Grain Pests Identification and Control Techniques：Technical Needs for Grain Pest Control


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Upgrades in storage facilities, technological advancements and climate change have significantly impacted the occurrence and development of grain pests. This includes both their distribution and growth at the macro level, as well as information changes at the micro level. To combat these pests, various techniques have been developed, such as pest control, chemical agents, low-temperature storage, and targeted strategies for different ecological regions. Additionally, rapid and accurate identification should be conducted through databases and systems, while adopting physical and biological control methods, including protective agents and natural enemies. Currently, the grain pests control techniques can be divided into three categories: physical, chemical, and biological. This technical guideline aims to follow integrated control principles and outlines scientific and technological developments in grain pest control in China.

1. Grain Pests Identification Techniques

Importance of pest identification:

Accurate and rapid identification of grain pests is crucial for effective pest control. However, there is a lack of molecular data and understanding of mechanisms behind control techniques. Therefore, it is crucial to develop molecular identification and analysis techniques for grain pests and mites, along with corresponding databases. This includes three major technical systems and their associated databases: molecular DNA barcode identification, 3D recognition, and mitochondrial genomes. These systems and databases will provide essential technical and basic data support for the classification, identification, and systematic research of grain pests and mites. They will also serve as valuable resources for monitoring, identifying, and controlling grain pests and mites, forming a key component of grain pest control.

1.1 DNA Barcode Identification

1.1.1 Grain Pests DNA Barcode Identification System

The "Certificate Specimen - Morphological Identification - Molecular Barcode -3D Digital Specimen" for grain storage pests and mites have been formed.

Step 1: Morphological identification

Displaying the morphological characteristics.

Step 2: DNA barcode gene identification

PCR amplification and screening of 3 genes: COI, ITS, 18S rDNA, targeting 8 different grain pests.

Step 3: DNA barcode sequencing

Taking at least 5 samples from each grain pest for testing and perform bidirectional sequencing to obtain their barcode sequences.

Step 4: Construction of a DNA barcode library for pests and mites

(1) Standard COI barcode sequence; (2) Sequence length not less than 600bp; (3) No missing bases, no terminators; (4) Maximum intraspecific genetic distance greater than minimum interspecific genetic distance.

Step 5: Validity analysis of DNA barcode identification

Phylogenetic analysis and evolutionary analysis of haplotype networks.

Figure 1-1 DNA Barcode Sequence Library

Based on COI gene sequences, a "Grain Pests DNA Barcode Identification System" has been established, covering 50 species of pests/mites. DNA barcode can effectively identify major grain pests and mites.

1.1.2 DNA Barcode Species-Specific Primer Identification Techniques for Closely Related Species of Grain Pests

Nucleotide sequence-specific sites for 18 species have been analyzed within 7 hours, and specific primers for closely related species have been designed, enabling identification without sequencing. Table 1-1 shows an example of the identification process for *Cryptolestes ferrugineus*.

Table 1-1 Comparison of Morphology and Molecular Identification of *Cryptolestes ferrugineus*

Morphology Identification	Time（d）			
	Cultivate to adults	Slide production and identification	Total	Average
Eggs	25	5	30	
Lava	1-20	5	5-25	17
Adults	0	5	5	

Table 1-2 Molecular Identification

Molecular Identification	Time（d）			
	DNA extraction	PCR	Sequencing /Electrophoresis	Total
DNA barcode	0.1	0.15	2.00	2.3
Specific primers	0.1	0.15	0.05	0.3

1.2 3D Digital Specimen System for Grain Pests

A 3D digital system has been established for common specimens of 25 grain pests, featuring real textures in 4K or higher resolution, high-definition VR display, and integrated pest specimen display capabilities. It can be used for common specimen substitution, identification support, and teaching and training purposes.

Figure 1-2 3D Digital Specimen System for Grain Pests

1.3 Grain Pests Mitochondrion Identification and Analysis System

The objective are to enhance gene identification in 1.1, advance basic research on pest control, and utilize mitochondrial DNA to improve the capabilities for rapid and accurate identification of grain pests and genetic diversity analysis in China. The main functions include information browsing and querying, as well as gene sequence alignment and identification.

1.4 Application and Social Benefits

Currently, this technique is only available in China. However, scientists are continuously supplementing data and improving the system.

1.4.1 Basic Applications in Pest Control

Complementing traditional morphological identification.

Revealing the genetic relationships between species.

Research on differences in pest resistance and outbreak patterns.

1.4.2 Molecular Identification of Grain Pests-Identification of Fragments and Damaged Samples

It can be used to identify non-adult and fragmented pest species, as well as for quarantine inspection of food and food imports/exports, serving pest and mite quarantine identification to ensure food safety.

2. Grain Pests Control Techniques in China

2.1 Food-Grade Inert Powder

Introduction: The food-grade inert powder uses fan-driven air to aerosolize inert powder, distributing it as a gas-solid two-phase flow uniformly between grain particles in the grain mass. The main component of the inert powder is $SiO_2 \cdot nH_2O$, which consists of small particles with a molecular size of approximately 0.5 m and a density of 0.2 g/cm^3. The product has low specific gravity and effectively controls grain pests at dosages of 4mg-20mg/kg. It provides physical protection, meets food-grade requirements, is environmentally sound, and features supporting equipment, high mechanization, low cost, and wide applicability. The technique complies with the "Code for safe storage of grain and oil" requirements and has become a standardized practice.

Application: It has been applied in more than 130 grain depots in 23 provinces of China by more than 50 processing enterprises and 500 farmers.

Effect: Pest control methods include treating empty grain depots, laying pest prevention lines, applying treatments to both grain surface and entire storage facilities, and storage protective agent for farmers. After initial fumigation, some grain depots use powder agents, which can meet the basic requirements for pest-free grain throughout the storage period without additional fumigation.

Figure 2-1 Food-Grade Inert Powder

Figure 2-2 Surface Application of Simple Corn Silo for Farmers

Figure 2-3 Surface Application of Simple Rice Silo for Farmers

2.2 Spinosad

Introduction: Through the cultivation of high-yield strains, the production of Spinosad can reach 10 tons or more. Spinosad has obtained pesticide registration certification. Developed automated equipment and robots are used for Spinosad application.

Application: Pesticides are applied on the surface of grain depots based on negative pressure ventilation, using robots for surface spraying. Upon entering the depot, the grain will be mixed with Spinosad. 10 pilot depots have been established in different grain storage ecological zones. Dosage: 1mg/kg.

Figure 2-4 Automatic spraying Equipment

Figure 2-5 Spraying machine of surface

Effect: The protective effect of this product lasts for 2 years and will not have any negative impact on grain quality.

2.3 S-Methoprene

Introduction: S-Methoprene is an insect growth regulator that plays a pivotal role in mitigating resistance to several contact insecticides and fumigants. S-Methoprene has the following benefits: (1) specific chemical structure. As an unsaturated fatty acid ester, it does not contain any toxic pesticide groups, such as halogens, heterocycles, or benzene rings but only carbon, hydrogen, and oxygen elements; (2) unique mechanism. The juvenile hormone in this compound interferes with the molting process of pests, inhibiting the transformation of eggs or larvae into adults. This ultimately causes adults to lose their reproductive ability, effectively controlling the growth of pest populations; (3) high activity with ultra-low dosage. The target pests are extremely sensitive to this compound, allowing for excellent control effects at ultra-low concentrations ranging from one to three parts per million; (4) unlike other pesticides, this compound doesn't target specific pest sites, making it difficult to develop resistance. Instead, it interferes with normal growth and development processes, eliminating the risk of resistance. There have been no reported cases of resistance to this compound; (5) safety and environmental protection. When exposed to light in the external environment, this compound decomposes into dioxide and water. It degrades quickly and leaves no residue, making it harmless to humans and the environment.

Effect: S-Methoprene has been proven effective for whole-depot application in preventing and controlling common pests in grain storage. By spraying it on grain surface or entire storage facilities, it effectively suppresses pest population development. This not only ensures grain quality, but also helps maintain its overall value. The use of S-Methoprene has also been proven to bring significant economic benefits to grain depots.

Figure 2-6 Treating Empty Grain Depots

Figure 2-7 Whole-Depot Treatment

Figure 2-8 S-Methoprene Agents

2.4 Predatory Mites

Introduction: Biological pest control using predatory mites (*Cheyletus malaccensis*) targets other mites and pests. This method relies on standardized, large-scale breeding techniques to boost predator populations. It involves release techniques based on established guidelines without requiring specialized equipment. This approach promotes green, eco-friendly, long-term, and sustainable pest control practices.

Application: For grain storage mites in China's grain depots, two beneficial natural enemies have been screened, and a biological control system using predatory mites has been established.

Figure 2-9 *Cheyletus malaccensis* preying on the egg of *Plodia interpunctella*

Figure 2-10 Release of predatory mites in granary

Effect: Predatory mites are released at temperatures above 15 ℃ to establish populations that help reduce pest eggs and larvae. Best results are achieved in areas with high temperature and humidity, providing long-lasting effects.

2.5 Atmospheric Regulation for Pest Control: N_2

Introduction: There are two types of nitrogen production equipment: pressure swing adsorption and membrane separation.

Application: Pests can be eliminated within 30 days at a concentration of over 98%;

and pest infestation can be prevented within 60 days at a concentration of over 95%.

Effect: The cost of nitrogen storage technology is about form \$0.1 to \$0.32 per ton of grain, and more and more grains are stored using nitrogen in China.

Figure 2-11 Nitrogen Generating Equipment

Figure 2-12 Grain Depots Covered with Film and Filled with Nitrogen

2.6 Fumigation

Introduction: Fumigation methods have been studied for common grain pests worldwide. Phosphine fumigation is widely used in the storage industry, and sulfuryl fluoride has also begun to be used in recent years.

Application: Phosphine is a chemical commonly used for fumigation. It is typically applied using specialized equipment, including pesticide application devices, circulation devices, and detection devices. The effectiveness of fumigation is influenced by multiple factors, including the duration in sealed areas, types of target pests, and the sealing level of grain depots. Additionally, chemical concentration is a crucial factor that needs to be determined through careful design, calculation, and monitoring processes, while also considering environmental temperature.

Effect: Usually, when the main stored grain pests reach 5 per kilogram, fumigation treatment is used for rapid pest control. When there are concentrated outbreaks of resistant pests eg. *Rhyzopertha dominica*, *Sitophilus oryzae* and *Cryptolestes ferrugineus*, phosphine concentrations can be 300 mL/m^3 - 500 mL/m^3.

Table 2-1 Reference Phosphine Concentrations for Different Pest Species Using Phosphine Fumigation at Different Sealing Durations and Temperatures

Pest species	**Temperature (°C)**	**Sealing duration（d）**		
		>14	**>21**	**>28**
Sensitive pests: *Sitophilus zeamais*, *Latheticus oryzae* Waterhouse, *Tribolium confusum* and other sensitive species	>25	200	150	100
	20-25	250	200	150
	15-20	-	250	200
Drug-resistant pests: *Rhyzopertha dominica*, *Sitophilus oryzae*, *Tribolium castaneum*, moths and other resistant species	>25	300	250	200
	20-25	350	300	250
	15-20	-	350	300

Temperature refers to the lowest grain temperature where the pest occurs.

3. Integrated Control Techniques

Background: The grain industry is taking steps to significantly reduce the use of chemical agents, making "integrated control" a necessary approach. Ongoing investment in scientific research has resulted in numerous advancements in new environmentally sound storage technologies. Additionally, the development of new equipment has made it possible to effectively demonstrate these green storage technologies.

Objectives: To determine optimal control timing through multi-parameter grain monitoring. Firstly, green control technology is adopted, including the use of low-temperature storage to reduce pest occurrence, combined with protective agent strategies such as inert powders, Spinosad, and S-Methoprene, as well as using natural enemies like predatory mites to control pest populations. In emergency situations, rapid pest control can be achieved by using aluminum phosphide or sulfuryl fluoride mixed with nitrogen fumigation technology, and to reduce fumigation dosage and increase pest control effectiveness. Ultimately, through monitoring, green protection, and emergency prevention and control, to achieve intelligent and sustainable storage, maintain quality and freshness, and reduce grain losses.

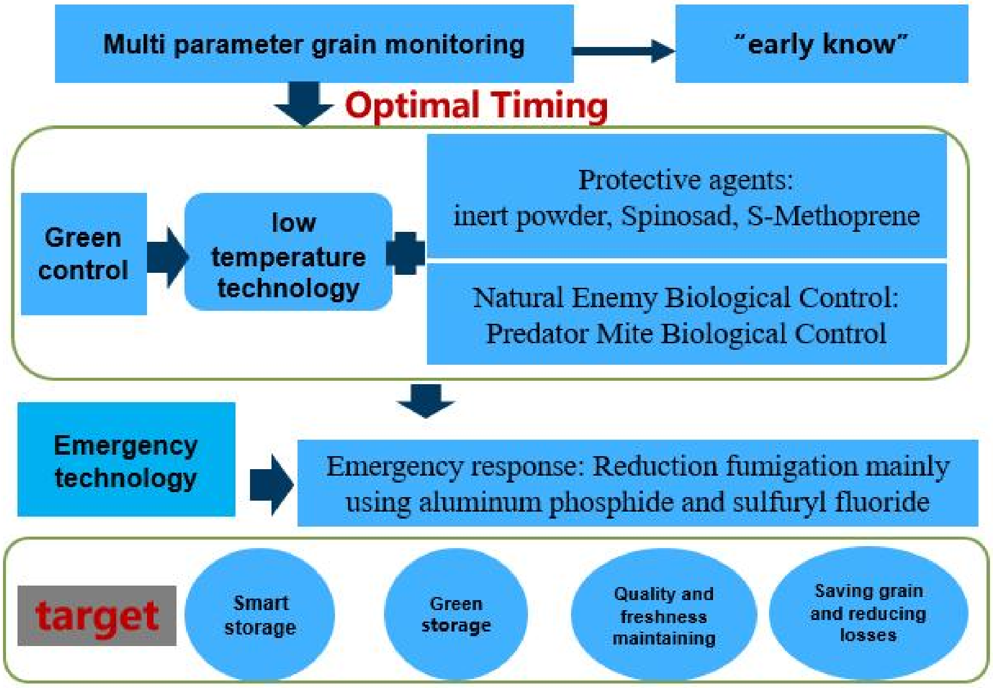

Figure 3-1 Integrated Control Technology System

Case 1. Integrated control techniques based on lateral ventilation at quasi-low temperature

Objectives: To improve the operational efficiency of inbound and outbound depot processes, preserve freshness, and reduce energy consumption at low temperatures.

Components: Zero-energy radiation-resistant refrigeration coating, polyurethane insulation, and mechanized operations including horizontal ventilation and depot robots. Other features include a cloud-based grain monitoring system, quasi-low temperature grain storage control, and sulfuric acid-nitrogen cycle fumigation.

Effect: The outbound efficiency has been increased by 50%, the temperature has been maintained at a quasi-low level, and the grain moisture loss has been reduced by 0.4%.

Case 2. Integrated control techniques based on intelligent monitoring

Objectives: To improve the level of intelligent monitoring.

Components: The intelligent monitoring system includes a grain condition cloud monitoring system, an online grain pest monitoring system, a mycotoxin monitoring and early warning system, and an online quantity monitoring system.

Effect: Reduced labor costs, timely controlled pests, and ensured food quality. When 1329 tons of rice were released from the warehouse, it made an additional profit of $17000 compared to other warehouses.

Case 3. Integrated control techniques based on sulfuryl fluoride fumigation

Objectives: To control resistant pests in grain depots with poor air tightness.

Components: Adopting polyurethane insulation to improve warehouse performance, a cloud-based grain monitoring system, quasi-low temperature grain storage control, and sulfuryl fluoride fumigation.

Effect: Rapid prevention and control of resistant pests, convenient and labor-saving process, and no pests during the entire one and a half year storage period.

Case 4. Integrated control techniques based on the whole-depot protection of S-Methoprene at quasi-low temperatures

Objectives: To explore the pest control effects of new green protective agents at quasi-low temperatures.

Components: S-Methoprene treatment for empty grain depots, surface and whole-depot protection.

Effect: Fumigation-free, efficient automated pesticide application, reduced energy consumption for temperature control.

Case 5. Integrated control techniques based on predatory mites

Objectives: To explore the pest control effects of the comprehensive approach combining natural enemy control and quasi-low temperature.

Components: S-Methoprene treatment for empty grain depots, quasi-low temperature grain storage control, and predatory mites .

Effect: Reducing two-thirds of chemical fumigants, effectively controls pest populations, lowers labor costs, and reduces energy consumption.