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NATURAL ENEMIES OF WILLOW (SALIX) TREE PESTS AND THEIR INTERRELATIONSHIPS

To‘laboyev Bobir Anorboy ugli
Independent Researcher, Research Institute of Rice growing
E-mail: bobirtulaboyev@umail.uz
ORCID: 0009-0008-7207-9404

Shukurov Xushvaqt Mamasaliyevich
Professor, Tashkent Branch of the Samarkand State University of Veterinary Medicine, Livestock and Biotechnology

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Abstract. Willow plantations play a significant role in maintaining ecological stability, reducing soil erosion, and conserving water resources. In recent years, due to climate change and anthropogenic impacts, willow stands have been increasingly affected by various pests. The aim of this study is to identify the main pests of willow trees under the conditions of Uzbekistan, to investigate their bioecology, and to evaluate the effectiveness of integrated pest management measures. The results show that an integrated protection system (including agrotechnical, biological, and, when necessary, chemical measures) reduces pest populations by 86–88%.

It is also important to identify parasitic and predatory entomophages present in willow biocenoses across Uzbekistan, conduct their systematic analysis, and study their biological characteristics in order to enhance pest control in forestry. The developed mathematical forecasting model enables early detection of pest risks and effective planning of control measures, with an accuracy of 92–95%. The findings of this research provide a scientific basis for the sustainable protection of willow plantations, the improvement of agroecological management, and the development of environmentally friendly pesticide strategies.

Keywords: Willow (Salix spp.), pests, population dynamics, natural enemies, entomophages, phytophages, biological control, integrated pest management (IPM), forecasting model, conditions of Uzbekistan.

INTRODUCTION. Willow trees (Salix spp.) have long been widely utilized by humanity for economic and ecological purposes. In addition to being valuable as a source of construction materials, furniture production, paper manufacturing, and fuel, they also play an important role in maintaining ecological stability. Willow plantations reduce soil erosion, conserve water resources, support biodiversity, and create a stable environment in agroecosystems.

In recent years, under the conditions of Uzbekistan, climate change, alterations in agrotechnical practices, and anthropogenic impacts have exposed willow plantations to various harmful pests. These pests damage leaves, branches, and roots, reduce the efficiency of photosynthesis, slow down the growth and development of willow trees, and consequently cause economic losses. Some pests also act as vectors of disease agents in willow trees, negatively affecting the quality of wood and plant productivity.

Under the conditions of Uzbekistan, identifying the parasitic and predatory entomophages occurring in willow biocenoses, conducting their systematic analysis, and studying their

biological characteristics are of great importance for improving pest control measures in forestry. During our research, experiments were conducted on the systematic analysis of parasitic entomophagous species associated with willow pests. According to the research findings, the parasitic entomophages of willow pests and the parasite–host relationships were studied.

In recent years, pest protection in forest biocenoses within our republic has mainly relied on chemical control methods. This is because nearly ten major pest species occur in forest biocenoses and cause significant economic damage during the growing season. At the same time, trees are affected by pests such as the gypsy moth, willow leaf beetle, city longhorn beetle, and willow moth. However, the mass rearing of beneficial entomophagous species in biological laboratories for the biological control of these pests has not yet been established.

Pests of Willow (Salix spp.) and the Bioecological Characteristics of Their Natural Entomophages

In willow (Salix spp.) biocenoses, the primary method used to reduce pest damage is chemical control. However, biological control measures possess a broad-spectrum mechanism of action against pests and provide long-term effectiveness, making them preferable for maintaining ecosystem stability. Unfortunately, information regarding the natural enemies of Melosoma populi L. is still insufficient. Nevertheless, several researchers have provided brief data concerning these species.

Studies conducted by a number of scientists in Romania and Turkey on the entomophages of the willow leaf beetle have reported Hexamermis albicans (Mermithidae) and Linobia coccinellae (Hemisarcoptidae) as parasitoids of leaf beetles. In addition, Schizonotus sieboldi (Ratz.) (Pteromalidae) has been identified as a widely distributed parasitoid species of the pupal stage.

During the analysis of pest development under field conditions, air temperature and relative humidity were recorded separately. Throughout the research, willow species distributed in the regions of Tashkent Province were identified, and the levels of infestation and pest species associated with them were analyzed. All samples of leaf and stem pests found on willow trees were collected under laboratory conditions and subjected to systematic analysis.

Table 1
Entomophagous Species of Willow Tree Pests (2022–2024)

No.	Pest species	Damaged part of the tree	Damaging stage of the pest	Period of infestation	Entomophag species
1	Willow leaf beetle Plagiodera versicolora Laich.	Leaf	Adult, larva, egg	Spring and summer	Lydella nigripes Fall.; Coccinella septempunctata L.; Chilomenes septempunctata W.
2	Gypsy moth Lymantria	Leaf	Larva	Spring	Elasmus albipennis Thomson

	dispar				
3	Willow gall mite Eriophyes tetanothrix N.	Leaf	Adult, larva	Spring	Coccinella septempunctata L.; Chilomenes septempunctata W.
4	Willow jewel beetle Cratomerus intermedius Obenb.	Branches, stem	Larva	Throughout the season	Cryptus insinuator Gr.
5	City longhorn beetle A. sarta Solsky	Stem	Larva	Throughout the season	Sclerodermus turkmenicus

Samples of willow leaf pests were collected, and their developmental stages throughout the season, the degree and period of tree infestation, as well as their entomophagous species, were investigated. It was determined that the identified pests occurred not only on willow trees but also on related plant species. Observations conducted during 2022–2024 revealed that infestation levels varied depending on pest species, and the population density of some species remained consistently high throughout the season. The dependence of this process on weather conditions was also recorded.

The main identified phytophagous pests belonged to 5 species classified within 2 classes, 3 orders, and 4 families. During our studies, the natural entomo-acariphagous species associated with willow tree pests, as well as their damaging stages and infestation periods, were identified.

At the same time, the city longhorn beetle (Aeolesthes sarta Solsky.) was found to be the most important and economically significant pest of willow trees. Due to the high abundance of adult beetles, the number of larvae was also observed to be approximately twice as high, and nearly one out of every five willow trees was found to be infested by this pest. Adult city longhorn beetles were more frequently encountered on trees growing in water-deficient areas and caused greater damage to willow trees compared to other tree species. In particular, they were found more commonly on trees older than 15–20 years.

Entomophagous species were observed in lower numbers compared to pest populations during the season, although their abundance increased especially during the autumn months. The parasitoid Cryptus insinuator Gr., associated with willow jewel beetles, and Sclerodermus turkmenicus, a parasitoid of the city longhorn beetle, were also identified. However, their low occurrence and limited effectiveness in regulating pest populations were noted.

Effectiveness of Applying Trichogramma dendrolimi Against Plagiodera versicolor Laich.

In the conducted studies, one of the major pests occurring on willow trees was identified as representatives of the order Coleoptera. This order includes numerous harmful as well as beneficial insect species within the world insect fauna.

Scientific research conducted in our country has also shown that a significant number of coleopteran species occur on ornamental and forest trees, causing serious damage. Among the coleopteran pests, the willow leaf beetle (Plagiodera versicolor Laich.) and the city longhorn beetle (Aeolesthes sarta) are considered the main pests of willow trees, and controlling their eggs is regarded as highly important. Scientific investigations were carried out on the application of the parasitic entomophagous species Trichogramma dendrolimi against the eggs of these pest species.

Based on extensive literature analysis and by studying the climatic conditions of the regions together with the biological characteristics of the species, it is important to identify species belonging to the family Trichogrammatidae and determine their effectiveness against pest species in order to ensure the proper use of entomophages.

In the experiments, the egg density of the willow leaf beetle (Plagiodera versicolor Laich.) and the city longhorn beetle (Aeolesthes sarta) on willow trees was determined. After determining the density levels, the application ratios of the parasitic entomophagous species Trichogramma dendrolimi were established according to the number of pest eggs.

Scientific studies were conducted in three replications using Trichogramma dendrolimi against the willow leaf beetle (Plagiodera versicolor Laich.). The parasitoid-host ratios applied were 1:5, 1:10, and 1:15. The trichogramma generations were distributed in pupal form using special drones and trichocards. During the experiments, the average air temperature was recorded as 27.1 ± 2°C, while the relative humidity was 57.2 ± 2%. In conducting the research, increasing the effectiveness of applying Trichogramma dendrolimi against pest eggs and determining the optimal application periods were considered important factors for the effective management of pest populations. Accordingly, average air temperature and humidity were taken into account when applying trichogramma entomophages against pests.

In the variant with a 1:5 ratio, the effectiveness of Trichogramma dendrolimi against the willow leaf beetle (Plagiodera versicolor Laich.) was determined. According to the results, in the first experimental variant, where Trichogramma dendrolimi was applied against pest eggs at a ratio of 1:5, the biological efficiency reached 30.1% on the 5th day, 49.8% on the 10th day, and 72.6% on the 14th day.

Figure 1. Eggs of *Plagiodera versicolor* Laich.
(Bostanliq District, Tashkent Region, 2022–2024).

Table 2. Application of Trichogramma dendrolimi Against the Willow Leaf Beetle (Plagiodera versicolor Laich.) and Determination of Biological Effectiveness (Bostanliq District, Tashkent Region, 2022–2024)

Option (parasitoid:pest egg ratio)	Average number of eggs per tree				Eggs damaged (%) by days				Eggs damaged (%) by days			
	cc	Parasitized by parasitoids by days (2022)				Parasitized by parasitoids by days (2023)				Parasitized by parasitoids by days (2024)		
		5	11	14		5	11	14		5	11	14
1:15	3,5	13,1±0,04	12,4±0,06	10,8±0,07	4,4	10,0±0,01	9,6±0,05	8,2±0,03	0,8	13,2±0,03	12,8±0,05	12,0±0,02
1:10	5,3	9,1±0,06	7,8±0,02	5,6±0,01	0,6	10,4±0,03	9,2±0,01	8,1±0,06	1,7	14,8±0,01	13,9±0,02	12,7±0,01
1:5	1,2	8,5±0,04	7,2±0,01	3,8±0,03	2,7	7,8±0,06	5,4±0,02	3,3±0,02	0,1	8,8±0,04	7,6±0,06	4,7±0,02
Control	1,3				6,4	13,1	14,2	15,7	2,4	12,5	14,3	16,3

Biological effectiveness (%)											Average		
Option		1	4	Option		1	4	Option		1	4		1	4
1:15	1,2	9,7	2,0	1:15	2,3	9,7	0,0	1:15	1,6	5,1	9,3	1,7	4,8	7,1

1 :10	6,1	1,4	2,1	**1 :10**	5,8	1,3	5,3	**1: 10**	2,5	8,2	2,4	**4,8**	**0,3**	**6,6**
1 :5	4,4	7,1	2,8	**1 :5**	6,9	5,9	4,2	**1: 5**	8,9	6,4	0,9	**0,1**	**9,8**	**2,6**

When Trichogramma dendrolimi was applied against the willow leaf beetle (Plagiodera versicolor Laich.) at a ratio of 1:10, the biological efficiency against pest eggs reached 14.8% on the 5th day, 30.3% on the 10th day, and 46.6% on the 14th day. In the 1:15 ratio treatment, the biological efficiency of Trichogramma dendrolimi against the eggs of Plagiodera versicolor Laich. was recorded as 11.7% on the 3rd day, 24.8% on the 5th day, and 37.1% on the 7th day.

Natural Entomophages of Plagiodera versicolor Laich. and the Effectiveness of PRESTIJ Liquid Formulation

In recent years, research aimed at improving biological control measures against willow leaf beetles such as Plagiodera versicolor Laich. has been actively conducted in foreign countries. Particularly in Europe and Turkey, significant scientific findings have been reported regarding the use of natural enemies against this pest.

Tachinid Flies

Tachinid flies parasitize the larvae of leaf beetles and are recognized as effective entomophages against representatives of the order Coleoptera in European biocenoses. These parasitoids have the potential to naturally suppress populations of Plagiodera versicolor.

Pupal Parasitoids (Hymenoptera)

Schizonotus sieboldi (Ratz.) (Pteromalidae)

These parasitoid wasps attack the pupal stage of leaf beetles closely related to Plagiodera versicolor, significantly reducing beetle emergence. Observations conducted in Scandinavian and Central European countries demonstrated the high effectiveness of this parasitoid (Pettersen, 1976).

Predatory Insects (Predatores)

Symmorphus murarius (L.), Ancistrocerus nigricornis (Curt.) (Eumenidae)

These predatory wasps prey upon leaf beetle larvae and transport them to their nests. Studies conducted in Kazakhstan and Eastern Europe reported their high biological efficiency against Plagiodera and Pyrrhalta species (Marikovskaja & Šterbakova, 1989).

Symmorphus murarius (L.) (Hymenoptera: Eumenidae) is a predatory wasp feeding on the larval stage of leaf beetles and plays an important role in suppressing pest populations in willow biocenoses. Ancistrocerus nigricornis (Curt.) is also a predatory wasp feeding on leaf beetle larvae and contributes to the natural regulation of pest populations in willow ecosystems.

General Entomophages

Lady beetles (Coccinellidae) and lacewings (Chrysopidae)

Although these entomophages are not specialized parasitoids, they play an important role in limiting pest populations by destroying eggs and young larvae.

Based on the above-mentioned information, considering that tall willow trees are widespread in the Tashkent region and that determining pest infestation ratios was relatively difficult under such conditions, the biological preparation PRESTIJ liquid, based on Bacillus thuringiensis var. thuringiensis BA–3000 IU/ml, was tested against the pests at application rates of 4.0, 5.0, and 6.0 L/ha. The experimental variants were arranged according to a 10 × 10 scheme with 10 trees per treatment. According to the results, the preparation was sprayed on 10 trees at the rates of 4.0, 5.0, and 6.0 L/ha (see Figure 4.16).

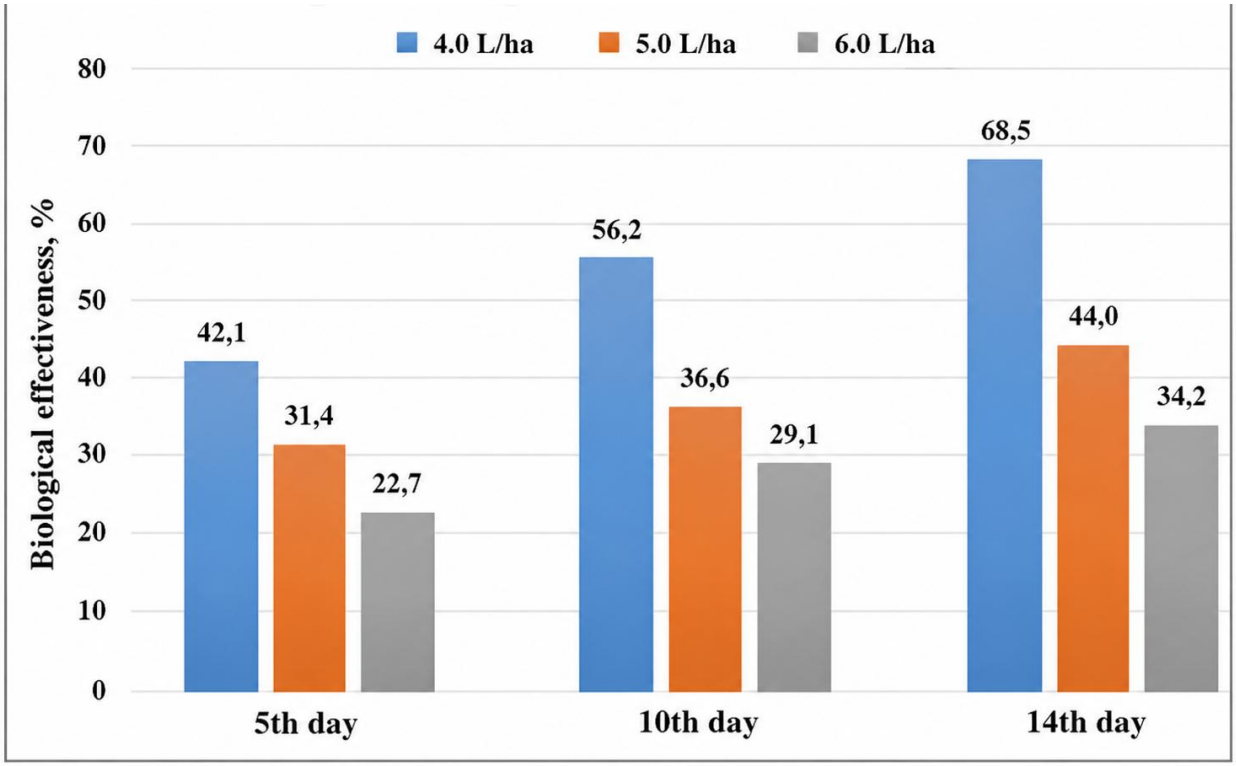

Figure 2. Biological effectiveness of PRESTIJ liquid biological preparation against Plagiodera versicolor Laich.
(Tashkent region, 2023–2025)

According to the preliminary results, when PRESTIJ liquid biological preparation was applied against Plagiodera versicolor Laich. at a rate of 4.0 L/ha, the biological effectiveness reached 42.1% on the 5th day, 56.2% on the 10th day, and 68.5% on the 14th day. When the preparation was applied at a rate of 5.0 L/ha against the willow leaf beetle Plagiodera versicolor Laich., the biological effectiveness was 31.4% on the 5th day, 36.6% on the 10th day, and 44.1% on the 14th day. When applied at a rate of 6.0 L/ha against the pest, the biological effectiveness was recorded as 22.7% on the 3rd day, 29.1% on the 5th day, and 41.3% on the 7th day.

The scientific study demonstrated that the PRESTIJ liquid biological preparation showed high effectiveness when applied against the eggs of representatives of the orders Coleoptera and Lepidoptera occurring in forest biocenoses. Due to the strong flight ability of forest trichogramma at higher altitudes, it can be effectively used against pest eggs found on tall trees within forest and ornamental tree biocenoses. It was determined that PRESTIJ liquid biological preparation is a highly specialized entomophagous agent against the willow leaf beetle (Plagiodera versicolor Laich.). Based on the obtained results, we concluded that PRESTIJ liquid biological preparation should be recommended for use against representatives of the order Coleoptera occurring in ornamental tree biocenoses throughout the republic.

Species Composition and Occurrence Level of Natural Enemies of Aeolesthes sarta

In nature, like other living organisms, longhorn beetles also possess their own natural enemies. Their distribution across different regions depends on the characteristics of the ecological system. Birds and parasitic entomophages serve as the main natural enemies of longhorn beetles. Birds play a particularly important role in controlling forest pests, especially wood-boring insects that damage tree trunks.

A number of studies have been conducted on the biological management of longhorn beetles, and certain positive results have been achieved. The United States Department of Agriculture Agricultural Research Service (ARS) and the Beneficial Insects Introduction Research (BIIR) organization carried out investigations on the entomophages of longhorn beetles. In these studies, parasitoid species specific to the larvae of two longhorn beetle species were identified. Scientists from ARS and BIIR, in collaboration with the Departments of Entomology at the Universities of Vermont and Illinois, also identified four species of parasitic entomophages affecting longhorn beetles. In subsequent studies conducted in Massachusetts, parasitic entomophages were observed in Asian longhorn beetle larvae.

Furthermore, it was determined that birds caused the mortality of approximately 15–17% of pests in floodplains, desert areas, and residential habitats. This demonstrates the important role of birds in regulating pest populations in nature. Among the entomophagous parasitoids identified were the tachinid fly (Liopygia argyrostoma) and the parasitoid Sclerodermus turkmenicus.

Natural enemy species of city longhorn beetles and their occurrence levels (2022–2025).

No.	Natural enemy species	Predatory/parasitic stage	Habitat	Occurrence level
Parasitic and predatory insects				
1	Tachinid fly	Adult (imago)	Deserts	+

	(Liopygia argyrostoma)			
2	Sclerodermus parasitoid (Sclerodermus turkmenicus)	Larva	Forest	+
Microorganisms				
3	Metarhizium anisopliae	Larva	Forest	+
4	Beauveria bassiana	Larva	Forest	+

These entomophages were identified in adult specimens collected under the conditions of the Tashkent region. The identified entomophages were found to have a relatively low role in regulating pest populations, with their effectiveness estimated at around 4–6%.

The parasitic tachinid fly is mainly specialized in other beetle species (soil-dwelling beetles) and only rarely damages adult city longhorn beetles. The parasitoid lays 2–3 eggs around the beetle's wings. After hatching, the larvae enter the beetle's midgut through the mouthparts and continue their parasitic activity there.

The parasitoid Sclerodermus turkmenicus attacks the larvae of the pest. It mainly parasitizes larvae while they are expelling excrement through the exit openings or when the larvae become weakened under unfavorable environmental conditions. After the larvae are paralyzed, the parasitoid lays eggs depending on the size of the host. Sclerodermus turkmenicus is classified as an ectoparasite [93; pp. 36–39, 94; pp. 23–26].

In addition, fungi belonging to the species Metarhizium anisopliae and Beauveria bassiana were identified from the larvae of the city longhorn beetle. However, larvae infected with these microorganisms were encountered very rarely (2–3%), mainly in forest areas.

Conclusion

1. Natural entomophages associated with 14 pest species occurring in willow biocenoses were identified, including those affecting the larval and adult (imago) stages of the pests.
2. When Trichogramma dendrolimi was applied against the willow leaf beetle (Plagiodera versicolor Laich.) at three different ratios, the highest biological effectiveness of 72.6% was recorded on the 14th day in the 1:5 ratio treatment.
3. The application of chemical preparations against the willow leaf beetle was integrated with the use of the parasitic entomophagous species trichogramma, and their combined effects were determined.

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