# Monitoring, Identification, and Evaluation of Rice Planthoppers Using an Intelligent Small Insect Monitoring and Forecasting System

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**Abstract** [**Objectives**] To assess the effectiveness of the intelligent small insect monitoring and forecasting system developed by Zhejiang Top Cloud－Agri Technology Co., Ltd. in monitoring, providing early warnings, and identifying rice planthoppers. [**Methods**] In 2024, an experiment involving the automatic identification and counting of rice planthoppers was conducted using the intelligent small insect monitoring and forecasting system in the rice production demonstration area of Qingxichang Sub-district, Xiushan Autonomous County, Chongqing City. The results obtained were subsequently compared and analyzed against those derived from manual identification. [**Results**] The intelligent small insect monitoring and forecasting system achieved recognition accuracy rates of 95.14%, 94.25%, and 97.78% for *Nilaparvata lugens*, *Sogatella furcifera*, and *Laodelphax striatellus*, respectively, resulting in an average accuracy rate of 95.72%. The outcomes derived from automatic recognition closely corresponded with those obtained through manual identification. [**Conclusions**] This research provides a reference for the optimization of the intelligent small insect monitoring and forecasting system.

**Key words** Rice planthopper, Intelligent small insect monitoring and forecasting system, Recognition accuracy, Correlation coefficient, Xiushan County

## 1 Introduction

Rice planthoppers, including *Nilaparvata lugens*, *Sogatella furcifera*, and *Laodelphax striatellus*, are major pests that pose significant threats to rice yields. Due to their migratory capabilities, the species composition and population densities of rice planthoppers fluctuate across different seasons and regions[1－4]. Consequently, accurate identification of rice planthopper species and assessment of their population sizes are crucial for precise prediction of pest outbreaks, timely implementation of control measures, and ensuring the safe production of rice[5]. Xiushan County is situated in the hinterland of the Wuling Mountain region in the southeastern part of Chongqing City. The rice planthoppers *N. lugens* and *S. furcifera* are unable to overwinter in this county. Each spring and summer, these insect populations migrate from the southern rice-growing regions of China via air currents[6]. The unique geographical location of Xiushan County renders it a critical corridor for the north－south migration of rice planthoppers in China, thereby making these two species the primary pests affecting rice production in this area[7]. Since 2004, Xiushan County has continuously employed a new generation of frequency vibration automatic pest monitoring lamps, equipped with 200 W incandescent light sources, to monitor the population dynamics of rice planthoppers through light trapping. This method has been utilized for 20 years and has yielded effective monitoring results. However, as the equipment only automates the collection, drying, and bagging of pests, manual classification and counting of the collected specimens are still required daily, resulting in a substantial workload[8－9]. In recent years, the rapid advancement of technologies—including computers, the Internet, the Internet of Things (IoT), artificial intelligence, remote sensing, geographic information systems, satellite positioning systems, and atmospheric circulation analysis—has significantly contributed to the monitoring and early warning of crop diseases and pests. This progress has facilitated the development of modern intelligent pest and disease monitoring equipment, such as intelligent insect forecasting lamps, smart traps, insect radars, low-altitude remote sensing, satellite remote sensing, and intelligent recognition applications. Furthermore, real-time monitoring and early warning systems for major pests and diseases have been established, substantially enhancing the timeliness and accuracy of pest and disease detection and prediction[10－11].

To more effectively evaluate the monitoring, early warning, and identification capabilities of the intelligent small insect monitoring and forecasting system developed by Zhejiang Top Cloud－Agri Technology Co., Ltd. for rice planthoppers, the Plant Protection and Plant Quarantine Station of Xiushan County conducted an automatic identification and counting experiment in 2024. This study was carried out in the rice production demonstration area of Qingxichang Sub-district, Xiushan Autonomous County, Chongqing City, with the aim of providing a reference for optimizing the intelligent small insect monitoring and forecasting system.

## 2 Materials and methods

**2.1 Overview of the experimental field** The experiment was conducted at Dafenbao Group, Donglin Community Committee, Qingxichang Town, Xiushan County, situated at an altitude of 368 m, with coordinates 28°24′18″ N, 108°54′1″E. The study area was characterized as a single-cropping mid-season rice cultivation zone, featuring flat terrain and accessible irrigation. The soil

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type was paddy soil exhibiting moderate fertility. The primary planting system was a rice-oil crop rotation, involving two crops per year. The first crop was rice, followed by rapeseed planted in winter. The rice variety used in the experimental area was Shen 9 You 28, which was planted by direct seeding. For an area of 667 $m^2$, 1.5 kg of seeds were used, and the rice was planted in contiguous plots. Rice was directly sown in early April and reached maturity by late August. In large-scale local production, rice is typically sown in early April, transplanted in early May, and matures between late August and early September. Pesticides are applied to rice plants 3–4 times annually.

**2.2 Experimental time** The experiment was conducted from May 9 to October 30, 2024.

**2.3 Materials** The intelligent small insect monitoring and forecasting system (Model: TPCB-FSCB-R), developed and supplied by Zhejiang Top Cloud – Agri Technology Co., Ltd., primarily comprised software components including an automatic data acquisition system, an automatic data transmission system, and an intelligent insect light trapping and forecasting system. This system employed a specially designed, specific trapping light source to attract millimeter-scale phototactic pests, such as rice planthoppers and leafhoppers. Insects were captured using negative pressure. A built-in 2 000 W high-definition industrial camera was employed to capture live images of the insects, with a default interval of 20 min per photograph; this interval could be adjusted to 10 min per photograph when insect populations were large. Utilizing AI-based automatic recognition technology, the species of small pests—including *N. lugens*, *S. furcifera*, and *L. striatellus*—were accurately identified and counted individually. The quantities were automatically recorded, and the data were transmitted wirelessly. Subsequently, the statistics were uploaded to a network, where statistical charts and dynamic curves were generated. Additionally, pest data from previous years could be compared and analyzed.

**2.4 Experimental design** This experiment involved two treatments: automatic counting and manual counting, both conducted using the intelligent small insect monitoring and forecasting system. The system was installed in the center of the paddy field ridge within the experimental area on May 9, 2024, in a relatively open location. During the experimental period, the operating time of the intelligent small insect monitoring and forecasting system was set to 8 h daily (from 19:00 to 03:00 the following day). This schedule was determined based on the sunlight patterns in the test area, the behavioral habits of rice planthoppers, and the continuous operational capacity of the equipment. Throughout this period, the system automatically captured images and uploaded them to the server for automatic identification and counting of target pests. Additionally, the Plant Protection and Plant Quarantine Station of Xiushan County conducted daily manual identification and counting of the uploaded images via the web platform and App, spanning a total of 175 d.

**2.5 Evaluation methods**

**2.5.1** Analysis of image recognition accuracy rate for target pests. The formula used to calculate the accuracy rate ($X$) of image recognition is as follows:

$$X\ (\%) = [1 - ABS\ (B - A)/A] \times 100\% \quad (1)$$

where $A$ represents the quantity of target pests in the image, determined through manual identification and quantification; $B$ denotes the quantity of target pests automatically identified and counted by the intelligent small insect monitoring and forecasting system.

**2.5.2** Correlation analysis of target pest data. To assess the correlation between the quantities of each target pest obtained through automatic recognition of the intelligent small insect monitoring and forecasting system and those obtained via manual image identification, the correlation coefficients between the daily pest quantities from both methods were calculated. The calculation formula is:

$$r\ (P,\ Q) = \frac{Cov\ (P,\ Q)}{\sqrt{Var\ (P)\ Var\ (Q)}} \quad (2)$$

where $Cov(P, Q)$ denotes the covariance between $P$ and $Q$, $Var(P)$ represents the variance of $P$, and $Var(Q)$ represents the variance of $Q$. Here, $P$ and $Q$ correspond to the daily pest quantities of the target pests obtained through two distinct methods: system automatic identification and manual image identification.

## 3 Results and analysis

**3.1 Pest quantities attracted by lamps** Since the commencement of the experiment, the Plant Protection and Plant Quarantine Station of Xiushan County has recorded daily automatic identification data from insect traps and performed manual identification and counting. Ultimately, a total of 175 d of monitoring data were collected.

The images of insects obtained through the intelligent small insect monitoring and forecasting system were manually identified. Regarding the total quantity of insects captured and identified by the equipment, the order was *N. lugens* > *S. furcifera* > *L. striatellus*. Over the experimental period, a total of 394 *N. lugens* individuals were captured on 70 d, averaging 5.63 captures per day. Among the collection dates, the highest daily capture was recorded on September 18th, totaling 49 individuals (Fig. 1). During the monitoring period, *S. furcifera* were captured on 57 d, with a total of 323 individuals collected, resulting in average daily captures of 5.67 individuals. The highest daily capture occurred on June 30th, with 43 individuals collected (Fig. 2). Additionally, a total of 20 *L. striatellus* individuals were captured on 15 d, corresponding to an average of 1.33 insects per day. The peak daily capture for this species was recorded on June 18th, with 3 individuals collected (Fig. 3).

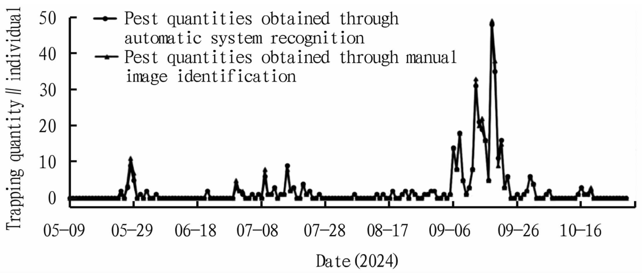


**Fig. 1 Trapping quantity of *Nilaparvata lugens***

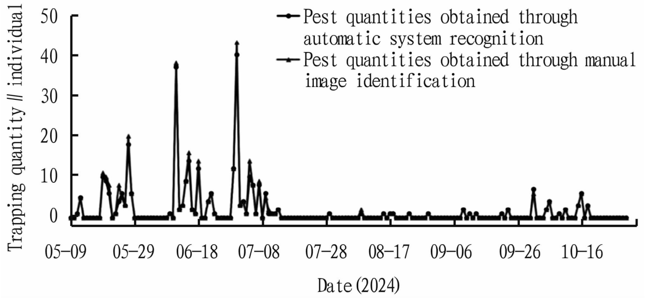


**Fig. 2 Trapping quantity of *Sogatella furcifera***

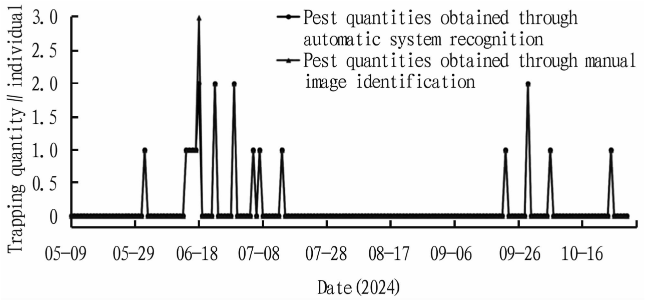


**Fig. 3 Trapping quantity of *Laodelphax striatellus***

**3.2 Algorithm recognition accuracy rate** By comparing and analyzing the daily insect quantities of the target pests obtained through two methods—automatic system recognition and manual image identification—it was determined that the algorithm recognition accuracy rates for *N. lugens*, *S. furcifera*, and *L. striatellus* under lamp conditions were 95.14%, 94.25%, and 97.78%, respectively (Fig. 4), resulting in an average recognition accuracy rate of 95.72%.

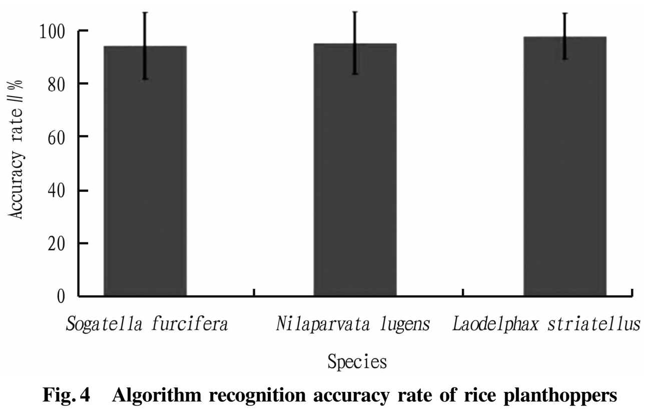


**Fig. 4 Algorithm recognition accuracy rate of rice planthoppers**

**3.3 Fitting degree of algorithm recognition model** Following manual identification conducted by the Plant Protection and Plant Quarantine Station of Xiushan County on insect images, it was determined that the algorithm achieved a recognition rate exceeding 90% for the three species of rice planthoppers under lamp conditions. To evaluate the model's goodness of fit, a comparative analysis was performed between the automatic recognition results obtained under lamp conditions and the manual identification of the images for the three rice planthopper species. The results showed that the correlation coefficient between algorithm automatic recognition and manual identification of *N. lugens* was 0.997 0 (Fig. 5). For *S. furcifera*, the correlation coefficient between the two methods was 0.995 4 (Fig. 6), and for *L. striatellus*, it was 0.985 6 (Fig. 7). These values indicated a strong degree of fit.

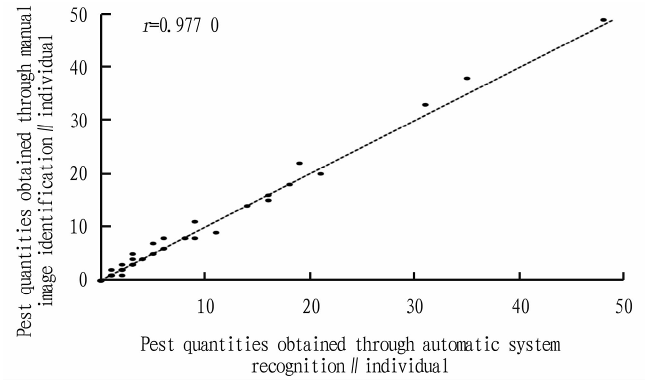


**Fig. 5 Correlation coefficient between automatic recognition and manual recognition of *Nilaparvata lugens* under lamp conditions**

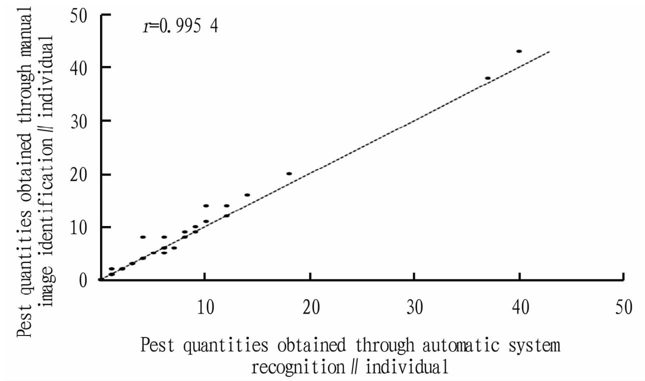


**Fig. 6 Correlation coefficient between automatic recognition and manual recognition of *Sogatella furcifera* under lamp conditions**

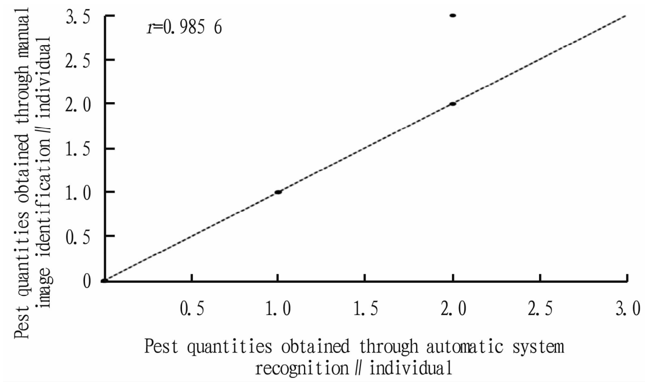


**Fig. 7 Correlation coefficient between automatic recognition and manual recognition of *Laodelphax striatellus* under lamp conditions**

**3.4 Analysis of algorithm recognition accuracy rate and correlation coefficient** The intelligent small insect monitoring and forecasting system demonstrated strong identification performance for major rice pests (*N. lugens*, *S. furcifera*, and *L. striatellus*), achieving an identification accuracy rate exceeding 90%. This accuracy was largely consistent with manual identification results (Table 1). Additionally, the system effectively captured the peak periods and trends of pest occurrence, which closely matched observed patterns[13].

**Table 1 Statistical analysis of the automatic identification and counting test data of rice planthoppers by the intelligent small insect monitoring and forecasting system**

| Species of target pest | Number of days for lamp identification//d | Pest quantities obtained through automatic system recognition//individual | Pest quantities obtained through manual image identification//individual | Recognition accuracy rate//% | Model correlation coefficient |
|---|---|---|---|---|---|
| *Nilaparvata lugens* | 70.00 | 380.00 | 394.00 | 95.14 | 0.997 0 |
| *Sogatella furcifera* | 57.00 | 301.00 | 323.00 | 94.25 | 0.995 4 |
| *Laodelphax striatellus* | 15.00 | 19.00 | 20.00 | 97.78 | 0.985 6 |
| Average | 47.33 | 233.33 | 245.67 | 95.72 | 0.992 7 |

## 4 Discussion and conclusions

The intelligent small insect monitoring and forecasting system used to track the occurrence of rice planthoppers demonstrates strong specificity for the target pests, with no overlap among insect bodies and complete individual identification. The system can automatically and accurately identify the species and quantities of rice planthoppers with high reliability. It enables timely monitoring of the field dynamics of rice planthopper populations, thereby providing effective guidance for the monitoring and control of rice pests. The promotion and application of this equipment can effectively reduce the costs associated with manual monitoring and forecasting while simultaneously improving the real-time accuracy of rice pest prediction and early warning. It also provides monitoring personnel with a reliable basis to understand the current status and trends of pest populations in real time, thereby reducing labor costs and work intensity. Furthermore, it facilitates the timely implementation of unified and environmentally friendly pest control measures by the plant protection department, achieving the goals of reducing pesticide use, increasing efficiency, and aligning with the development direction of the modern plant protection industry. In practical monitoring applications, the intelligent small insect monitoring and forecasting system still requires further optimization in certain areas. The existing issues and proposed improvements are as follows. (i) After extended use, the insect-catching plate tends to become dirty due to residues such as insect body fluids, wings, limbs, and natural dust. Mild to moderate dirt has a relatively minor impact on insect identification; however, severe contamination necessitates manual cleaning before the system can function properly. Therefore, implementing a regular automatic cleaning feature for the insect-catching plate is recommended. (ii) The intelligent small insect monitoring and forecasting system is powered by solar energy. Prolonged periods of rainy weather can lead to power shortages, resulting in equipment disconnections, unstable data transmission, or complete transmission failures. Consequently, it is imperative to enhance the solar panels and the system's network transmission devices to improve the monitoring system's resilience to interference. (iii) At present, the overall recognition rate exceeds 90%, satisfying the requirements for monitoring and forecasting tasks. Future research should prioritize improving equipment stability to ensure continuous operation and expanding the range of insect species that can be accurately identified.

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