomol., Vancouver, B.C., Canada, July 3 to 9, 1988. 419 p.

Zwölfer, W. 1962. Waldbodendüngung und Schädlingsbekämpfung. Landwirtschaft-Angewandte Wissenschaft 114: 1-5.

Total of 27 references