Effects of Chemical and Biological Insecticides on the Community and Diversity of Litter Insects

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Abstract. The research objectives were to determine the species community, composition and diversity of pine litter insects and compare effects of chemical and biological insecticide treatments on non-target organisms in forests undergoing outbreaks of pine beauty moth (*Panolis flammea* Shiff.). Pine beauty moth is one of the most important insect pests in Lithuania. Periodic outbreaks of defoliating insects can change the microclimatic conditions in forest ecosystems. The research was conducted in Scots pine (*Pinus sylvestris*) stands that were damaged by pine beauty moth in the Druskininkai forest enterprise in 2001. The chemical insecticide Arrivo, independent of concentration, had a negative effect on the abundance of pine litter insects. The Shannon diversity index was >2 in all plots, indicating medium diversity of pine litter insects.
Keywords: pine litter insects, community, diversity.

I. Introduction

Damage from defoliating insects usually expands to big areas and in many cases it may cause extensive dieback of trees in pine forests. The pine beauty moth (*Panolis flammea* Shiff.) is the one of the most damaging insects pests in Lithuania. Periodic outbreaks of defoliating insects can change the microclimatic conditions in forest ecosystems. This may help explain the arrival of new insects species. For example, 52.9% of all the *Carabus arcensis* ground beetles collected were from the epicenter of an insect defoliator outbreak whereas only 37.4% were collected from the peripheral part of the outbreak [1].

Chemical and biological insecticides are often applied to avoid defoliation. In 2001, approximately 3150 ha of Scots pine (*Pinus sylvestris*) stands were sprayed with the insecticide Foray – 48 B and 1547 ha were treated with the insecticide Arrivo to control the pine beauty moth in the southern part of Lithuania. Litter insects and other arthropods like spiders are very important in the self – regulation processes of forest ecosystems, because they are predators and can efficiently control the abundance of insect pests in the forest [6]. Therefore, investigations of side effects during area – wide pest suppression campaigns, including the impacts of chemical and biological insecticide treatments on non-target organisms, are always of high importance.

Species diversity is very important in the sustainability of forest ecosystems. Species diversity, or the taxonomic variety of living organisms, is one of the three principal levels of biological diversity, which include genetic diversity within species, species diversity and ecosystem or community diversity [8]. In most environmental assessments, however, biodiversity is identified as synonymous with species diversity and is measured by the number of species occurring in an area [5].

The objective of this research was to investigate the effects of chemical (Arrivo) and biological (Foray-48 B) insecticides on the abundance and diversity of pine litter insects.

II. Methods

The research was conducted in 2001 in Scots pine stands in the Druskininkai forest enterprise that were damaged by pine beauty moth. Insecticide treatments of Arrivo (conventional pyrethroid) and Foray-48 B (biological insecticide) were applied right on the pine litter. Three different doses of Arrivo (4 g/ha, 40 g/ha, 400 g/ha) and Foray-48 B (0.4 l/ha, 4 l/ha, 40 l/ha) were used. Litter insects and other arthropods (spiders) were collected in pitfall traps (150 ml plastic cups) filled with 10% formalin. Twelve pitfall traps were installed per each dose tested of Arrivo and Foray-48 B and another 12 traps were placed in the unsprayed area (control). Traps were placed in a 2x2 m rectangular design with three replications; the distance between the replications was 20 m [4]. Traps were emptied about once a month from May to October 2001. The catch results were calculated for 20 day periods to avoid problems due to irregularities in the collecting dates among treatments.

The diversity of pine litter insects was calculated using the following diversity indices [2, 3]:

Shannon diversity index (H'):

$$H' = \sum p_i (\ln p_i),$$

where: p_i = proportional abundance of i^{th} species (n_i/N);

Evenness (E):

$$E = H'/\ln S,$$

where: H' = Shannon diversity index,

S = species number;

Berger – Parker diversity index (d):

$$d = N_{max}/N,$$

where: N_{max} = number of individuals for the most abundant species,

N = number of individuals.

Diversity indices are typically used to estimate the variety of organisms in an area. Indexes, where mentioned, usually show the diversity of wide taxonomical groups (mammals, insects, birds, trees). Results can vary from species richness

to evenness [11]. These indexes were calculated with Bio-Dap program.

III. Results

The abundance of insects (mean ± SE number per trap per 20 days) significantly decreased from 4.4 ± 0.32 to 1.7 ± 0.13 (t = 2.32) on plots after treatment with Arrivo at 4 g/ha, from 4.0 ± 0.22 to 2.3 ± 0.21 (t = 1.29) on the plots treated with Arrivo at 40 g/ha, and from 4.7 ± 0.24 to 1.5 ± 0.16 (t = 2.21) on plots treated with Arrivo at 400 g/ha (compared May – before treatment, with June – after treatment). Moreover, the insect community was almost 1.5 times more abundant in the unsprayed control plots (3.3 ± 0.22 number per trap per 20 days) than in plots treated with Arrivo (in June, Fig. 1).

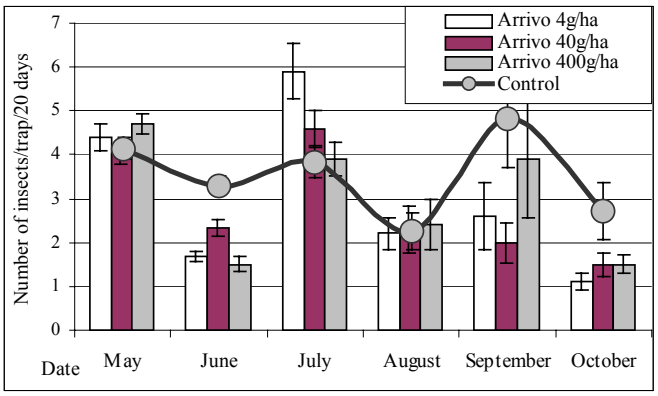

Fig.1. Influence of different concentrations of the insecticide Arrivo on pine litter insects.

The chemical insecticide Arrivo, independent of concentration, had a negative effect on the abundance of pine litter insects. However, this effect occurred immediately after spraying, in June. The number of insects on the Arrivo treated plots exceeded the number on the control plots (3.8 ± 0.35) in July, one month after the treatments were applied; there were 5.9 ± 0.64 insects per trap in the plots treated with Arrivo at 4 g/ha, 4.6 ± 0.42 in the plots treated with Arrivo at 40 g/ha and 3.9 ± 0.38 in the plots treated with Arrivo at 400 g/ha (Fig. 1).

The dynamics of the pine litter insect's community was the same for treatments using Foray – 48 B (Fig. 2).

Foray – 48 B is a biological insecticide, made with *Bacillus thuringiensis.* This insecticide impacts only the larvae of butterflies (in the order *Lepidoptera*); it is innocuous to warm – blooded animals and the environment [9, 10].

The number of species (S) and the number of individuals (N) were the same in only two research plots (Table 1). A total of 59 species were collected in the plot treated with Arrivo at 4 g/ha and Foray – 48 B at 40 l/ ha. Furthermore, the number of individuals was greatest in these same plots: 1816 (Arrivo 4 g/ha) and 1818 (Foray – 48 B 40 l/ha). Only 50 species and 1022 individual insects were collected in the untreated control plots.

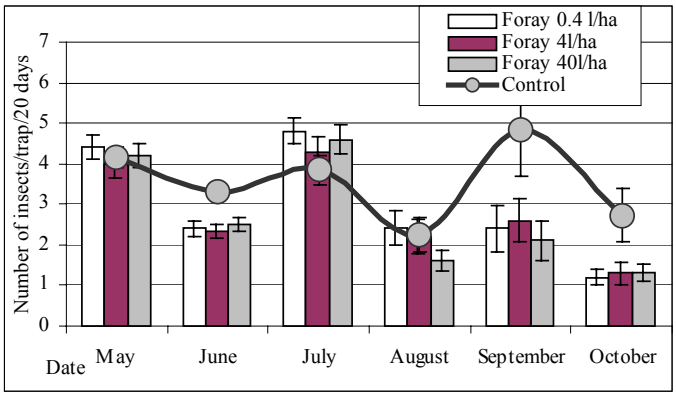

Fig. 2. Influence of different concentrations of the insecticide Foray – 48 B on pine litter insects.

The range of Evenness (E) is from 0 to 1. That means evenness of species was lowest (0.59) in the plots sprayed with the highest dose of Arrivo. Species were distributed most evenly (E = 0.65) in the control and Foray – 48 B at 40 l/ha plots (Table 1). The number of individuals for the most abundant species (Nmax) was 571 in the Arrivo at 400 g/ha plots and 349 individuals in the Foray – 48 B at 4 l/ha plots. There were only 196 individuals of the most abundant species in the control plots (Table 1).

Table 1. Main parameters of species diversity.

	Diversity parameters			
Research plots	N	S	E	Nmax
Arrivo 4 g/ha	1816	59	0.61	322
Arrivo 40 g/ha	1553	53	0.61	278
Arrivo 400 g/ha	1796	52	0.59	571
Foray 0.4 l/ha	1803	55	0.61	331
Foray 4 l/ha	1701	57	0.64	349
Foray 40 l/ha	1818	59	0.65	330
Control	1022	50	0.65	196

The Shannon diversity index depends on species number (S) and evenness (E). The index increases with increasing species number and then the abundance of species distributes evenly. The range of the Shannon diversity index is from 0 – (lowest diversity) to ln (S) – (highest diversity) [7]. So, the total number of insect species (S) was 107 in all research plots and Ln (S) = Ln (107) = 4.67. The Shannon diversity index values indicated medium diversity of pine litter insects, because it was >2 in all plots (Table 2).

Furthermore, the Shannon diversity index H' was 2.44 in the Arrivo at 40 g/ha plots, 2.32 in the Arrivo at 400 g/ha plots and 2.42 in the Foray – 48 B at 0.4 l/ha plots; H' was 2.55 in the control plots (Table 2). This result implies there is a negative influence of insecticides on the species diversity of

litter insects, because the diversity index was significantly higher in the control plots (accordingly *t* test was: 2.199, 4.602, 2.612, *p*=0.01). Diversity differences were not significant in the other treatment plots (Arrivo at 4 g/ha, Foray – 48 B at 4 and 40 l/ha) in comparison with the control plots (Table 2). The Shannon index values show the influence of strong doses of chemical insecticides on the diversity of pine litter insects.

Table 2. Indexes of species diversity

	Diversity indexes		
Research plots	Shannon (H')	Berger – Parker (d)	1/d
Arrivo 4 g/ha	2.47	0.177	5.64
Arrivo 40 g/ha	2.44	0.179	5.586
Arrivo 400 g/ha	2.32	0.318	3.145
Foray 0.4 l/ha	2.42	0.184	5.447
Foray 4 l/ha	2.58	0.205	4.874
Foray 40 l/ha	2.66	0.182	5.509
Control	2.55	0.192	5.214

The Berger – Parker index (d) is based on species dominance. It is simple to measure, but is not widely used [11]. To ensure that the index increases with increasing diversity, the reciprocal form of the measure is usually adopted (1/d). The lowest diversity was in the plots treated with Arrivo at 400 g/ha. The Berger – Parker index was 0.318 in this plot, which shows only one species dominated and comprised 31.8% of the individuals collected in the plot. When the Berger – Parker index increases, it means one or a few species predominated, so, diversity is lower. The index was very similar for all the research plots, because a few species dominated: 17.7% (individuals of most abundant species) in plots treated with Arrivo at 4 g/ha, 17.9% in plots treated with Arrivo at 40 g/ha, 18.4% in plots treated with Foray – 48 B at 0.4 l/ha, 20.5% in plots treated with Foray – 48 B at 4 l/ha and 19.2% in the untreated control plots (Table 2).

Spiders (*Aranei*) were the most abundant species – 322 individuals were collected in the Arrivo at 4 g/ha plots, 278 individuals in the Arrivo at 40 g/ha plots, 349 individuals in the Foray – 48 B at 4 g/ha plots and 330 individuals in the Foray – 48 B at 40 g/ha plots. Spiders predominated in the control plots too (196 individuals). The beetle *Calatus micropterus* (571 individuals) predominated in the Arrivo at 400 g/ha plots, whereas there were 331 individuals of the beetle *Pterostichus ablongopunctatum* collected in the Foray – 48 B at 0.4 l/ha plots (Table 3).

All dominant species, except *Strophosomus capitatus* are entomophagous. They arrived at the research plots because of the pine beauty moth. They are predators and the pine beauty moth might be an indirect nutritive base, then it goes down to the litter for hibernation.

IV. Conclusions

1. The chemical insecticide Arrivo, independent of concentration, had a negative effect on the abundance of pine litter insects. However, this effect occurred immediately after spraying.
2. Evenness of species was lowest (0.59) in the research plots sprayed with highest dose of Arrivo.
3. The Shannon diversity index values indicated medium diversity of pine litter insects, because it was >2 in all plots.
4. The Berger – Parker index was lowest (0.318) in the plots treated with the highest concentration of Arrivo (400 g/ha); this indicates only one species dominated and comprised 31.8% of the individuals in these plots.

References

[1] LMI metinė ataskaita, Kaunas, Girionys, 1997, unpublished.
[2] T.R.E. Southood, "Ecological methods". Chapman and Hall, London, New – York,, 420-455 p. 1987.
[3] Ю. Одум, "Основы экологии". М., Мир, 740 с. 1975.
[4] К.К. Фасулати, "Полевое изучение насекомых безрозвоночных". М.с. 320, 1971.
[5] K. J. Gaston, "Species richness: measure and measurement, Biodiversity. A Biology of nubers and difference, Blackwell, Oxford, pp. 77-113, 1996.
[6] А.Н. Литвинова, Т.П. Панкевич, Р.В. Молчанова, "Насекомые сосновых лесов", Минск, 22-28 с. 1985.
[7] S. H Hulbert, "The nonconcept of species diversity: a critique and alternative parametres", Department of entomology, University of California, Riverside, 1971.
[8] J. L. Harper, D. L. Hawksworth, "Preface in biodiversity: measurement and estimation", 1995.
[9] B. Glowacka, "The control of the nun moth with the use of Bacillus thuringiensis in Poland", Proceedings of the first jodint

Table 3. The dominant species in the research plots.

		Arrivo (g/ha)			Foray – 48 B (l/ha)			
		4	40	400	0.4	4	40	Control
Species	Order	Number of individuals						
Calathus micropterus	*Coleoptera*	317	207	571	236	198	223	174
Pterostihus ablongopunctatum	*Coleoptera*	229	223	235	331	300	214	100
Carabus arcensis	*Coleoptera*	198	193	189	310	159	260	146
	Aranei	322	278	238	298	349	330	196
Myrmica rubra	*Hymenoptera*	279	259	173	139	162	232	150
Strophosomus capitatus	*Coleoptera*	185	136	82	175	140	122	44
Total		1816	1553	1796	1803	1701	1818	1022

meeting. Bulletin, OILB – SROP, 57-60 p. 1996.
[10] A. Lindelow, "Outbreak of pine looper moth in Sweden", Tallmataruroft pa Uokensas, Vaxtsyddsnostirr, 5 ref, 100-103 p. 1997.
[11] A. E. Maguran, "Ecological diversity and its measurement", Princeton Univ. Press, Princeton, N.Y, 179 p., 1988.