Efficient use of Dimilin insecticide in forestry of the region

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Abstract. Insects have a strong influence on the state of forests. Damage by pests often results in negative changes in the forest ecosystem. The benzoylphenylurea insecticide Dimilin is widely used in agriculture and forestry to control pests. The purpose of the study is to estimate possible forest damage from *Acantholyda posticalis* and to analyze the effectiveness of the Dimilin insecticide. The paper provides the following description of possible damage from *Acantholyda posticalis*: with the extent of damage to crowns of 74%, the blight of pines will be 9%; with the predicted crown damage from tree browsers the potential loss of pine tree recruitment will be 93%; shrinkage of forest stands by 0.09% will result in the loss of water protection properties of forests amounting to 5.33 thousand EUR; the loss of water regulation functions will amount to 2.13 million EUR.

1 Introduction

The forest fund of the Samara region has a status of a protection forest. However, in forestry we do not always assess the reduction in protective properties due to the impact of pests. *Acantholyda posticalis* (*Hymenoptera*, *Pamphiliidae*) is a widely spread pine pest [1-3]. Pest population outbreaks occur in the undergrowth, mature and overmature forests. The breeding ground often covers large areas in the European part of Russia, Southern Transurals, south of West Siberia, Altai and Transbaikalia [4-6].

Acantholyda posticalis significantly influences the stand conditions: it can decrease the resistance of forest stands to secondary pests and diseases, reduce recruitment of trees, lessen the recreational appeal of forests and affect water protection and regulation functions of the forest [7-10].

The forest fund of the Samara region faces challenges associated with large areas of a breeding ground for needle-eating insects that threaten the pine stands. This results from the weather conditions favorable to insect outbreaks and a small number of pest control

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activities undertaken in 2018. Pests suppression and eradication activities should be undertaken to prevent damage to forest stands.

The study of insect population dynamics is an integral part of environmental measures to protect forest stands from the impact of population outbreaks of needle-eating insects [11-15]. Insects have a strong influence on the state of forests. Damage by pests often results in negative changes in the forest ecosystem. Mass reproduction of pests causes total or partial instability of biopersistence of forest stands, loss of tree recruitment and other adverse consequences [16-18].

To identify the patterns and determine their development in the Samara region, we need to conduct a deep and detailed study of climate and weather conditions, sanitary state of forests, stages of establishment of homogeneous forest stands and pest control measures [19-21].

2 Methodology

Changes in pests population and level of population are inferred from population density (average or absolute colonization), reproductive rate, infection of pests with entomophages and diseases, the internal state of the organism (fertility, pupas, number of eggs in batches, etc.). Places where the population of insects grows usually become a breeding ground for pests. The breeding ground is a forest plot populated by pests, where their number threatens the forest stands with the loss of more than 30% of needles (or more than 50% of leaves). In such cases there is a need for pests suppression and eradication activities.

Measures to contain and eradicate pest harborage areas include forest care activities with the use of special equipment and methods of treatment (land-based and aerial) with chemical and biological products.

3 Results and Discussion

Preservative treatments in harborage areas of *Acantholyda posticalis* were first applied in the middle of the XX century. If pyrethroid insecticides are only applied once they cannot provide effective pest control because not all of the individuals are affected by the product. Early treatment is also not effective, as some adults are still in the process of egg-laying, and if treated too late, some of the larvae would have finished feeding and burrowed into the soil.

However, practical experience shows that it is problematic to obtain reliable results of preservative treatments against *Acantholyda posticalis*. The most appropriate method of needle leaf trees protection is single treatments with the Dimilin insecticide - dry powder, 250 g/kg of the active ingredient. Treatment should be applied when adult insects are still flying and most pests in the forest stands are still in the process of egg-laying or are in the larvae stage. When the Dimilin insecticide contacts with leaves, it coats them and almost does not wash away with the rain. The metabolism of the insecticide is rather slow, and its relative amount applied on leaves decreases mostly because the plants grow. Described characteristics of the product, as well as its high resistance to sunlight and temperature, predetermine the length of the protection period of the insecticide, which is at least 3-4 weeks. In soil, the half-life of Dimilin is ranging from 2 to 7 days, in water, its half-life is about 24 hours, unlike most organophosphorus pesticides (about a month) and pyrethroids (from 17-29 days to 13 weeks) [22, 23].

The calculations of costs of *Acantholyda posticalis* eradication and suppression activities in the Stavropol forest stands, presented in table 1, show that the highest costs were for the rent of units - 357.4 thousand RUB (49%) and purchase and delivery of the

product - 339.29 thousand RUB (47%). Other costs, such as the price of the insecticide diluent, spring control examinations of pests harborage areas, estimation of efficiency and activities on the restriction of individuals' presence in forests, were no more than 4% [24].

Table 1. Estimated costs of activities on *Acantholyda posticalis* eradication and suppression in Stavropol forest stands.

Costs	Unit	Volume	Total cost, EUR	Costs, EUR /ha
Units rent	Ha	755.6	4306.01	5.70
Purchase and delivery of the product	Kg	66.49	4087.87	5.41
Cost of diluent for the insecticide	L	2426.9	0.76	0.001
Total			8394.64	11.11
Spring control examinations of pests harborage areas	Control points	7	16.30	0.02
Estimation of effectiveness	Control points	7	46.73	0.06
Activities on the restriction of individuals' presence in forests	EUR		239.05	0.32
Including equipment costs			178.92	0.24
Total			302.08	0.40
Overall			8696.71	11.51

The cost of 1 kg of the insecticide was described as the lowest based on three price lists. The three major suppliers of the product are OOO 'Company Agroprogess' (Krasnodar, Krasnodar Krai) - the price of the product is 62.81 EUR/kg, OOO "HimAgro Group" (Krasnodar, Krasnodar Krai) - 61.48 EUR/kg and 'Agroprogess' (Saint-Petersburg) - 61.48 EUR/kg.

To obtain the desired results with least amount of money, we chose the insecticide supplied by OOO "HimAgro Group" (Krasnodar, Krasnodar Krai) based on the value for money principle, as this supplier offers the insecticide at the lowest price (61.48 EUR). The amount of required insecticide is 66.49 kg. In accordance with table 2, the total cost of the product is 4.09 thousand EUR for the workload of 755.6 ha, provided that treatments are applied with a 10% overlap and the application rate is 0.08 l/ha.

Table 2. Price of the Dimilin dry powder and the diluent (water) used to prepare the insecticide for treatment.

Treated area, ha	Area treated with a 10% overlap, ha	Application rate of the insecticide or diluent, l/ha	The amount of required insecticide or diluent, l/kg	Price of the insecticide or diluent per 1 l/kg	Total cost of the insecticide or diluent, EUR
The Dimilin dry powder					
755.6	831.16	0.08	66.49	61.48	4087.87
The diluent (water) used to prepare the insecticide for treatment					
755.6	831.16	2.92	2426.9	0.001	0.76

According to table 2, rate of water per 3 litres of the insecticide is 2.92 litres (per 1 ha of the harborage area), rate of water per total amount considering the 10% overlap is 2426.99 litres.

Table 3 shows that the cost of renting the Gard unit was 4.3 thousand EUR for the total workload of 831.16 ha considering the 10% overlap.

Table 3. The costs of renting the ground unit for the treatment.

Works	The name of the unit	Area, ha	Area considering a 10% overlap	Cost of renting, EUR/ha	Total cost of renting, EUR
Treatment of forest stands	Gard	755.6	831.16	5.18	4306.00
Workers transporting	Included in the rent				
Driving the unit					
	Total	755.6	831.16	5.18	4306.00

Table 4 shows calculations of costs of the Stavropol forest district of the state public institution 'Samara forest districts' of the Samara Ministry of forestry, environment and nature of the activities on the restriction of individuals' presence in forests during pests suppression and eradication activities.

One newspaper advertisement for the activities on restriction of individuals' presence in forests during pests suppression and eradication activities costs 12.05 EUR. Two advertisements are needed, therefore, their total cost is 24.1 EUR. The cost of information signs is 19.88 EUR/piece, 9 signs are required.

Leaflets on the restriction of individuals' presence in forests during pests suppression and eradication activities cost 21.69 EUR, 150 leaflets are required.

Table 4. Costs of the activities on the restriction of individuals' presence in forests during pests suppression and eradication activities in the Stavropol forest district in 2018.

Types of work	Workload	Date	Amount of money, EUR
Advertisements in the newspapers	2	The 1 st decade of April	24,10
Leaflets	150		21,69
Sign making, placement and removal, including:	9	The 2 nd and 3 ^d decades of April	178,92
Salary	2 man days		12,12
Cost of petroleum, oil and lubricants (Lada Niva): Highway - 12.3 per 100 km (price per liter - 0.42 EUR); Off-road - 14.2 per 100 km (price per liter - 0.42 EUR)	160 100		8.33 6.01
Consumable materials	Included in the cost of sign making		
Total			239.05

Salaries of workers involved in the activities on the restriction of individuals' presence in forests during pests suppression and eradication activities are 12.12 EUR.

Costs of petroleum, oil and lubricants for Lada Niva (the necessary mileage of 260 km) are 14.34 EUR.

The total cost of the activities on the restriction of individuals' presence in forests during pests suppression and eradication activities in the Stavropol forest district is 8.7 thousand EUR, at a cost of 11.50 EUR/ha. Costs of groundworks amount to 8.39 thousand EUR, at the cost of 11.11 EUR/ha.

Table 5 shows the costs of the activities on the restriction of individuals' presence in forests during *Acantholyda posticalis* suppression and eradication activities and costs of estimation of technical efficiency of the Stavropol forest district treatment.

Table 5. Costs of control examination of harborage areas and estimation of technical efficiency of the Stavropol forest district treatment in 2018.

Types of work	Workload	Date	Amount of money, EUR
Control examination of harborage areas, including:	755.6 ha (7 units)	The 1 st decade of April	
Salary, travel expenses, bonuses			
Cost of petroleum, oil and lubricants (Lada Niva):	160		8.33
Highway - 12.3 per 100 km (price per liter - 0.42 EUR);			
Off-road - 14.2 per 100 km (price per liter - 0.42 EUR)	100		6.01
Gloves, pcs	2		1,95
Total			16,30
Technical efficiency estimation (twice), including:	7 units	1 day before treatment, on the 13 th day after treatment	
Salary, travel expenses, bonuses			
Cost of petroleum, oil and lubricants (Lada Niva):	320 km		16.67
Highway - 12.3 per 100 km (price per liter - 0.42 EUR);			
Off-road - 14.2 per 100 km (price per liter - 0.42 EUR)	200 km		12.03
Consumable materials (canopy), pcs.	1		8,67
Respirators, pcs.	7		2,53
Gloves, pcs.	7		6,83
Total			46,73
Total			63,03

The costs of control examinations of *Acantholyda posticalis* harborage areas and estimation of technical efficiency of the Stavropol forest district treatment amount to 63.03 EUR. Control examinations of harborage areas are scheduled on the 1st decade of April. Technical efficiency is estimated twice: 1 day before treatment and on the 13th day after treatment.

We conducted the estimation of technical efficiency of treatments in *Acantholyda posticalis* harborage areas in 17, 2, 7 divisions of the Fedorovsk forest district and in 9, 13, 31, 59 divisions of the Musorsk forest district on the area of 64.8 ha.

Estimations were conducted on 7 units 1 day before treatment and on the 13th day after treatment. To conduct these estimations, we used the paired-tree method.

The specific feature of this method is that only living larvae are estimated before and after the treatment. The method does not include the estimation of dead larvae. Every estimation unit consists of two trees of the same species growing near each other. Trees of one unit should be similar in the crown development and pest colonization. On one of the trees in pair, larvae are estimated before the treatment and on the other one - approximately after 5-6 days after the treatment. To determine the number of larvae, trees and their crowns are cut onto the entomological canopy or a cleared area. Different quantities of larvae on both trees are taken as the number of dead insects.

The results show that egg batches and caterpillars were treated with the Dimilin dry powder using the ground chemical method within the period from 7 June to 11 June 2018. Table 6 provides data on technical efficiency of measures to contain and eradicate *Acantholyda posticalis* harborage areas in Stavropol forests in 2018.

Table 6. Technical efficiency of measures to contain and eradicate *Acantholyda posticalis* harborage areas in Stavropol forests in 2018.

Number	Number of larvae before treatment, spec.	Number of larvae before treatment, spec.	Technical efficiency, %	Damaged forest stands on treated plots, %
Minimum	4132	32	90.1	0.4
Maximum	10219	824	99.6	9.9
Average number per working area	7176	428	94.9	5.2

Before these activities the minimum number of *Acantholyda posticalis* per tree was 4132 larvae, the maximum number was 10219 larvae, the average number per one tree was 7176 larvae.

After treatment with the Dimilin dry powder, the minimum number of *Acantholyda posticalis* was 32 spec./tree, the maximum number was 824 spec./tree and the average number per one tree was 428 spec.

Technical efficiency of measures to contain and eradicate pests harborage areas ranged from 90.1 to 99.6%. The average percentage for all units was 94.9%.

The minimum damage to forest stands after the described measures were undertaken was 0.4%, the maximum damage was 9.9% and the average percentage was 5.2%.

Hence, the activities on suppression and eradication of *Acantholyda posticalis* harborage areas in the Stavropol forest district have proven to be effective and have not severely damaged the pine stands. Damage to crowns caused by *Acantholyda posticalis* can result in the blight of pines, which can result in forest mortality. Crown damage caused by these needle-eating insects is 74%, therefore, the blight of pines is 9%. Possible losses from damage to forest stands can be expressed in the loss of pine trees recruitment and water protection properties of the forest.

The shift of forest reproduction cycle can be tracked through the calculation of the loss of pine recruitment caused by damage to tree crowns. Provided that the potential damage from tree browsers is 74%, the loss of pine recruitment will be 93%. Water protection functions of the forest are based on the increase in the flow of underground sources due to surface waters. Damage from total or partial tree mortality is estimated based on the decrease in groundwater recharge with surface water. The loss of water protection properties of forests due to the 0.09% blight of the forest stand area amounts to 5.32 thousand EUR. Soil protection properties of forests include water regulation properties and express in an increase in flow, a decrease in salinization and contamination of water bodies

and rivers with wastewater, drainage water and erosion. The loss of water regulation properties of the forest due to the 0.09% blight of the forest stand area amounts to 2130.12 thousand EUR. The absorptive properties of the forest lie in the absorption of polluting emissions from industrial facilities, transport, agricultural production. The surface of soil and plants is the main absorbent of pollutants from the underground ecosystems. Pests harborage areas amount to 755.6 ha. The average number of trees per 1 ha is 3430. If we examine 1% of the area, we can see that the blight of 9% of these trees results in an economic loss of 28.1 thousand EUR. Unfortunately, because of the absence of norms, we cannot estimate the damage from the blight of forest stands, the loss of tree recruitment, the loss from possible water and wind erosion, and the reduction in recreational value.

Considering the weakened state of forest stands and predicted browsing of 74%, we can safely assume that without measures to contain and eradicate harborage areas, biological stability will be reduced and a part of forest stands will die [25]. All of this in combination with economic losses confirms the need for ground measures to contain and eradicate *Acantholyda posticalis* harborage areas in the forest fund of the Stavropol region.

4 Conclusion

Within the research, we analyzed natural and climatic conditions of the forest district, recommended ground activities on the eradication of *Acantholyda posticalis* in forests of the Stavropol forest district. Harborage areas of *Acantholyda posticalis* in the Stavropol forest district amounted to 755.6 ha in 2018, including 390.1 ha of forest stands (52% of the harborage area) with the damage rate varying from 50 to 75%. The total cost of pests suppression and eradication activities in the Stavropol forest district is 8.39 thousand EUR, at the cost of 11.11 EUR /ha.

The results of eradication activities undertaken in 2018 show that the technical efficiency of the treatment ranged from 90.1% to 99.6% and the average percentage for all units was 94.9%.

In 2018 after treatment with the Dimilin insecticide, the damage rate amounted to 0.4-9.9%, the average percentage was 5.2%.

The potential damage to forest stands from *Acantholyda posticalis* can be described as follows: with the extent of damage to crowns of 74%, the blight of pines will be 9%; with the predicted crown damage from tree browsers the potential loss of pine tree recruitment will be 93%; shrinkage of forest stands by 0.09% will result in the loss of water protection properties of forests amounting to 5.33 thousand EUR; the loss of water regulation functions will amount to 2.13 million EUR.

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