Effect of Insecticide Arrivo on Ground Beetle (*Coleoptera*, *Carabidae*) Species Diversity in Scots Pine Stands

JŪRATĖ LYNIKIENĖ
Lithuanian Forest Research Institute. Liepu str. 1, Girionys, LT-53101 Kaunas distr., Lithuania.
Phone: +370 37 547 269, E mail: lynikiene@yahoo.com

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Abstract

The research was performed in Druskininkai forest enterprise in 2001. The objective was to estimate the impact of chemical insecticide Arrivo upon ground beetle species diversity in pine stands damaged by pine beauty moth (*Panolis flammea* Schiff.). Test plots were established in Scots pine (*Pinus sylvestris* L.) stands and ground beetles were collected in the areas of operational aerial spray against pine beauty moth. Ground beetles were trapped with Barber ground traps. Total number of ground traps was 72.

Quantitative parameters (total number of species *S* and total number of individuals *N* per season) were compiled from trap catches. Species richness and diversity were evaluated using Shannon (*H*) species diversity index and measure of evenness (*E*). Species dominance was estimated according to Simpson's index (*D*) and Berger-Parker's index *d.* Sorenson index was used to evaluate similarity between ground beetle species composition in variants. The catch data of ground traps were fitted to the model of logarithmic species abundance distribution.

Shannon's species diversity index (*H)* was 1.29 in Arrivo 40 g/ha treated variant. Species diversity index was the same in the last two variants (20 g/ha treated and untreated control, *H*=1.25). According to Berger-Parker's index, the most abundant species of ground beetle comprised: in Arrivo 20 g/ha treated variant - 35%, in Arrivo 40 g/ha treated variant - 44% and in untreated control - 40% of all collected ground beetles.

Key words: insecticide Arrivo, species diversity, ground beetles, pine stands

Introduction

The last invasion of pine beauty moth (*Panolis flammea* Schiff.) in Lithuania during 1999-2002 impaired the condition of the pine stands in Dzukija. The pest expanded in the territory over 44800 ha (Zolubas 2001), defoliation few years in a row made a significant damage to whole forest ecosystem. The outbreaks of the defoliating pests may change the environmental conditions (sunlight and ground water regime) and result in the abundance and species composition of harmless and/or beneficial insects (Žiogas *et al*. 1997). Therefore, the application of insecticides is necessary when the defoliating insect pests spread in wide areas. Presently the organic phosphorus, synthetic pyrethroid insecticides are used in forest protection against insect pests. Chemical preparation Arrivo is assigned to the group of synthetic pyrethroids. The active substance of insecticide Arrivo is cypermetrin. Arrivo is characterized by selective influence and it is very toxic for the insects. Arrivo and other synthetic pyrethroids (Ripkordo, Sherpa) are characterized by high biological activity and fast fragmentation in the soil. However, these insecticides are strongly or meanly toxic for human and warm-blooded animals *(Miško apsaugos vadovas* 2000).

It was determined that the chemical treatment (including Arrivo) had drastic impact on non-target insects species as they comprised 54% of all dead insects, 27% were neutral (mostly from *Diptera* order) and 19% – entomophagous. Most carabids are predatory, consume a wide range of food types, and experience food shortages in the field (Lovei and Sunderland 1996). The mortality of ground beetles, predators regulating the abundance of the defoliating insect pests, increased after consuming dead pest larvae that were found on the litter (Žiogas and Gedminas 1996). Predatory carbids are beneficial in forest protection being the natural enemies of defoliating insects. Three species were identified of ground beetles, which damages the pupae of pine beauty moth in Scotland. The abundance of these carabid species was 10% higher in pest outbreak comparing with the areas without outbreak (Walsh *et al*. 1993). The activities of forest protection (application of insecticides) can give the undesirable secondary effect. After the application of insecticides (chemicals especially) the number of insect pest, as well as natural enemies can decrease. Consequently, it makes the risk of further occurrence of pest outbreak (Берриман 1990).

Species diversity, considered as a part of the forest ecosystem stability, can be reduced most probably after the application of the insecticides in forest protection. The quantitative parameters of litter insect species diversity (abundance and species richness) may be changed. Moreover, the dominance of one or several resistant species may increase, leading to low overall diversity (Goodman 1975).

The wide range of diversity indexes are used in entomological research. Most popular of them are Shannon diversity index, Simpson's and Berger-Parker's dominance indexes. According to Shannon's diversity index Hungarian scientists estimated significantly higher diversity of ground beetle species in forest edge and grassland than in the forest (Magura *et al.* 2001). Shannon diversity index showed higher species diversity of ants in undamaged pine and oak stands as compared with damaged ones, in Mexico (Flores–Maldonado, *et al.* 1999). The same diversity indices were used to examine the non-target insect species diversity in the bark beetle (*Ips typographus* L.) pheromone traps in Lithuania. (Zolubas 2000).

There is no agreement, which diversity index or abundance distribution model is the best and fit to particular conditions. From the entomological point of view the log series model is the best expressing the insect species abundance distribution (Taylor 1978).

By now most of entomological studies in Lithuania were oriented towards the effect of insecticides (used for forest protection) on insect pests as well as on their natural enemies in pine crowns (Žiogas *et al*. 1997). The persistence of the insecticides, including Arrivo in forest ecosystem is known (Žiogas and Zolubas 1995). The litter insects of pine stands were studied in detail (Gedminas and Žiogas 1998). However, little is known about the effects of the chemicals on the diversity of ground beetle species, occurring in pine litter. This aspect is very important because ground beetles are predators, which can regulate the abundance of the defoliating pests, while they hibernate in the litter.

The objective was to determine the impact of the conventional insecticide Arrivo upon ground beetle species diversity in pine stands damaged by pine beauty moth.

Materials and methods

The field investigations were carried out in 2001. Scots pine stands damaged by the pine beauty moth were selected for the research in Druskininkai forest enterprise. In order to determine the effect of the pyrethroid insecticide Arrivo, test plots were established and ground beetles were collected in the areas of operational aerial spray against pine beauty moth. Pine stands were of immature and mature age, growing on poor soils with normal watering (Na, Nb), with 0.6-0.7 relative density index, and heavy crown defoliation (50-70%). Ground beetles occurring in pine litter were collected in three different variants: 1) in the areas treated with 40 g/ha norm of pyrethroid Arrivo; 2) in the areas treated with 20 g/ha norm of pyrethroid Arrivo; 3) untreated pine stand – control (Fig.1).

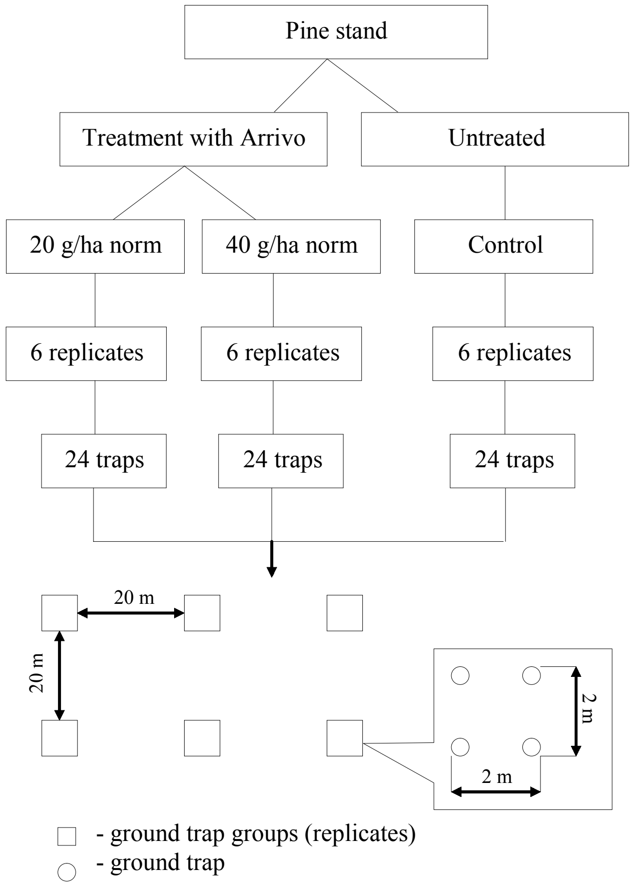

Figure 1. The scheme of test plots arrangement and layout of ground traps

Ground beetles were trapped with Barber ground traps (Фасулати 1971, Gedminas *et al.* 1996, Barševskis *et al*. 2004, Browarski 2004, Czerniakowski and Olbryncht 2004, Lynikienė 2003, Lynikienė *et al.* 2004) – plastic cups of 6.5 cm diameter and 150 ml volume. They were installed at the level of litter surface, 1/3 of the traps was filled with the 10% of formalin. Ground traps were installed in groups of 4 traps, organized in 2x2 m square shape. The distance between trap groups was 20 m. 6 replicates were used in each variant (Fig. 1). Total number of ground traps was 72.

Traps were inspected and cleaned every 3-4 weeks. The data were analysed using the methods of elementary statistics (Čekanavičius and Murauskas 2001, 2002).

Species richness and diversity were evaluated calculating by Shannon's (H) species diversity index (Magurran 1988):

$$H' = -\Sigma p_i \ln p_i,$$

where

$p_i = n_i/N$,

n_i – number of individuals of ith species;

N – total number of individuals.

The maximum diversity (H_{max}) which could possibly occur would be found in a situation where all species were equally abundant. The ratio of observed diversity to maximum diversity can therefore be taken as a measure of evenness (E) (Pielou 1969):

$$E = H/H_{max} = H/\ln S,$$

where

H – index of diversity;

S – total number of species.

E is constrained between 0 and 1.0 where 1.0 representing a situation in which all species are equally abundant. This measure of evenness assumes that all species in the community are accounted for in the sample.

The second group of heterogeneity indices is referred to as dominance measures since they are weighted towards the abundances of the commonest species rather than providing a measure of species richness. Simpson's index (D) gave the probability of any two individuals drawn at random from an infinitely large community belonging to different species (Magurran 1988) as:

$$D = \Sigma p_i^2,$$

where

$p_i = n_i/N$;

n_i – number of individuals of ith species;

N – total number of individuals.

Berger-Parker's index d is simple dominance measure. The index expresses the proportional importance of the most abundant species:

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

where

N_{max} – number of individuals of the most abundant species;

N – total number of individuals.

Sorenson's index (Magurran 1988) was used to evaluate similarity between ground beetles species composition in variants:

$$C_s = 2j/(a+b),$$

where

j – the number of species found on both sites;

a – the number of species on site A;

b – the number of species on site B.

This index is designed to equal 1 in cases of complete similarity (that is where two sets of species are identical) and 0 if the sites are dissimilar and have no species in common (Magurran 1988).

The catch data from ground trap was fitted to the model of logarithmic species abundance distribution:

$$\alpha x,\ \alpha x^2/2,\ \alpha x^3/3 \ldots \alpha x^n/n,$$

where

αx being the number of species predicted to have one individual, $\alpha x^2/2$ – those with two and so on.

x is estimated from the iterative solution of: $S/N = [(1-x)/x][-\ln(1-x)]$, where

S – the total number of species;

N – the total number of individuals.

α has been obtained from the equation:

$$\alpha = N(1-x)/x$$

with confidence limits set by:

$$\mathrm{Var}(\alpha) = \alpha/-\ln(1-x)$$

The procedure for fitting the model is to calculate the number of species expected in each abundance class and compare that with the number of species actually observed using a goodness of fit χ^2:

$$\chi^2 = (\text{observed - expected})^2/\text{expected}$$

Results

Totally 25 species of ground beetles were collected in pine litter in 2001. According to the number of individuals 3 species of ground beetles were dominated: *Carabus arcensis* Hbst., *Pterostichus oblongopunctatus* Fabr. and *Calathus micropterus* Duft. These species were most abundant in all research plots. Only 4 and 3 individuals of *Carabus violaceus* L. were found in pine litter after the application of Arrivo 20g/ha and 40 g/ha norm, while 20 individuals were detected in untreated control. *Carabus cancellatus* Ill., *Pterostichus atterrimus* Hbst., *Nothiophilus biguttatus* Fabr., *Amara communis* Panz., *Patrobus atrorufus* Strom. might be coincidental because was collected only 1 individual of each species in all plots per season (Table 1).

Table 1. The list of ground beetle species and number of individuals per season

Species	Arrivo 20 g/ha	Arrivo 40 g/ha	Control
	Number of individuals		
Carabus arcensis Hbst.	249	630	843
Pterostichus oblongopunctatus Fabr.	217	452	606
Calathus micropterus Duft.	168	226	553
Carabus hortensis L.	19	1	0
Pterostichus niger Schall.	16	16	21
Pterostichus versicolor Sturm.	6	1	3
Carabus violaceus L.	4	3	20
Pterostichus vernalis Panz.	4	1	4
Calathus erratus C.	3	12	2
Carabus glabratus Payk.	2	0	0
Pterostichus lepidus Mull.	2	4	0
Calathus melanocephalus L.	2	0	0
Nothiophilus palustris Duft.	2	20	3
Carabus cancellatus Ill.	1	0	0
Pterostichus atterrimus Hbst.	1	0	0
Calathus fuscipes Goeze	1	0	0
Nothiophilus biguttatus Fabr.	1	3	3
Harpalus quadripunctatus Dej.	1	1	1
Amara communis Panz.	1	0	0
Cychrus caraboides L.	0	1	0
Agonum fuliginosum Panz.	0	5	0
Harpalus tardus Latr.	0	2	0
Patrobus atrorufus Strom.	0	0	1
Harpalus rufipes Deg.	0	1	1
Carabidae, larva	4	1	3

Pine litter ground beetle species diversity was poor according to Shannon's index (from 1.25 to 1.29), and the differences between variants were unreliable (p=0.2). The evenness of species distribution was medium (E=0.45-0.51) in all variants. Shannon's diversity index and index of evenness showed poor diversity of ground beetles species not only after aerial treatment with insecticide Arrivo, but in untreated control too (Table 2).

Table 2. The diversity and evenness of ground beetles species

Index	Variant		
	Arrivo 20 g/ha	Arrivo 40 g/ha	Control
	1	2	3
Shannon's *H*	1.25 0.002	1.29 0.001	1.25 0.0003
Probability, *p*	H_{1-2}=0.2	H_{1-3}=0.2	H_{2-3}=0.2
Evenness *E*	0.51	0.45	0.45

According to Berger-Parker's index most abundant species comprised: 35% in Arrivo 20 g/ha treatment, 45% in Arrivo 40 g/ha treatment and 41% in untreated control, of all collected ground beetles species. Species dominance was highest (0.45) after Arrivo 40 g/ha application. It means lowest species diversity. Highest species diversity according to Berger-Parker's (d=0.35) and Simpson's (D=0.28) indices showed in Arrivo 20 g/ha treatment, because species dominance was lowest comparing with Arrivo 40 g/ha treatment and the control (Table 3).

Table 3. Species dominance parameters

Index	Variant		
	Arrivo 20 g/ha	Arrivo 40 g/ha	Control
Berger-Parker's *d*	0.35	0.45	0.41
Simpson's *D*	0.28	0.34	0.32

Ground beetle species were found very similar in all research variants in 2001. Sorenson similarity measure ranged from 0.74 to 0.78 between research variants (Table 4).

Table 4. The similarity of ground beetle species composition in variants

Variant	Arrivo 20 g/ha	Arrivo 40 g/ha	Control
	Sorenson C_S		
Arrivo 20 g/ha	*	0.74	0.78
Arrivo 40 g/ha	*	*	0.77

The distribution of ground beetles species abundance fitted to log series model after aerial treatment with insecticide Arrivo against pine beauty moth and in untreated control (Fig. 2). Differences between the species observed and expected were unreliable: in Arrivo 20 g/ha treatment χ^2=12.37, p=0.1 in Arrivo 40 g/ha treatment χ^2=8.75, p=0.5 and in control χ^2=9.57, p=0.5.

Discussion

Carabids, due to their small dimensions and biology, are very strongly connected to the microhabitat of their occurrence: litter, soil, and, in large part, the tree-stand cover. Every considerable interference in the environment changes their living conditions. As a result of their sensitive reaction to anthropogenic changes in the habitat quality carabids are considered of bioindicative value for cultivation impacts (Kromp 1999). For example, cutting tree-stands and plowing soil for regeneration is an especially strong disturbance (Skłodowski *et al.* 2004). Consequently, application of insecticides for forest protection, especially chemicals, can change the composition and structure of carabids fauna.

Species richness of ground beetles was poor (25 species) after the application of insecticide Arrivo, comparing with total number (287 species) of ground beetle species known to occur in Lithuania (Pileckis and Monsevičius 1995). Generally species richness in Scots pine stands litter are poor in normal condi-

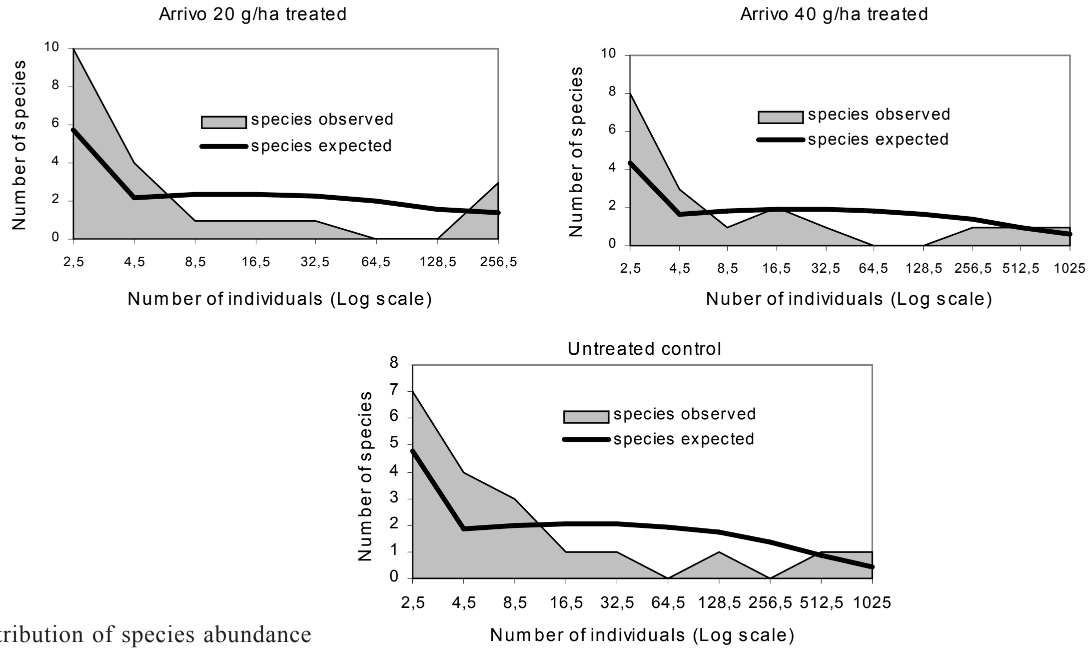

Figure 2. The distribution of species abundance

tions of the environment. Only one or few species of insects are dominating in this type of stands (Литвинова 1985). The latter proposition was confirmed by our results, which showed that only 3 species of ground beetles were mostly abundant according to the number of individuals (Table 1). The predominance of one or a few species in the sample shows poor species diversity (Magurran 1988). It was confirmed by low measures of Shannon's diversity index. Therefore, differences of Shannon's index in Arrivo treatments and the control were unreliable. It could be concluded, that 20 and 40 g/ha norm of pyrethroid insecticide Arrivo used against pine beauty moth had no influence on species diversity of ground beetles in pine litter.

Therefore, according to our results, Shannon's diversity index contradicts species dominance indexes (Berger-Parker and Simpson). For example: after the application of insecticide Arrivo 40 g/ha norm Shannon species diversity index was highest (comparing with last variants) and the indices of species domination were highest too, showing poor diversity. The reason for this contradiction is explicable by the sensibility of Shannon's, Simpson's and Berger-Parker's indexes to different diapasons of the species relative abundance. Simpson's index is heavily weighed towards the most abundant species in the sample while being less sensitive to species richness. Shannon's index depends on the number of all rather frequent species. If the number of "rather frequent" species is increasing and the number of "very common" species is decreasing, Shannon's diversity and species dominance indices are increasing (Magurran 1988).

A log series pattern would, however, result if the intervals between the arrivals of these species were random rather than regular (Boswel and Patil 1971, May 1975). The small number of abundant species and the large proportion of "rare" species (the class containing one individual is always the largest) predicted by the log series suggest that it will be most applicable in situations where one or a few factors dominate in the ecology of the community. So, one of the factors – application of insecticide Arrivo has not influenced the distribution of ground beetle species abundance (Fig. 2).

Conclusions

1. The insecticide Arrivo applied against pine beauty moth had not influenced ground beetle species composition occurring in pine litter.

2. The negative influence of 20 g/ha and 40 g/ha norms of insecticide Arrivo on ground beetle species diversity in pine litter was not found. Differences of Shannon's diversity index were unreliable in treatments and the control.

3. Sorenson measure (ranged from 0.74 to 0.78) showed high similarity between ground beetle species in all research variants.

4. The distribution of ground beetle species abundance fitted to log series model after aerial treat-

ment with insecticide Arrivo and in untreated control. Differences between the number of species observed and expected were unreliable. The factor of the ecosystem disturbance – application of insecticide had no influence on the distribution of ground beetle species abundance.

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ВЛИЯНИЕ ИНСЕКТИЦИДА АРРИВО НА РАЗНОВИДНОСТЬ ЖУЖЕЛИЦ (*COLEOPTERA*, *CARABIDAE*) В СОСНОВОЙ ПОДСТИЛКЕ

Ю. Линикиене

Резюме

Исследование было проведено в 2001 г. в Друскининкайском лесном предприятии. Площадки исследования были установленны в сосняках, поврежденных сосновой совкой (*Panolis flammea* Schiff.). С целъю определить эффект инсектицида Arrivo на рарнообразие видов жужелиц, ловушки были установленны на участках, где проводилось авиаопрыскивание против сосновой совки. Жужелицы сосновой подстилки были собраны ловушками Барбера. Общее количество ловушек было 72.

Количественные параметры (общее количество видов *S* и общее количество индивидов *N* в сезон) жужелиц были установлены по данным в ловушках. Богатство разновидности и разнообразие были оценены, вычисляя Шаннон (*H*) индекс разновидности и равномерность разспределения *(E)*. Доминирование видов жужелиц было оценено, вычисляя индексы Симпсона (*D*) и Бергера-Паркера (*d*). Индекс Соренсона использовался, чтобы оценить подобие между составом видов жужелиц каждого варианта. Данные землянных ловушек были приспособлены к модели логарифмического распределения изобилия видов.

Индекс разнообразия Шаннона был *H*=1.29 после применения инсектицида Arrivo 40 г/га нормы, а после нормы 20 г/га и в контроле - *H*=1.25. Согласно индексу Бергера-Паркера, самый обильный вид жужелиц составлял: после применения 20 г/га нормы инсектицида Arrivo - 35 %, после Arrivo 40 г/га нормы - 44 % и в контроле (инсектицида не было пременненно) - 40 % всех собранных жуков.

Ключевые слова: инсектицид Arrivo, разнообразие видов, жужелица, сосняки.