

ЗАХИСТ ЛІСУ

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<https://doi.org/10.33220/1026-3365.138.2021.91>**V. L. MESHKOVA¹, A. D. RIDKOKASHA², A. R. OMELICH², D. O. BATURKIN²**
THE FIRST RESULTS OF THE BIOLOGICAL CONTROL OF *IPS SEXDENTATUS*
USING *THANASIMUS FORMICARIUS* IN UKRAINE¹*Ukrainian Research Institute of Forestry and Forest Melioration named after G. M. Vysotsky*²*State Specialized Forest Protection Enterprise 'Kharkivlisozahyst'*

Thanasimus formicarius (Linnaeus 1758) (Coleoptera: Cleridae) is a predator of many coleopterous species. In 2018, the rearing of this predator started in the State Specialized Forest Protection Enterprise 'Kharkivlisozahyst'. The aim of this research was to evaluate the first results of the release of *Th. formicarius* to prevent the bark beetle spreading. The experiment was carried out with five variants of application of the fertilizer and predator, one variant of predator release without fertilizer, one variant of fertilizer treatment without predator release, and one variant without any treatment. The more rapid collapse of bark beetle outbreak as compared to the control was registered for the plots with predator release. The release of the predator together with the use of mineral fertilizer by spraying the crowns provided a more significant improvement in the stand health condition and a decrease in the viability of bark beetle populations than the only predator release.

Key words: bark beetle; predator, health condition index, density of larval galleries, density of exit holes.

Introduction. Recently, in pine forests of many regions, the outbreak of multivoltine bark beetles *Ips acuminatus* (Gyllenhal, 1827) and *Ips sexdentatus* (Börner, 1776) (Coleoptera: Curculionidae: Scolytinae) have been registered (Colombari et al. 2013, Meshkova et al. 2017, Andreieva & Goychuk 2018, Meshkova 2021). This resulted in the sanitation felling in Scots pine stands within a large area with obtaining a poor quality timber (Selikhovkin 2017, Meshkova 2019). Prevention of bark beetle outbreaks and a decrease of negative consequences for forests can be achieved through the measures aimed at increasing the sustainability of forest stands, in particular, the use of fertilizers, insecticides, and entomophages (Kenis et al. 2004, Glare et al. 2011, Selikhovkin 2017).

Thanasimus formicarius (Linnaeus 1758) (Coleoptera: Cleridae) is a predator of many coleopterous species (Zondag 1979, Gninenko & Khegai 2016). It is reared in laboratories and released into the foci of mass propagation of different bark beetles, particularly, *Ips typographus*, *Dendroctonus* sp. in different regions (Kenis et al. 2004, Warzee et al. 2006). In 2018, the rearing of *Th. formicarius* has been started in the State Specialized Forest Protection Enterprise "Kharkivlisozahyst", which initiated the first experiments on the release of this predator into the bark beetle foci (Meshkova et al. 2019).

The aim of this research was to evaluate the first results of the release of *Th. formicarius* into the bark beetle foci.

Material and Methods. The study was carried out in the bark beetle foci in Scots pine (*Pinus sylvestris* L.) stands in Kharkiv (Zhovtnevyi Forest Enterprise), Sumy (Konotop, Krolevets, Okhtyrka, and Sumy Forest Enterprises), and Chernigiv regions (Yalyvschina Regional Landscape Park and "Sviate" Nature Reserve Stand). The pine stands were pure, of 65–75 years old, with a relative density of stocking 0.6–0.8. Totally, the eighteen monitoring plots were established for this study. The larvae of *Th. formicarius* were reared in the State Specialized Forest Protection Enterprise "Kharkivlisozahyst", then they were moved to the forest in individual vials in cooler-bag on different dates, and released randomly into the standing (of the 4th–6th category of health condition) and lying trees, populated with bark beetles. On average, about four predator larvae were released per tree.

In some stands, predators were introduced along with the treatment with mineral fertilizer 'Iaros' carried out with a generator of aerosol controlled dispersion (GARD) at the rate of 100 ml/ha.

The control plots were of three types: K-1 – release of predator larvae without applying the fertilizer; K-2 – fertilizer treatment without the release of predator; K-3 – without fertilizer treatment and without the release of predator (Table 1).

Table 1

Design of experiment on predator release into bark beetle foci

Variant index	Fertilizer treatment	Release of predator larvae
V-1	August and October 2018	August and October 2018
V-2	July 2018	July 2018 and October 2018
V-3	July 2019	August 2019
V-4	September 2018	September 2018
V-5	October 2018 and August 2019	August 2019
K-1	Without treatment	July 2018
K-2	July 2018.	Without predator release
K-3	Without treatment	Without predator release

The changes in the health condition of trees and bark beetles' survival were the criteria for evaluating the effectiveness of the treatment. The assessment of both the health condition of trees and survival of bark beetle larvae were carried out in each variant in five replicates – in randomly selected fragments within the treated plots. Since the trees of the 5th and 6th categories of health condition in the stands were used for the predator release, the effect of the treatment was assessed by changing the health condition index of viable trees (1st–4th categories) and by the proportion of the trees of the 1st–3rd categories for the period from 2018 to 2020.

In July 2018 and 2020, the average number of larval galleries of *Ips sexdentatus* and a number of the larvae that successfully completed development were assessed, and then a proportion of the individuals that successfully completed development was calculated on the model trees of the experimental and control plots.

The effect of the treatment was estimated by the Formula 1:

$$E_i = 100 - 100 \times K_0/K_i \times P_i/P_0 \quad , \quad (1)$$

where K_0 and K_i – the values in the control plot (K-3) in 2018 and 2020, respectively,
 P_0 and P_i – the values in the experimental (treated) plots in 2018 and 2020, respectively.

Summary statistics, one-way analysis of variance (ANOVA), and Tukey HSD test with a significance level of $p < 0.05$ were performed (Atramentova & Utevskaia 2008). Microsoft Excel software and statistical software package PAST: Paleontological Statistics Software Package for Education and Data Analysis (Hammer et al. 2001) were used.

Results and Discussion. The analysis of the survey data in 2018 did not reveal any significant differences in the category of the health condition of viable trees in the plots of different variants (Table 2). In 2020, the health condition of the trees improved in V-1–V-5, while it worsened in K-1–K-3. It must have happened due to the fact that the predator increased its number in favourable conditions and effectively reduced the population of bark beetles.

The efficiency of different combinations of the fertilizer treatment and a release of the predator, evaluated by the change in the health condition of viable trees, made from 14.7% in V-5 to 28.3% in V-1 (Table 2).

The highest efficiency of V-1–V-3 may be connected with the summer treatment in the year when the bark beetles outbreak started to go down (in 2018). The health condition of the stands significantly improved in those three variants, and insignificantly in V-4 (the fertilizer treatment in September) and did not change in V-5 with the fertilizer treatment in October 2018.

The measures taken contributed to the fact that the health condition of the stands ceased to deteriorate. The dead trees fell out of the stand composition, however, further deterioration of the

health condition of the stand went on. The obtained conclusion is supported by a comparison of the proportion of trees of the 1st–3rd categories of health condition in different variants (Fig. 1). For two years, the proportion of such trees in most of the experimental plots increased, it changed insignificantly in V-5, and decreased in the control. However, a significant improvement in this indicator was noted only in V-1, which can be associated with an initial distribution of the trees before the start of the experiment.

Table 2

Health condition index of vital trees in the bark beetle foci and effect of treatment in different experimental variants

Variant index	Fertilizer treatment	Release of predator larvae	Health condition index		Efficiency, %
			2018	2020	
V-1	August and October 2018	August and October 2018	3.24 a	2.65 c	28.3
V-2	July 2018	July 2018 and October 2018	3.10 b	2.72 c	23.1
V-3	July 2019	August 2019	3.16 b	2.85 c	20.9
V-4	September 2018	September 2018	3.47 c	3.22 d	18.6
V-5	October 2018 and August 2019	August 2019	3.25 a	3.17 ad	14.7
K-1	Without treatment	July 2018	3.29 a	3.60 e	4.1
K-2	July 2018.	Without predator release	3.26 a	3.67 e	1.2
K-3	Without treatment	Without predator release	3.26 a	3.73 e	–

Note: 1. The data for all inspected stands were pooled for each variant.
 2. Values followed by different letters in each column are significantly different at the 95 % confidence level.

However, in V-4 (the fertilizer treatment and release of predator larvae were carried out in September 2018) the proportion of the trees of the 1st–3rd categories was the lowest in 2018 and it increased by 1.2 times (by contrast, by 1.5 times in V-1, by 1.1 and 1 times in V-2 and V-3, respectively, and 1.1 times in V-5). The proportion of viable trees for two years significantly decreased in the control plots (1.7, 2.3, and 2.8 times in K-1, K-2, K-3, respectively).

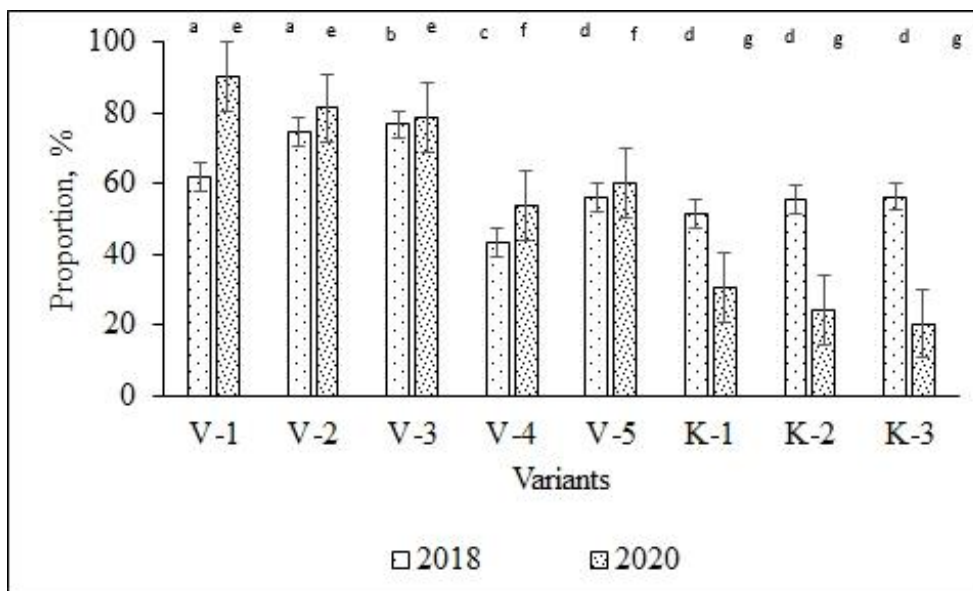


Fig. 1 – Proportion of the trees of the 1st–3rd categories of health condition in the bark beetle foci in different variants of the experiment (see Table 1) by assessment of 2018 and 2020. Values followed by different letters are significantly different at the 95 % confidence level

In 2018, the density of *I. sexdentatus* population in all plots exceeded 3 larval galleries /dm² (Table 3). The value was above the middle level for this species in V-1, K-1, and K-3 (4 larval galleries /dm² – Methodical recommendations 2010). From 62.5 to 89.7% of larvae successfully

completed development in 2018, particularly 78.6–89.5% in V-1–V-5, 84% and 78.3% in K-1 and K-2, respectively, and 89.7% in K-3.

Table 3

Survival of *Ips sexdentatus* larvae in different variants in 2018

Variant index	Fertilizer treatment	Release of predator larvae	Density per dm ²		Survival, %
			larval galleries	exit holes	
V-1	August and October 2018	August and October 2018	4.46 a	3.51 d	78.6
V-2	July 2018	July 2018 and October 2018	3.86 b	2.41 e	62.5
V-3	July 2019	August 2019	3.55 b	3.07 f	86.4
V-4	September 2018	September 2018	3.06 c	2.57 e	84.2
V-5	October 2018 and August 2019	August 2019	3.02 c	2.71 e	89.5
K-1	Without treatment	July 2018	4.18 a	3.51 d	84.0
K-2	July 2018	Without predator release	3.71 b	2.91 f	78.3
K-3	Without treatment	Without predator release	4.66 a	4.17 g	89.7

Note: 1. The data for all inspected stands were pooled for each variant.

2. Values followed by different letters in each column are significantly different at the 95 % confidence level.

According to the 2020 assessment, the density of larval galleries of the bark beetle decreased in all plots compared to 2018 (Table 4). It is consistent with the data on the collapse of the outbreak. At the same time, in the variants of the experiment, this value decreased by 2.1–1.5 times in V-1–V-5 and by 1.5 times in the K-1–K-2. In K-3 it decreased by 1.4 and remained maximal (3.8 galleries / dm²).

Table 4

Survival of *Ips sexdentatus* larvae in different variants in 2020

Variant index	Fertilizer treatment	Release of predator larvae	Density per dm ²		Survival, %
			larval galleries	exit holes	
V-1	August and October 2018	August and October 2018	2.58 a	0.97 d	37.5
V-2	July 2018	July 2018 and October 2018	2.37 a	0.78 d	33.0
V-3	July 2019	August 2019	2.75 a	1.30 d	47.1
V-4	September 2018	September 2018	2.29 a	1,14 d	50.0
V-5	October 2018 and August 2019	August 2019	2.42 a	1.45 d	60.0
K-1	Without treatment	July 2018	3.49 b	1.94 e	55.6
K-2	July 2018	Without predator release	4.18 c	2.18 e	52.3
K-3	Without treatment	Without predator release	3.87 c	2.45 e	63.4

Note: 1. The data for all inspected stands were pooled for each variant.

2. Values followed by different letters in each column are significantly different at the 95 % confidence level.

From 2.57 to 4.17 exit holes / dm² were registered in 2018 and from 0.97 to 2.45 exit holes / dm² in 2020. These numbers decreased by 3,6–1,9 times in V-1–V-5, by 1.8 times in K-1, by 1.3 times in K-2, and by 1.7 times in K-3.

From 33 to 63.4 % of larvae successfully completed their development in 2020, particularly 33–60 % in V-1–V-5, 55.6% and 52.3 % in K-1 and K-2, respectively, and 63.4% in K-3 (Table 4).

Calculation of the effectiveness of the experiments according to Formula 1 using the characteristics of the health condition of viable trees and the condition of bark beetle population allows us to draw similar conclusions.

The efficiency is significantly higher for the combined use of fertilizer with the introduction of a predator in comparison with the use of these measures separately (Fig. 2). The highest efficiency was obtained in V-1 (28.3% and 32.5% for the health condition of trees and for bark beetles, respectively). However, these results do not statistically differ from V-2 (23.1% and 25.3 %).

The efficiency of the V-4 with the use of fertilizer and the introduction of a predator in September 2018 was significantly less than V-1–V-3 in terms of the health condition of viable trees (18.6%) but did not differ from them in terms of the condition of the bark beetle population (16 %). Therefore, we suggest that a treatment timing does not affect significantly the efficiency while a number of applications does affect it.

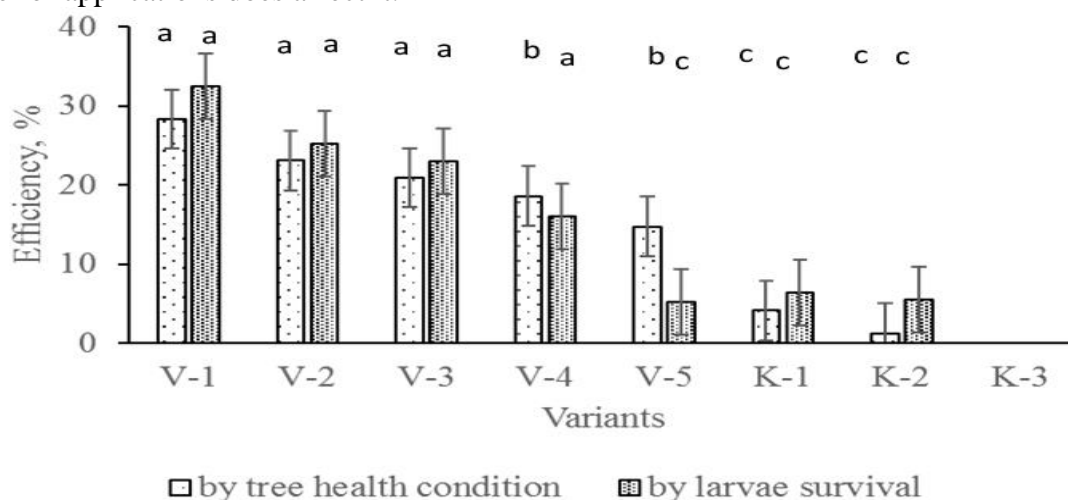


Fig. 2 – Efficiency of treatment of Scots pine stands with fertilizer and release of *Th. formicarius* in the foci of *Ips sexdentatus* estimated considering the health condition of vital trees and larvae survival in different variants of the experiment (see Table 1). The data for all inspected stands were pooled for each variant. The values followed by different letters are significantly different at the 95 % confidence level

The efficiency of the V-5 with the use of fertilizer in October 2018 and August 2019 and the release of a predator in August 2019 evaluated by tree health condition (14.7%) is significantly lower than in V-1–V-3 and significantly higher than in K-1–K-2, while in K-1 and K-2 the efficiency did not differ significantly. The effectiveness of the measures applied, calculated by the change in the viability of bark beetles, did not significantly differ in V-1–V-4, on the one hand (32.5–16.5%), and V-5–K-1–K2 (5.2–6.4 %), on the other hand. Publications indicate a maximum efficiency of the biological method during the period of outbreak collapse (Kenis et al. 2004, Warzee et al. 2006). At the same time, the increase in the efficiency of predators is facilitated by their repeated release into the pest focus (Zondag 1979). Our first experience with the *Th. formicarius* release into the focus of *Ips sexdentatus* in Ukraine showed that the release of predator along with the fertilizer treatment increases the efficiency of forest protection.

The release of predator without additional fertilizer treatment in the stand (K-1), as well as fertilizer use without a release of predator (K-2) provide less efficiency than the joint application of these measures, on average 3.2–5.2 and 3.7–17 times, respectively. Fertilizer treatment and release of a predator in July and twice a year (in July–August and October) turned out to be more effective than in September 2018. Its application in August 2019 was more effective carried out along with fertilization in July than in October 2018 and August 2019.

Conclusions.

1. The release of predator *Thanasimus formicarius* into the focus of bark beetle *Ips sexdentatus* promotes a more rapid collapse of the outbreak as compared to the control.
2. The release of a predator along with spraying mineral fertilizer on crowns provides a more significant improvement of the stand condition and a decrease in the viability of bark beetle population than the release of a predator only.

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ПЕРШІ РЕЗУЛЬТАТИ БІОЛОГІЧНОГО КОНТРОЛЮ *IPS SEXDENTATUS* ІЗ ЗАСТОСУВАННЯМ *THANASIMUS FORMICARIUS* В УКРАЇНІ

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Thanasimus formicarius (Linnaeus 1758) (Coleoptera: Cleridae) – хижак багатьох видів твердокрилик. У 2018 р. розпочалося вирощування цього хижака у Державному спеціалізованому лісозахисному підприємстві «Харківлісозахист». Метою цього дослідження було оцінювання перших результатів випуску *Th. formicarius* в осередки короїдів. У досліді випробовано такі варіанти: 5 варіантів із застосуванням мінеральних добрив і хижака, один варіант із випуском хижака без внесення добрив, один варіант із внесенням добрив без випуску хижака і один варіант без внесення добрив і хижака. Найшвидше згасання спалаху розмноження короїда у порівнянні з контролем відбулося на ділянках із випуском хижака. Випуск хижака разом із обробленням насаджень мінеральним добривом забезпечував більше покращення стану насаджень і зменшення життєздатності популяції короїдів, ніж у варіанті лише випуску хижака.

Ключові слова: короїд, хижак, індекс санітарного стану, щільність личинкових ходів, щільність вихідних отворів.

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