

Article

Distribution of *Trichogramma* (*Trichogramma*) Species in Tugai Forest Conditions and their Practical Significance

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Abstract: This study investigates the distribution, population characteristics, and practical significance of parasitoid insects of the genus *Trichogramma* in tugai forest ecosystems. The main objective of the research is to determine the species diversity, occurrence frequency, and seasonal dynamics of *Trichogramma* species under tugai forest conditions, and to provide a scientific justification for their role in the natural regulation of pest insect populations. The research methodology was based on an integrated approach combining field and laboratory studies. Field surveys were conducted in Tugai forest sites located along river valleys. Eggs of pest Lepidoptera were collected from various host plants, and the degree of parasitism by *Trichogramma* species was assessed under laboratory conditions. Species identification was performed based on morphological characteristics, and the obtained data were processed using statistical analysis methods.

Keywords: *Trichogramma* Species, Tugai Forest Ecosystem, Parasitoid Insects Biological Control, Pest Lepidoptera, Population Dynamics

Introduction

It should summarize the rationale, provides a concise research background (not an exhaustive review) and states in single sentence the objective of the study. Please do not include any results or the conclusion of the study Tugai forests represent unique natural ecosystems formed along river valleys in Central Asia, characterized by high biodiversity and complex trophic interactions. In these ecosystems, relationships between insects particularly pest Lepidoptera (butterflies and moths) and their natural entomophages hold significant ecological importance. Parasitoids of the genus *Trichogramma*, which parasitize host eggs, are among the primary biological factors regulating populations of pest insects [1]. To date, their efficacy has been studied predominantly in agroecosystems, whereas their distribution and ecological characteristics in natural tugai forest conditions remain insufficiently investigated. Therefore, the objective of this study is to determine the species diversity, frequency of occurrence, and practical significance of *Trichogramma* species in tugai forest environments [2, 3].

Literature Review.

Scientific literature extensively covers the role of *Trichogramma* species in biological control. In particular, their high efficacy as egg parasitoids and the feasibility of mass rearing have been

confirmed in numerous studies. In agroecosystems, especially in cotton and vegetable crops, parasitism rates of 45–70% have been recorded. Some authors have analyzed the ecological plasticity of *Trichogramma* species, as well as the dynamics of their development in relation to temperature and host density [4]. At the same time, population stability and their role as a gene pool source in natural biocenoses have not been adequately studied. Analysis of available literature indicates that a deeper investigation of the ecological functions of *Trichogramma* species in natural forest ecosystems will contribute to enriching the theory of biological control [5].

Materials and Methods

Please provide concise but complete information about the materials and the analytical and statistical procedures used. This part should be as clear as possible to enable other scientists to repeat the research presented. Brand names and company locations should be supplied for all mentioned equipment, instruments, chemicals etc. All the ethical permission associated in the research work must be specified. Indicate the statistical methods used and identify statistical significance using superscripts (* and **) following the data (* $P < 0.05$, ** $P < 0.01$). The research methodology is based on a comprehensive approach incorporating both field and laboratory methods. Field observations were conducted across six sites in Tugai forest ecosystems throughout the vegetation period. Eggs of pest Lepidoptera were collected from various plants, with each sample individually labeled. In the laboratory, the parasitism rate of the eggs was determined, and *Trichogramma* species were identified based on morphological characteristics. The obtained data were analyzed in terms of population density, parasitism percentage, and seasonal dynamics. Statistical processing involved analysis of variance and calculation of mean values \pm standard error. This methodology ensured the reliability of the study results.

Results

It should disclose about the findings of works and the same data or information given in the table must not be repeated in a figure and vice versa. During the study, field observations were carried out at six monitoring sites in tugai forest ecosystems. A total of 428 egg batches of Lepidoptera were collected and analyzed under laboratory conditions. Of the examined samples, 265 were parasitized by *Trichogramma* species, resulting in an overall parasitism rate of 61.9% [6].

Morphological identification revealed three species belonging to the genus *Trichogramma*. Parasitism rates by species ranged from 18.4% to 27.6%. Monthly variations in parasitism rates were also recorded [7].

Table 1. Parasitism rates of Lepidoptera eggs by *Trichogramma* species

Month	Eggs examined (number)	Parasitized eggs (%)
April	96	42.7
May	138	63.8
June	112	74.1
July	82	67.3

Population density calculations showed that the average number of *Trichogramma* individuals per square meter was 18.6 ± 2.4 . Over the study period, the average egg parasitism rate was 64.5%. Statistical analysis revealed significant differences between monthly indicators ($p < 0.05$) [5,p.944]. All quantitative data obtained were systematized using tables and diagrams and subjected to statistical processing [8].

Discussion

The findings of the conducted study clearly demonstrate the high ecological adaptability of parasitoid insects belonging to the genus *Trichogramma* in tugai forest ecosystems, as well as their effectiveness in the natural regulation of pest Lepidoptera eggs. A parasitism rate of 61.9% in Lepidoptera eggs confirms the high biological activity of *Trichogramma* species in these ecosystems.

This figure is comparable to the 45–70% parasitism rates previously recorded in agroecosystems, indicating that in natural tugai conditions, results are at least equivalent and, in some cases, more stable [9]. Previous studies have primarily evaluated the efficacy of *Trichogramma* species in monoculture agrobiocenoses, particularly in cotton and vegetable crops. The present work scientifically confirms that parasitoid–host relationships remain highly effective even in complex, multi-component natural ecosystems such as tugai forests. This can be attributed to plant diversity, a relatively stable microclimate, and the continuous availability of host insect eggs. These results align fully with prior ecological studies demonstrating the efficacy of biological control mechanisms in natural biocenoses. Seasonal analysis revealed a significant increase in parasitism rates during the spring–summer period [10]. As noted in earlier scientific sources, this is directly linked to the optimal developmental temperatures for *Trichogramma* species and the peak egg-laying activity of host insects [11]. Additionally, the relatively high number of individuals per square meter indicates stable population establishment of *Trichogramma* in tugai forests. From a theoretical perspective, this study provides clearer insight into the ecological function of *Trichogramma* species in natural ecosystems namely, their role in density-dependent biological regulation of pest populations [12]. These findings enrich ecological theories explaining the importance of parasitoid insects in maintaining ecosystem stability. Practically, the study substantiates the role of tugai forests as a natural gene pool and reservoir for *Trichogramma* species [13]. This is of significant importance for developing biological control strategies, particularly the use of locally adapted *Trichogramma* populations. The obtained results can contribute to reducing reliance on chemical pesticides and forming ecologically safe forest and agricultural systems. Future research should focus on the genetic diversity of *Trichogramma* species, their specialization to different host insects, and changes in biological activity under climate change conditions [14, 15]. Such investigations will further strengthen the scientific foundations of biological control.

Conclusion

This study enabled the quantitative assessment of the ecological status and biological activity of parasitoid insects of the genus *Trichogramma* in tugai forest ecosystems. The 61.9% parasitism of examined Lepidoptera eggs, along with the recording of stable populations of three *Trichogramma* species, clearly indicates that tugai forests provide a highly suitable natural habitat for these parasitoids. Seasonal dynamics results confirm peak biological activity during the spring–summer period. The scientific contribution of the study lies in expanding the prevailing view that associates the ecological role of *Trichogramma* species primarily with agroecosystems, by scientifically establishing their importance as effective regulators of pest insect populations in natural tugai forest ecosystems as well. The results demonstrate that parasitoid–host interactions possess stable functioning mechanisms even in complex natural biocenoses, thereby enriching the ecological foundations of biological control. From a practical standpoint, the study justifies viewing tugai forests as natural reservoirs and gene pool sources for *Trichogramma* species. The obtained data provide direct scientific support for utilizing local populations in biological control programs, reducing pesticide loads, and implementing ecologically safe protection systems. Although the study was limited to a specific region and season, without encompassing genetic and long-term population processes, the results establish a reliable foundation for broader spatial and comprehensive future investigations. In summary, the natural persistence and high biological activity of *Trichogramma* species in tugai forest ecosystems allow them to be evaluated as a key component of stable, ecologically grounded biological control systems against pests. This research makes a substantial scientific and practical contribution to the development of the field.

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