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ORIGINAL ARTICLE

Control of adult cockchafers *Melolontha* spp. with Mospilan 20 SP

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Abstract

For the period of the last 20 years, cockchafer grubs have caused in Europe considerable losses in plant production and forestry. Until recently, pest grubs were controlled with carbamate or organophosphorus insecticides applied into soil. Presently, after environmental regulatory implementation which disallow application of soil-applied insecticides control of adult cockchafers have gained more recognition. The aim of the study carried out during cockchafer swarming in mixed stands with oak (*Quercus robur*) was to evaluate the efficacy of insecticide treatments using aircraft and ground equipment to control *Melolontha melolontha* and *M. hippocastani* with Mospilan 20 SP at a rate 0.4 kg/ha. In 2007, helicopter sprays at a rate 5 l of working solution/ha were performed in the Forest District Spała (central Poland). In 2001, insecticide treatments at a rate 200 l of working solution/ha were applied with a tractor sprayer in the Forest Districts Spała and Smardzewice (central Poland). Treatment efficacy was evaluated 3 weeks after insecticide application by assessment of defoliation degrees in sprayed and not sprayed trees with the use of LIŚĆ (LEAF) computer software. Regardless the form of treatment application, observed leaf damage on sprayed trees ranged from 0.2–1.75%, while leaf damage on not sprayed trees was 86–95%. The results obtained will be used in the registration procedure of Mospilan 20 SP as the insecticide for the protection of oaks against cockchafers.

Key words

Melolontha spp., grubs, acetamiprid, Mospilan 20 SP

Introduction

In the last 20 years, cockchafer grubs *Melolontha melolontha* L. and *M. hippocastani* Fabr. brought about essential losses in plant production and forestry (De Goffau 1996; Mattedi and Varner 1996; Keller and Brennen 2005; Malinowski 2007; Oltean *et al*. 2010; Svestka 2010). Keller and Zimmermann (2005) reported the results of the inquiry conducted in 11 European countries indicating that in central Europe both abovementioned cockchafer species occurred on the area of 200 thousand hectares causing economic losses on 80 thousand hectares. Usually, the strategy of preventing grub damages includes application of chemical or derived from plants insecticides as well as mechanical methods. In addition, a lot of interest has been shown in biological preparations

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with *Beauveria brogniartii* (Enkerli et al. 2004; Laengle et al. 2005; Łabanowska and Bednarek 2011).

Until recently, cockchafer grubs were controlled directly with the use of soil-applied insecticides containing carbofuran (Furadan 5G), carbosulfan (Marshal suSCon 10 CG) diazinon (Diazinon 10 GR, Basudin 10 GR) or chloropyrifos (Dursban 480 EC). At the same time, there was carried out research on possibilities of indirect prevention of grub damages through control of adult cockchafers during their swarming. Consequently, there were tested insecticides from various chemical groups. Among others, Buchi and Jossi (1979) who conducted investigations on the reaction of *M. melolontha* to diflubenzuron under laboratory conditions, stated that beech leaves sprayed with 1% Dimilin WP 25 and used as cockchafer food showed the effect of 100% egg mortality in females. Also, Woreta (1999) studied sensitivity of cockchafer adults to pyrethroids under laboratory conditions. The author showed that alphamethrin (alpha-cypermethrin), deltamethrin, lambda-cyhalothrin and zeta-cypermethrin applied at low rates caused high insect mortality.

In field trials on control of adult cockchafer there were obtained fast lethal effects with Decis containing 2.5% deltamethrin (Rhode 1996), Fastac 10 EC – 10% alpha-cypermethrin (Adomas 1998) and Karate Zeon – 5% lambda-cyhalothrin (Benker and Leuprecht 2007). Similar results, i.e. high mortality of adult cockchafers under field conditions, were obtained by Rhode (1996) as well as Froeshle and Glas (2000) with applications of Rubitox containing the organophosphate active ingredient – phosalone. In Germany, several field trials were conducted on control of adult cockchafers with the use of azadirachtin extracted from *Azadirachta indica* seeds and applied in a form of preparation NeemAzal (Kaethner 1991; Rohde 1996; Froeshle and Glas 2000). In general, azadirachtin did not show a direct lethal effect. On the other hand, however, in cockchafer adults which fed on sprayed trees there were observed flight activity decrease, feeding intensity reduction, and also egg production by females was restrained. In all the above cases there was observed a decrease of population size in subsequent cockchafer generation emerging in areas adjacent to azadirachtin treated stands.

As a result of recently introduced restrictive regulations on application of plant protection products (Regulation (EC) No 1107/2009 of the European Parliament), no practical possibilities exist at this point to control cockchafer grubs with soil-applied insecticides. Then again, the area of cockchafer occurrence continually expands after subsequent swarming of pest imagines which emerge cyclically every few years.

In Poland, in the years 1995, 1999, 2003, 2007 and 2011 succeeding swarmings of *Melolontha melolontha* and *M. hippocastani* took place in forests on 15, 26, 46, 99 and 120 thousand hectares, respectively. For several dozen years, particularly detrimental damages due to grub feeding have been observed within the region under authority of the State Forest Regional Directorate Łódź (central Poland) where many forest districts are now described as "persistently grub-infested" since tree seedlings in nurseries as well as juvenile trees planted in newly reforested areas and growing in young stands within these regions are permanently damaged. Given that the results of the abovementioned laboratory and field studies (Rhode 1996; Adomas 1998; Woreta 1999) indicated high sensitivity of cockchafer imagines to pyrethroid insecticides, in the year 2003, the decision was taken by the State Forest Regional Directorate Łódź to carry out aerial insecticide treatments with Fastac 100 EC (10% alpha-cypermethrin). In May, overall about 10 thousand hectares of mixed stands with oak in the Forest Districts Piotrków, Smardzewice and Spała, where for several dozen years there had been observed considerable damages due to feeding of grubs of both *Melolontha* species, were air sprayed with the insecticide at a rate 0.07 l/ha mixed with water and adjuvant Ikar. Nonetheless, even if at the start the evident treatment effect comprising high insect mortality was achieved, the action of the preparation appeared to be short-term. Only after a one-week period it was observed that cockchafer adults flied onto sprayed trees and started easy feeding. Taking into consideration that pest swarming was going on, it was decided to repeat the treatment on half of already treated areas (Głowacka and Olczyk 2009).

In 2007, during subsequent cockchafer swarming in this region there was performed the next trial on aerial treatment with the preparation Mospilan 20 SP with the active ingredient acetamiprid – a pesticide from the neonicotinoid class of insecticides. The latter is characteristic of contact and stomach insecticidal activity for sucking and biting insects and indicates low toxicity for warm-blooded animals and pollinating insects. The main advantage of neonicotinoids is their systemic insecticidal activity, which means that they are incorporated by treated plants *via* leaves or roots and then distributed inside plants through the vascular system, eg. into newly developing leaves. The conducted trial was based on a presumption that due to acetamiprid systemic properties its activity would persist longer than that of less stable pyrethroids – thus, Mospilan 20 SP would be more efficient to control cockchafers.

The efficacy of the treatment assessed by monitoring of tree crown defoliation as well as the number of grubs (after 2 years) on treated and not treated areas appeared to be satisfactory. In the year 2011, in the period of subsequent cockchafer swarming which was observed on 44 thousand hectares, Poland's Ministry of Agriculture and Rural Development credited the permission for just the once application of the insecticide against cockchafers. Mospilan 20 SP was aerially sprayed on 15.5 thousand hectares within the area of the State Forest Regional Directorate Łódź. Also, on a relatively small area there was carried out the insecticide treatment using a tractor sprayer.

The aim of the present study was to assess the efficacy of aerial (2007) and ground (2011) insecticide treatments with Mospilan 20 SP in control of adult *Melolontha melolontha* and *M. hippocastani*. Assessments were conducted based on observed degrees of tree crown defoliation in the Forest Districts Spała and Smardzewice (State Forest Regional Directorate Łódź).

Material and methods

Aerial and ground cockchafer control treatments were carried out with application of the insecticide Mospilan 20 SP produced by Nippon Soda Co. Ltd., which contained 20% of acetamiprid at rates and working solution volumes which are presented in Tab. 1.

In the year 2007, in the Forest District Spała, Forest Division Luboszewy in the mixed stand with prevailing oak *Quercus robur* L., there were designated 5 experimental plots, each of the area of 10 ha. In the evening on 23 May, the tree stands within plots were aerially sprayed with the use of a helicopter equipped with electric atomizers AR 470.04. The oak stand situated in vicinity of a watercourse was chosen as control (not sprayed). The assessment of insecticide spray efficacy was performed based on measurements of damage of tree leaves collected 3 weeks after spraying. On each of 5 experimental plots there were selected randomly 12 trees, and 4 leaves from each tree were cut out with the use of clippers. Altogether there were collected 240 oak leaves. At the same time, there were collected 80 oak leaves from not-sprayed stand. All the leaves were collected at the height of about 5 m from trees growing close to forest section separating lines.

The area of cockchafer feeding damage on leaves was determined with the use of the specially designed software LIŚĆ (LEAF), which allowed entering the scans of damaged leaves into the computer programme for further analyses. The process of evaluations using the software comprised 2 steps: firstly, each scan of leaf placed on background sheet was covered by a square grid, and secondly the grid squares were validated, i.e. dark squares were valued as 1 (one point) and empty spaces (feeding damage displayed on the background) were valued as 0. The software computed the number of grid squares per leaf and calculated obtained values into absolute values (mm^2). When the leaf analysed was damaged on its edges, the graphic software program allowed sketching missing parts so as to obtain enclosed damage area. When graphic approximation of original leaf area was impossible, e.g. in case of considerably damaged leaves collected from control trees, percent-

Tab. 1. Characteristics of experimental areas treated with Mospilan 20 SP

Forest District/ Division/Year	Geographical coordinates	Habitat type/ oak age	Treatment rate and working solution volume/ha	Type of sprayer
Spała/Luboszewy/2007	51° 34' 18'' N 20° 04' 11'' E	Coniferous fresh forest/ 40–60 years	0.4 kg + 4 l water + + 1 l adjuvant Ikar 90 EC	Helicopter Mi-2R
Spała/Borki/2011	51° 28' 37'' N 19° 59' 12'' E	Coniferous fresh forest/ 20–40 years	0.4 kg + 200 l water + + 1 l adjuvant Ikar 90 EC	Tractor sprayer ODW-1
Smardzewice/Tomaszów/2011	51° 30' 38'' N 19° 59' 17'' E	Coniferous fresh forest/ 20–40 years	0.4 kg + 200 l water + + 1 l adjuvant Ikar 90 EC	Tractor sprayer ODW-1

age damage was estimated based on the average area of not sprayed leaves.

The trial on cockchafer control by application of Mospilan 20 SP with the use of ground equipment was conducted in the Forest Districts Smardzewice and Spała in 2011. Within mixed forest stands with oak *Quercus robur* L. there were selected 3 experimental plots of the area 2 hectares each. Not sprayed plots were designated in stands of the same age situated in a distance of several (3–5) ha away. Insecticide spraying of experimental plots was performed on 16 and 17 May with the use of a tractor mounted sprayer. After more than 3 weeks, 4 leaves from 12 random trees growing on each experimental plot were collected following the procedure performed in the year 2007. In total there were collected 144 leaves from insecticide treated trees and 144 leaves from not treated trees. The assessment of leaf damage was conducted with the use of LIŚĆ software.

Statistical analyses

The results of aerial and ground trials were analyzed using identical statistical procedures. Firstly, normality of distribution of data obtained in the experiments was tested by the Shapiro-Wilk test: group 1 – leaves treated with Mospilan 20 SP (A), group 2 – not sprayed leaves (C). Next, significance of differences between groups A and C in all experimental trials was tested with the use of non-parametric Mann–Whitney U test. The calculations were carried out with the use of Statistica 8.0 (StatSoft, 2008).

Results

In the years 2007 and 2011, in the treated stands there were observed first dead cockchafers which were dropping down onto the forest floor only 2 hours after insecticide application. The intensity of dropping down decreased after a few days. For the duration of 3 weeks after spraying, feeding cockchafers on sprayed leaves were not found (Fig. 1, 2).

The results of defoliation degree analyses carried out in 2007 after the aerial treatment with the use of helicopter are presented in Tab. 2. The assessment of damage of leaves collected from treated and control trees conducted using LIŚĆ software indicated high efficacy of Mospilan 20 SP treatment. It was shown that cockchafers damaged 0.2–0.6% leaves in insecticide sprayed stands while 89.8–95.2% of leaves were damaged in control (not-sprayed) trees.

Fig. 1. Leaves of oak *Quercus robur* sprayed with Mospilan 20 SP

Fig. 2. Leaves of control (not sprayed) oak *Quercus robur*

The results of the experiment carried out in 2011 are presented in Tab. 3. These indicate that in both Forest Districts, on the plots treated with Mospilan 20 SP applied with ground equipment there were damaged 0.7–1.8% leaves, while 86.1–93.6% leaves were damaged on control plots.

For all groups of trial data obtained from aerial and ground treatments as well as from not treated control plots the null hypothesis that samples came from a normally distributed population was rejected ($p < 0.05$ for all cases).

Tab. 2. Oak *Quercus robur* L. leaf damage in aerially treated stands in the Forest District Spała in 2007

Forest District/ Plot number	Experi- mental variant	Average leaf area [mm²]		Damage [%]
		Damaged	Not damaged	
Spała/1	Mospilan 20 SP	8.5	5218.5	0.2
	Control	4844.4	382.6	92.6
Spała/2	Mospilan 20 SP	10.3	5217.8	0.2
	Control	4977.2	250.9	95.2
Spała/3	Mospilan 20 SP	29.6	5914.5	0.5
	Control	5469.7	474.3	92.0
Smardzewice/4	Mospilan 20 SP	14.2	5827.1	0.2
	Control	5242.5	598.7	89.8
Smardzewice/5	Mospilan 20 SP	32.1	4941.9	0.6
	Control	4498.5	475.5	90.4

Tab. 3. Oak *Quercus robur* L. leaf damage in stands treated with the use of ground equipment in the Forest Districts Spała and Smardzewice in 2011

Forest District/ Plot number	Experi- mental variant	Average leaf area [mm²]		Damage [%]
		Damaged	Not damaged	
Spała/1	Mospilan 20 SP	34.4	4374.6	0.8
	Control	3883.9	525.1	88.1
Spała/2	Mospilan 20 SP	62.3	4924.8	1.3
	Control	4608.9	378.2	92.4
Spała/3	Mospilan 20 SP	81.1	4553.9	1.8
	Control	4337.4	297.6	93.6
Smardzewice/4	Mospilan 20 SP	38.0	5170.6	0.7
	Control	4485.9	722.6	86.1
Smardzewice/5	Mospilan 20 SP	40.6	4906.6	0.8
	Control	4107.1	411.9	90.9
Smardzewice/6	Mospilan 20 SP	49.6	5585.6	0.9
	Control	5071.5	563.7	90.1

Since it was concluded that the data did not come from a normally distributed population, the Mann–Whitney U test was chosen as a non-parametric test for assessing whether differences between the samples collected from insecticide sprayed (both aerial and ground treatments) and untreated plots were statistically significant. The results of the analyses showed significant reduction of leaf area damage in insecticide sprayed stands when compared to control stands ($p < 0.001$), both in case of sprays applied with the use of helicopter and ground equipment.

Discussion

In Europe, aerial sprays with azadirachtin or pyrthroids were until recently applied to control imagines of cockchafers. In case of azadirachtin application, direct mortality of insects was not observed but it caused reduction of insect vital functions (Kaethner 1991; Schnetter et al. 1996; Rohde 1996; Froeshle and Glas 2000; Hummer and Kleeberg 2004; Benker and Leuprecht 2007). Lethal effects of pyrethroids appeared shortly after contamination and resulted in considerable reduction of cockchafer numbers (Rhode 1996; Adomas 1998; Benker and Leuprecht 2007). However, taking into consideration the protection of environment, future authorization for application of pyrethroid insecticides by aerial sprays is highly unlikely. Furthermore, pyrethoroids indicate short-term insecticidal activity as a result of their predisposition to inactivate under sunlight exposure. Bearing in mind negative environmental side effects this feature is advantageous, however it has unfavourable effects in view of by and large complicated control of cockchafer imagines.

A review on problems connected with cockchafer control was published by Malinowski (2007). The author pointed out difficulties with setting the timing of treatments which is caused by extending period of adult emergence from soil after overwintering as well as behavior of females, who after egg deposition continue feeding on trees for a relatively long period of time. It seems that both factors: short-term activity of alpha-cypermethrin and durability of cockchafer feeding on trees caused low efficacy of the treatments with preparation Fastac 100 EC (Głowacka and Olczyk 2009).

Acetamipirid applied as Mospilan 20 SP in the years 2007 and 2011 is characteristic of ability to penetrate plant tissues and move inside plants. Therefore, it is more resistant to exterior factors and can be transferred to young leaves which protect young foliage against feeding insects. The results obtained in this study indicate high efficacy of acetamipirid in the protection of oaks against cockchafers.

In 2008, Mospilan 20 SP was registered for control of the nun moth in forests with the use of aircraft equipment in agreement with current regulations on the protection of environment (Regulation (EC) 2009). Positive results of the assessment of Mospilan 20 SP efficacy observed during the trials carried out within the area of the State Forest Regional Directorate Łódź indicates prospects of broadening this registration for the purpose of aerial treatments of cockchafer imagines.

Due to the fact that for aerial insecticide treatments in vicinity of watercourses there is required preservation of 500 m wide buffer zone, in 2011 there were conducted trials on application of Mospilan 20 SP with the use of a tractor sprayer. For ground insecticide spraying in vicinity of watercourse there is required a buffer zone only 20 m wide. Registration of the tested insecticide for control of cockchafers with the use of both types of insecticide application will ease taking future decisions on insecticide treatments around watercourses or bird breeding sites in case of necessity of restraining chemical treatments in such areas.

Conclusions

– The results obtained indicate that Mospilan 20 SP efficiently protects oaks against cockchafers and can be recommended for forest protection aerial application at a rate 0.4 kg/ha.
– In case of necessity of cockchafer control treatments in forest stands situated nearby watercourses, insecticide spraying should be carried out with the use of ground equipment. This allows maintaining 20 m wide buffer zone as opposed to 500 m wide buffer zone mandatory for aerial treatments.

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