Short-term effects of selected insecticides on non-target soil invertebrates of a forest ecosystem

ALEXANDER JÄKEL & MECHTHILD ROTH

Jäkel, A. & Roth, M.: Short-term effects of selected insecticides on non-target soil invertebrates of a forest ecosystem.
Soil Zoological Problems in Central Europe. Pižl, V. & Tajovský, K. (eds.): 65-69. České Budějovice, 1998. ISBN 80-902020-4-7

Investigations on the short-term responses of non-target soil invertebrates to selected chemical and biological insecticides (Dimilin: Diflubenzuron, Foray 48 b: *Bacillus thuringiensis* var. *kurstaki*) were carried out in spring 1995 in 65-years-old monocultures of Scots pine (*Pinus sylvestris* L.) located in Northeast Saxonia (Germany).
Objectives of the study have been the dominant groups of the invertebrate soil fauna, integrated e.g. in litter decomposition processes (Diplopoda, Collembola, Oribatei) or functioning as potential antagonists to pest insects (predatory arthropods: Araneae, Chilopoda, Carabidae, Staphylinidae). Invertebrates were collected in two-week-intervalls using ground photoeclectors and pitfall traps within the first 6 weeks after applying the insecticides to the investigation plots by operational air craft.
As a result of pest control, especially Collembola and Acari showed higher activity abundances on areas treated with insecticides than on control plots. The highest densities of springtails and mites were found on areas treated with Dimilin (Collembola: 187 % of the control area, Acari: 275 % of the control area). As opposed to this, the emergence of Diptera decreased under the influence of insecticides. The strongest decline occurred on Foray plots. Similar result were found for spiders.

Keywords: insecticides, Dimilin, *Bacillus thuringiensis*, side effects, soil invertebrates, forest ecosystems.

Alexander Jäkel, Mechthild Roth, Chair of Forest Zoology, Technical University of Dresden, Pienner Str. 7, FRG - 01735 Tharandt.

Introduction

Monocultures of Scots pine (*Pinus sylvestris* L.), the dominant forest type in the plain of northeastern Saxonia, are susceptible to infestations of pest insects. In recent years especially gradations of pine moth (*Dendrolimus pini* L., Lepidoptera, Lasiocampidae) and nun moth *Lymantria monacha* L., Lepidoptera, Lymantriidae) caused widespread damages due to the defoliation of tree crowns. As part of a moth supression programme of the Saxonian forest administration chemical (Dimilin) and biological (Foray) pest control agents were applied to the infested stands.

Dimilin with the active ingredient Diflubenzuron is widely used to control forest defoliating insects. Belonging to the group of insect growth regulators, the benzoylphenylurea insecticide produces his effects during the molting process, an essential event in the life cycle of all arthropods. Diflubenzuron acts primarily by inhibiting the synthesis of chitin, the major component of the exoskeleton of arthropods (Grosscourt and Jongsma 1987). Since mortality occurs during molting Dimilin is most effective against larval stages of insects (Maas et al. 1981). In general, lethality to adult insects is low. Ovicidal effects either by direct egg contact or through female adults are known (Maas et al. 1981).

Foray is a *Bacillus thuringiensis* preparation, containing *Bacillus thuringiensis* var. *kurstaki*. The biological pest control agent produces its effect on the digestive tract of sensitive species. In a pH-dependent reaction within the lumen of the midgut, bacterial endotoxins are disengaged and lead, mediated by the activity of proteolytic enzymes, to the destruction of the resorptive epithelium of the intestine (Ellar et al., 1990, Yamamoto and Powell, 1993).

Contrary to the impacts on pest organisms only few investigations have been carried out on the side effects of these insecticides, especially under field conditions. Because natural enemies of pest organism may lead to the reduction of insecticide input, they are of special interest among non-target species. As lepidopterans with temporarily soil dwelling larvae (*Dendrolimus pini*: hibernation of L III or L IV in the litter layer; *Lymantria monacha*: dropping of caterpillars from the crown to the soil after mechanical disturbance e.g. by wind with subsequent reclimbing of the trees; Jacobs and Renner 1987) predatory arthropods of the soil surface have to be taken into consideration. The second important group of non-target organisms in forest ecosystems are saprophagous invertebrates, which are integrated in litter decomposition processes and thus keep a key position in ecosystem functioning.

Material and methods

Investigations were carried out in spring 1995 (2 May - 16 June 1995) in 65-years-aged monocultures of Scots pine (*Pinus sylvestris* L.) located in Northeast Saxonia (Germany). The study sites are characterized by oligotrophic acid soils developed from glacial sands. The humus form is of the raw type. Mean annual precipitations are low (575 mm/year).

A control area (1,8 ha) and 2 investigation plots (3,5 ha) treated with either Dimilin (75g a.i./ha) or Foray (4 l /ha), were taken into consideration. The study was focused on temporarily or permanently soil living invertebrates belonging to e.g. litter decomposers (Diplopoda, Collembola, Oribatei) or predators (Araneae, Chilopoda, Carabidae, Staphylinidae). The sampling of the soil fauna was started immediately after spraying chemicals to the study sites by operational aircrafts. On each plot invertebrates were collected by ground photoeclectors (n = 5, surface area: 1 m^2 Funke, 1971), pitfall traps (n = 5, diameter: 7 cm, Mühlenberg, 1994). Animal were killed by a saturated solution of picric acid, sampled in two-week-intervals, and preserved in 70 % ethanol.

Results and discussion

According to ground-photoeclectors and pitfall traps the invertebrate soil fauna of the pine stands is dominated by Collembola, Diptera, Acari, Hymenoptera, Araneae and Coleoptera (Tab. 1, 2).

Moth suppression with *Bacillus thuringiensis* toxins (Foray-plot) and the development-inhibitor Diflubenzuron (Dimilin-plot) caused taxon specific, distinct impact on emergence / activity density of permanently or temporarily soil inhabiting invertebrates at the pine forest. Short-term side effects were measured within the first 6 weeks following the application of the chemicals by operational air craft (Tab. 1, 2).

According to ground-photoeclectors the emergence /activity density of Diptera was reduced especially on areas treated with preparations of *Bacillus thuringiensis* var. *kurstaki* (Tab. 1). Mann-Whitney-U-test showed statistical significance on the $p < 0.05$ level. As the catch results of the emergence traps proved Foray acts immediatly after insecticidal treatment. Effects were seen in the first and second sampling interval, following the applipation of Foray (Fig. 1).

Table 1. Emergence / activity density (ind./m^2: mean values $\bar{x}$ ± standard deviation SD) of invertebrate animals on the control area and on study sites treated with Dimilin or Foray - results according to samples of ground-photoeclectors within the first six weeks after application of the insecticides (2. May - 16. June 1995) *: p < 0.05 tested by Mann - Whitney U - Test.

	control area		Dimilin plot		Foray plot	
ind./m^2	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD
Diptera	554.0	172.3	482.0	61.3	416.8 *	115.0
Lepidoptera	1.4	1.7	1.0	0.7	5.8	9.8
Hymenoptera	99.4	15.2	131.6	31.4	117.4	13.9
Formicidae	11.4	12.6	16.2	16.3	60.0	32.3
Coleoptera	27.4	3.2	35.8	9.5	42.8	8.9
Carabidae	1.4	1.7	0.4	0.5	0.6	1.3
Staphylinidae	3.6	2.3	6.4	4.2	4.8	2.5
Homoptera	17.0	9.2	17.0	8.4	15.0	9.2
Heteroptera	8.2	5.1	14.8	2.3	5.6	5.6
Collembola	1124.2	289.3	2408.8 *	1140.6	1415.8	397.1
larvae insecta	3.2	2.8	2.2	1.3	1.2	1.1
Chilopoda	0.2	0.4	0.0	0.0	0.0	0.0
Isopoda	0.0	0.0	0.4	0.9	0.0	0.0
Araneae	52.4	14.8	49.8	16.3	42.2	11.8
Opiliones	0.8	1.3	0.8	1.1	0.4	0.5
Acari	430.6	113.3	711.8 *	230.8	746.0	224.4
Gastropoda	0.2	0.4	0.2	0.4	0.4	0.5

Table 2. Activity density (ind./pitfall trap: mean values $\bar{x}$ ± standard deviation SD) of invertebrate animals on the control area and on study sites treated with Dimilin or Foray - results according to pitfall traps sample within the first six weeks after opplication of the insecticides (2. May - 16. June 1995).

	control area		Dimilin plot		Foray plot	
ind./m^2	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD
Diptera	82.0	40.8	66.0	19.3	56.2	17.0
Lepidoptera	0.2	0.4	0.0	0.0	0.4	0.9
Hymenoptera	9.8	1.1	11.2	2.7	14.4	2.4
Formicidae	7.4	2.4	8.0	4.6	10.8	5.1
Coleoptera	11.8	3.2	9.6	2.3	17.8	3.5
Carabidae	1.2	0.8	0.8	1.3	3.4	3.4
Staphylinidae	4.0	1.2	2.4	1.1	5.2	3.1
Homoptera	26.4	14.7	27.6	10.3	13.8	10.1
Heteroptera	0.8	0.8	0.2	0.4	1.6	0.5
Collembola	1180.0	429.9	1718.8	535.3	1320.6	1059.3
larvae insecta	17.6	14.1	8.8	3.9	5.0	2.9
Diplopoda	0.0	0.0	0.2	0.4	0.0	0.0
Araneae	70.6	9.1	69.0	12.0	41.6	11.4
Opiliones	1.2	1.3	0.8	0.8	6.4	3.3
Acari	409.8	143.5	852.6	581.0	589.0	231.5
Gastropoda	3.8	3.3	1.8	2.0	1.2	0.8

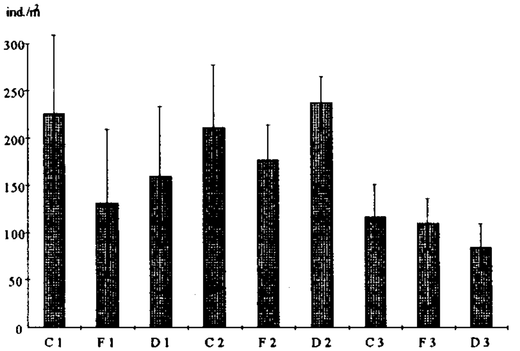

Fig. 1: Emergence / activity density (ind./m^2) of Diptera on the study sites according to catch-results of ground-photoeclectors C: control area, F: Foray plot, D: Dimilin plot, 1: 02.05. - 15.05.1995, 2: 15.05. - 29.05.1995, 3: 29.05. - 12.06.1995.

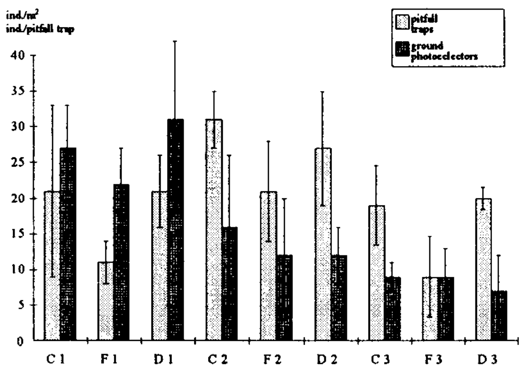

Fig. 2. Activity density (ind./m^2) of spiders on the study sites according to catch results of ground-photoeclectors and pitfall traps at two week-intervals; C: control area, F: Foray plot , D: Dimilin plot, 1: 02.05. - 15.05.1995, 2: 15.05. - 29.05.1995, 3: 29.05. - 12.06. 1995.

Also spiders belonged to the invertebrate groups, which were negatively affected by the biological pest control agent (Tab. 2). Compared to the results of pitfall traps on the control area individual numbers of the Araneae decreased after the application of Foray (Tab. 2). The effects on spiders were evident during all 3 two-week sampling intervals of the investigation period (Fig. 2).

As opposed to this, enhanced activity densities were manifested by ground-photoeclectors for the Collembola particularly on Dimilin-plots ($p < 0.05$, Mann-Whithey-U-test), for on Dimilin ($p < 0.05$, Mann-Whitney-U-test) and Foray plots (Tab. 1). Similar results were found with pitfall traps (Tab. 2). Enhanced activity densities of soil invertebrates caused by an increase of the locomotive activity is a common sublethal effect of several pesticides (Pfeifer et al., 1995, Roth and Funke 1993). In the case of the Collembola - according to pitfall traps - this phenomenon was observed within the first two weeks - according to ground-photoeclectors - within six weeks after spraying Dimilin to the investigation plot (Fig. 3). The time-dependent differences in the results of the sampling methods may be caused by the method specific interferences with climatic factors.

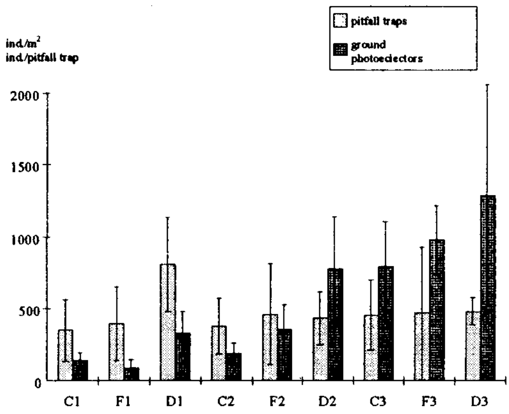

Fig. 3. Activity density (ind./m^2) of springtails on the study sites according to catch results of ground-photoeclectors and pitfall traps at two week- intervals; C: control area, F: Foray plot, D: Dimilin plot, 1: 02.05. - 15.05.1995, 2: 15.05. - 29.05.1995, 3: 29.05. - 12.06.1995.

Literature

Ellar, D.J., Knowles, B.H., Carroll, J., Horsnell, J., Haider, J., Haider, M.Z., Ahmad, W., Nicholls, C.N., Armstrong, G., Hodgeman, C. 1990. Genetic and chemical studies on the mechanism of action of *Bacillus thuringiensis* entomocidal d-Endotoxins. In: Rappuoli et al. (Eds.) Bacterial protein toxins. Zbl. Bact. Suppl. 19: 499-507

Grosscourt, A.C., Jongsma, B. 1987. Mode of action and insecticidal properities of diflubenzuron. In: Wright, J.E., Retnakaran, A. (Eds.), Benzoylphenyl Ureas. Plenum Press, New York. p. 75-99

Jacobs, W., Renner, M., 1987. Biologie und Ökologie der Insekten. 2. Auflage. Gustav Fischer, Stuttgart, New York, 690 pp.

Maas, W., Van Hes, R., Grosscourt, A.C., Duel, H.D., 1981. Benzoylphenylurea Insecticides. In: Wegler, R. (Ed.), Chemie der Pflanzenschutz- und Schädlingsbekämpfungsmittel. Springer, Berlin, p. 423-470

Pfeifer, M., Rau, U., Jans, W., Roth, M.; Funke, W., 1995: Auswirkungen von Pflanzenschutzmitteln und Aromatischen Kohlenwasserstoffen auf die Insektenfauna (Diptera, Collembola) eines Fichtenforstes. In: Mitt. Dtsch. Ges. Allg. Angew. Ent. 9, Giessen.

Roth, M., Funke, W., 1993. Auswirkungen von Stoffeinträgen auf Tiergesellschaften von Wäldern. In: Forstw. Cbl. 112, Paul Parey, Hamburg und Berlin, p 75-88

Yamamoto, T., Powell, G.K. 1993. *Bacillus thuringiensis* Crystal proteins: Recent advances in understanding its insecticidal activity. In: Kim, L. (Ed.), Advanced engineered pesticides. Marcel Dekker, Inc. New York, Basel, pp. 3-43