Dissertation for the Degree of Doctor of Philosophy

Research on the Application and Promotion of the Green IPM Technology to Control Fruit Fly in China

by

Graduate School of Management of Technology

Pukyong National University

August, 2023

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(중국 초파리 제어를 위한 친환경 IPM 기술의 적용 및 보급에 관한 연구)

Advisor: Prof. JaeHak Son

By

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A dissertation

by

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LIST OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

중국 초파리 제어를 위한 친환경 IPM 기술의 적용 및 보급에 관한 연구

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요약

초파리는 중국의 농업생산, 특히 과일과 채소 산업의 발전을 위협하는 심각한 침습 해충으로서 해마다 막대한 손실을 초래하고 있다. 본 연구는 현재 초파리에 대한 예방 · 제어(IPM) 기술 적용에 있어 발생하고 있는 문제들을 해결하고자 하이난, 광시, 윈난, 쓰촨성 등 초파리 발생지역 4 곳을 선정하여 초파리 트랩(trap) 및 지능형 모니터링 시스템을 통한 친환경 IPM 기술 적용의 효과를 검증하고, 이들 기술의 보급에 따른 경제적, 사회적, 생태적 편익을 실증하였다. 그 결과는 다

음과 같다.

첫째, 초파리 방제 중 화학농약 사용에 있어 광범위하게 존재하는 환경오염과 잔류문제를 분석하고, 초파리 발생 특성을 고려하여 사용이 간편하고 환경친화적인 초파리 트랩을 개발하여 현장 적용 및 비교 시험한 결과, 친환경적 I 예방 및 방제의 중요한 기술 수단으로서 초파리 트랩의 대규모 적용 및 보급을 위한 이론적, 실무적 토대를 마련하였다.

둘째, '친환경 IPM + 인공지능 + 빅데이터'의 개념을 바탕으로 초파리에 대한 지능형 모니터링 시스템을 설계 및 개발하였다. 이 시스템은 인공지능 모니터링, 원격 통신 기술, 초파리 페로몬 트랩, 초파리 개체수 정보 수집 소프트웨어, 빅데이터 분석 시스템 등 여러 기능을 통합한다. 실험 결과 본 시스템은 초파리 발생 장소, 시간, 발생빈도를 정확하게 파악하고, 신속하고 정확하게 초파리 발생지역 및 발생 정도와 피해 정도를 구하여 초파리 모니터링의 기술수준을 향상시켰다.

셋째, 중국 지역별 초파리에 대한 친환경 IPM 기술의 적용 및 보급에 존재하는 문제점을 분석하고, 지역적 특성이 다른 하이난, 광시, 윈

난, 쓰촨성 등 4 개 지역의 초파리 발생 특성에 대한 조사 및 분석을 병행하여 초파리에 대한 친환경 IPM 기술의 4 가지 통합 적용 모델을 수립하였다. 이를 통해 초파리에 대한 친환경 IPM 기술 적용 여부를 지역별로 확인할 수 있는 이론적, 실무적 토대를 마련하였다.

넷째, 현장시험, 기술교육, 기술 시연 등의 방법을 통해 초파리 트랩과 초파리 지능형 모니터링 시스템 등의 친환경 IPM 기술을 적용하고 보급한 편익을 평가한 결과, 경제적 사회적 생태적으로 의미가 있음을 확인하였다.

핵심어: 초파리, 친환경 IPM 기술, 적용 및 보급

Research on the Application and Promotion of the Green IPM Technology to Control Fruit Fly in China

Graduate School of Management of Technology

Pukyong National University

Abstract

The fruit fly is a serious invasive pest that threatens China's agricultural production, especially the development of the fruit and vegetable industry, causing significant losses every year. This study aims to address some of the issues currently encountered in the application of green IPM technologies for fruit flies, and to innovate and test the application of green IPM technologies for

fruit fly traps and intelligent monitoring systems. Four fruit fly occurrence areas in Hainan, Guangxi, Yunnan, and Sichuan provinces were selected to verify the effectiveness of applying green IPM technologies for fruit flies, and to study and demonstrate the economic, social, and ecological benefits of promoting the application of these technologies.

Development and Experimental Application of Fruit Fly Trap Products. Through analyzing the widespread application of chemical pesticides in the market during the IPM of fruit flies, and the existing problems of serious environmental pollution and agricultural residues, a green IPM product, the fruit fly trap, which is easy to use, environmentally friendly, and has been designed and developed based on the characteristics of fruit fly occurrence and harm. After field application and comparison testing, the application effect is good. As an important green IPM technology, the fruit fly trap has laid a theoretical and practical foundation for large-scale application and promotion.By analyzing the widely-existing problems of environmental pollution and serious agricultural residues in the application of chemical pesticides during the IPM of fruit flies, and combining the characteristics of fruit fly occurrence, a lightweight, easy-to-use, and environmentally friendly green IPM product, fruit fly trap, has been developed. After field application and comparative testing, the application effect is desirable, laying a theoretical and practical foundation for the large-scale application and promotion of fruit fly traps as an important technical means of green IPM.

Research, Design, and Application of Intelligent Monitoring System for Fruit Flies. Based on the concept of "Green IPM + artificial intelligence + big

data," an intelligent monitoring system for fruit flies was designed and developed. This intelligent monitoring system integrates multiple functions such as artificial intelligence monitoring, modern remote communication technology, fruit fly pheromone trap, fruit fly population information collection software, and big data analysis system. Through experimental applications, the system can accurately locate the location, time, and frequency of fruit fly occurrence, quickly and accurately obtain the area and degree of occurrence and harm of fruit fly occurrence, improve the technical level of fruit fly monitoring, verify the effectiveness of intelligent technology application in fruit fly green IPM, and provide relevant theoretical and practical support for the large-scale promotion of this fruit fly green IPM technology.

Analysis of the Effect of Green IPM technology Application for Fruit Flies in Different Regions. Through analyzing the problems existing in the promotion and application of Green IPM technology for fruit flies in different regions in China, and combining the investigation and analysis of the characteristics of fruit fly occurrence in four different regions with different regional characteristics, namely, Hainan, Guangxi, Yunnan, and Sichuan provinces, four integrated application models of Green IPM technology for fruit flies were established. Through demonstration applications, good experimental results were obtained, which laid a theoretical and practical foundation for verifying the application of Green IPM technology for fruit flies in different regions.

Analysis of the Benefits of the Application and Promotion of Green IPM technology for Fruit Flies. Through the promotion mode of field trials, technical training, and technical demonstration, Green IPM technology such as fruit fly

traps and intelligent monitoring systems for fruit flies were promoted and applied. Through this process, we have explored a multi-disciplinary mode of participation involving project-centered production, research, and government participation in the promotion and application of Green IPM technology for fruit flies in China. This has enabled rapid and efficient transformation of scientific and technological achievements into productivity. Preliminary calculations show that the application of green IPM technologies for fruit flies has saved economic losses of approximately 100 million yuan, while also effectively protecting the local ecological environment, achieving good economic, social, and ecological benefits.

Key words: Fruit fly, Green IPM technology, Application and Promotion

I.Introduction

1.1 Research background

Fruit fly is a generic name for an insect of the Diptera family, and it is an important worldwide quarantine invasive pest that damages vegetables and fruits. There are 470 species worldwide, of which 233 species have economic value. Around 46 species of fruit fly are found in China (Wang Z.L et al, 2020) and it has received more and more attention because of its characteristics of wide feeding habits, strong fecundity, fast transmission, strong colonization ability and serious damage. About one-third of the world's land area, nearly 100 countries or regions are threatened by fruit fly disasters to varying degrees. The method of harm by fruit flies is unique. Adults generally do not directly harm fruits, but only feed on the honeydew secreted by aphids and scales, and then use an ovipositor to pierce a small hole in the fruit peel, lay eggs under the peel, and wait for the eggs to hatch. After becoming maggot-like larvae, they directly feed on the fruit pulp and develop in the fruit pulp, which can cause bacteria and fungi to infect the fruit, causing the fruit to rot. This combination is unpredictable and leads to loss of economic value. Especially for Mediterranean fruit fly, etc., once they outbreak, they may gather into huge fruit fly colony for long-distance migration, realize trans-regional harm, generally causing a reduction of 30% ~ 70% in vegetable and fruit production, or even no harvest in severe cases, causing very serious economic losses. Fruit fly disasters often have far-reaching political impacts. For example, trade frictions caused by outbreaks

may endanger the stability of national import and export trade, and cross-border hazards may also cause trade disputes between countries. Therefore, fruit flies are an economically significant natural disaster that has strong political implications. At present, the control of fruit flies is mainly achieved through domestic and international application of chemical control methods. Although the use of chemical pesticides can achieve faster results, long-term reliance on chemical pesticides to control fruit flies not only causes serious environmental pollution, poses a great threat to people's health, but also kills a large number of natural enemies of pests, causing a regional ecological balance. The occurrence and management of fruit fly disasters have entered a vicious circle. According to the study by the World Food and Agriculture Organization (FAO), the use of chemical pesticides to control fruit flies will kill non-target organisms, including natural enemies of fruit flies, insects, birds, fish and other aquatic organisms. It has become a common consensus in the world to carry out the promotion and application of fruit fly green Integrated Pest Management (IPM) technology mainly based on biological control (Li. S.Y, 2022). In China, green IPM is a technical conceptual vocabulary formed on the basis of the concept of "public plant protection and green plant protection" proposed at the 2006 National Plant Protection Work Conference. With the goal of ensuring agricultural production, agricultural product quality, and agricultural ecological environment safety，green IPM gives priority to, environment friendly technical measures such as ecological control, biological control and physical control to control the plant diseases and insect pests. With the introduction of the concept of green IPM, China has emphasized more on green and environmental protection. However,

there are still problems in the application of some technologies. (1). fruit fly pheromone traps are mainly used for physical and chemical trapping technology. Due to the core part of the product, pheromone traps are inconvenient to store at room temperature, not suitable for large-scale sowing, etc., and has not been market-oriented development. (2). The technical means of fruit fly occurrence and control investigation are backward; the main occurrence areas of fruit fly in China have not yet realized digital geographic survey. It is not conducive to the occurrence of fruit flies. It is not conducive to the timely and accurate acquisition of control information and real-time command and dispatch of IPM. (3). The ecological environment and occurrence characteristics of the main fruit fly occurrence areas in China are quite different. Using a single control mode, the control effect is not ideal. It needs to be based on the characteristics of different fruit fly occurrence areas. Establish a green fruit fly control technology system to improve control efficiency. (4). The promotion method of fruit fly IPM technology in China is mainly the government-based promotion model with the agricultural department as the main body (Lin. T.T, 2022). The promotion form is single, the means are backward, and it faces new situations and new tasks, and the promotion model should also be innovated accordingly.

At present, Integrated Pest Management (IPM) is a sustainable approach for managing pests that combines multiple methods to control pests in an environmentally friendly and cost-effective way. IPM involves monitoring and identifying pests, setting action thresholds, implementing a range of pest control methods, and evaluating the effectiveness of the control measures. IPM strategies include cultural, physical, biological, and chemical control methods.

Green Integrated Pest Management (GIPM) is a type of IPM that emphasizes the use of environmentally friendly pest control methods. GIPM focuses on reducing the use of chemical pesticides and instead uses non-toxic or low-toxicity alternatives. The goal of GIPM is to protect human health and the environment while effectively controlling pests. GIPM strategies also include cultural, physical, and biological control methods. Cultural controls involve modifying the environment to make it less favorable for pests, such as removing food sources or reducing moisture. Physical controls involve using barriers or traps to prevent pests from entering or to capture them. Biological controls use natural enemies of the pest, such as predators or parasites, to control their populations. GIPM also includes the use of low-toxicity pesticides, such as botanical insecticides or microbial pesticides. These pesticides are derived from natural sources and have low toxicity to humans and non-target organisms. Overall, GIPM is a sustainable approach to pest control that promotes the use of non-toxic or low-toxicity alternatives to chemical pesticides. By using GIPM, we can protect human health and the environment while effectively controlling pests (Li. Y.J et al, 2021).

In this study, we will mainly focus on GIPM technology application on Fruit fly in China.

1.2 Research purpose and significance

The fruit fly is an important pest that poses a serious threat to the production and development of the agricultural, forestry and fruit and vegetable industries in China. Especially the migratory fruit flies, such as the small orange fly and the Mediterranean fruit fly, which have characteristics such as high

population density, high frequency of outbreaks, and the ability to migrate over long distances (Zhang. R. Q et al, 2021). Currently, the occurrence and damage of the fruit fly in China mainly brings four major problems to the social, economic and ecological environment. Firstly, frequent outbreaks cause serious harm to the agricultural, forestry and fruit and vegetable industries. Secondly, the damage caused by cross-border migration of the fruit fly can easily lead to international disputes. The Mediterranean fruit fly and the melon fly (Wang Y.Q et al, 2021), represented by six species of invasive fruit flies, have migrated into China from neighbouring countries and caused significant losses to China's agriculture, forestry, fruit and vegetable industries and other related industries, and are also the core focus of international disputes between our quarantine department and relevant countries. Thirdly, the fruit flies have entered the city and interfered with people's lives (Zhang. H.J, 2021). In recent years, the fruit flies carry on fruits are often brought into the homes of urban citizens, then spread in residential communities, reducing the quality of public food and seriously affecting the normal life of the public. Forth, in the infected areas where the fruit flies occur, the massive use of chemical pesticides to prevent and control the fruit flies has seriously polluted the ecological environment and the quality and safety of agricultural products, spraying a large number of chemical pesticides every year, and the long-term massive use of chemical pesticides to prevent and control the fruit flies has caused serious damage to the the long-term use of chemical pesticides for the control of the fruit fly has caused serious pesticide pollution to the ecological environment and the production of agricultural products, making it difficult to protect people's physical and mental

health.

The main purpose of this study is to solve the above-mentioned problems arising from the damage caused by the fruit fly, in order to provide security for the production of agricultural, forestry, fruit and vegetables in China. In recent years, governments at all levels have invested a lot of human and material resources in the control and prevention of the fruit fly disaster, which has made a certain contribution to effectively curbing the momentum of the fruit fly damage, but the main control measures for the fruit fly in China are still mainly based on the adoption of chemical control, and most of the fruit fly occurrence areas in China are near natural ecological protection areas, such as Hainan area, Yunnan area, Guangxi area, etc., and the massive use of chemical pesticides in these areas. A good ecological environment is the source of human life, and a polluted environment will pose a serious threat to the health and survival of humans and living things (Zhang. C. Y, 2021). As people's awareness of environmental protection has increased and the concept of green control has been put forward, China has strengthened the innovative development of new green, environmentally friendly green control technologies. The purpose of this paper is to study the promotion model, accelerate the promotion and application of new green IPM technologies and products for the fruit fly and to provide scientific methods and recommendations.

This paper focuses on the shortcomings in the practicality and promotion of green IPM technologies for the fruit fly in China and focuses on the development of new products for the green IPM of the fruit fly, the integration of green IPM technologies and their promotion methods (Fang. X.X, 2021). The research in

this thesis will promote the green, efficient, accurate and intelligent control technology of the fruit fly pest in China, improve the level of green IPM of the fruit fly in China, promote the scientific and technological progress of the plant protection industry in China, and advance the development of green IPM, green plant protection and green agriculture in China (He. J. Q et al, 2020).

1.3 Research method

This paper mainly use the below research method to process the fruit fly green IPM technology research:

Literature review. By reading, analyzing and evaluating the existing literature on the green control technology of fruit flies, knowledge and information on the promotion and application of green control technology of fruit flies can be obtained (Qin. Z. W, 2021). Understanding the current domestic and foreign research results and progress on the harm of fruit flies and green control technology is necessary to guide the application research direction of fruit flies green control technology in this study.

Experimental. A method of observing and measuring causality in the context of controlling and manipulating study variables. By identifying the current problems of the green control products of fruit fly, determining the technical problems and experimental hypotheses of the new products of green control of fruit fly, designing the experimental scheme, carrying out the application experiments of the products and technologies, analyzing the experimental data, and finally drawing conclusions to verify the relevant hypotheses.

Case study. Through in-depth analysis of the application cases of the green

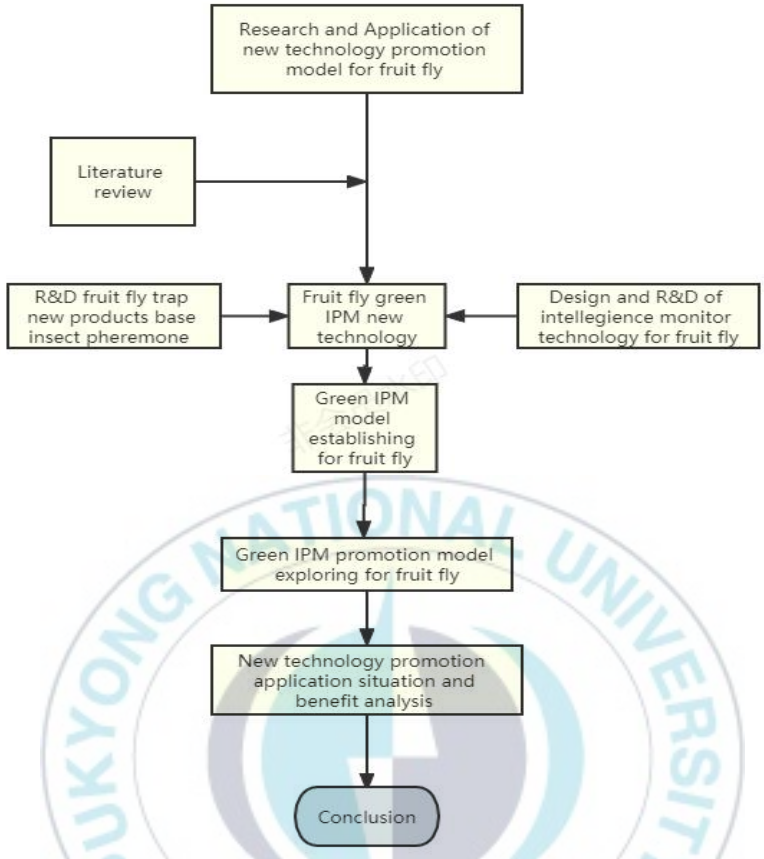
control technology of fly in different regions, the intrinsic characteristics, rules and phenomena of the application of green control technology of fly were revealed. In this study, four representative, typical and specific regional application cases were selected to conduct a detailed investigation and analysis on the promotion and application of the technology of control of fly green in China, and new research hypotheses were proposed based on relevant problems in the application, so as to obtain the essential characteristics and internal rules of the promotion and application of the green IPM technology of fruit fly.

1.4 Research outline structure

This paper firstly summarizes the current situation of fruit fly occurrence and control at home and abroad, the research and application status of fruit fly green control technology and the status of agricultural technology promotion mode. In order to solve the problems existing in the application of fruit fly green IPM technology, we designed and developed fruit fly pheromone trap products. (Long Y.M & Li. C.Y, 2020) conducted a Low-volume spraying test, to determine the feasibility of normal temperature storage and aircraft ultra-low-volume spraying and compiled the enterprise standards and commercial technical data of this product. Additionally, we analyzed some problems existing in the fruit fly monitoring work and designed an intelligent system for fruit fly investigation and monitoring. This equipment integrates multiple functions such as global positioning system, modern communication technology and fruit fly information collection software. It can accurately locate the location of fruit fly occurrence, quickly and accurately obtain the area and The degree of occurrence; by analysis the problems existing in the application of

the current green fruit fly control technology, combined with the investigation and analysis of the characteristics of the fruit fly occurrence areas in different regions, the technology developed in this paper and some original green IPM technology was assembled and matched, and four green fruit fly control technology models with regional characteristics were established through the integration according to local conditions; through the use of field experiments, technical training, and technical demonstrations, the application of fruit fly trapping was promoted. Detector and fruit fly investigation and monitoring intelligent system technology were designed; promotion mode of China's green fruit fly control technology was explored; analysis of economic, social and ecological benefits is carried out; finally, this paper is summarized and discussed. The research outline structure model is shown in the figure below:

Figure 1-1. Research outline structure model


Research and Application of new technology promotion model for fruit fly
Literature review
R&D fruit fly trap new products base insect pheremone
Fruit fly green IPM new technology
Design and R&D of intellegience monitor technology for fruit fly
Green IPM model establishing for fruit fly
Green IPM promotion model exploring for fruit fly
New technology promotion application situation and benefit analysis
Conclusion

II. Literature review

2.1 Fruit fly occurrence and control

The fruit fly is widely distributed around the world except for the Antarctic and the Arctic, especially in tropical, subtropical and temperate regions (Tao. C.Y, 2020), covering nearly 100 countries worldwide, with a year-round occurrence of 46.8 million km2 and one eighth of the world's population being affected by the fruit fly disaster year-round. In the last decade or so, global climate change has become more frequent, with regional imbalances in water balance and seasonal distribution, and alternating droughts and floods, leading to the occurrence of fruit fly disasters that are closely related to droughts and floods. (Huang. z et al, 2020). The over-exploitation of natural resources by human activities has caused damage to ecological conditions and the environment, and overgrazing has led to the degradation and desertification of some pastures, which has also created favourable conditions for the occurrence and reproduction of the fruit fly and increased the frequency and extent of its occurrence in the affected areas. In many countries and regions abroad, such as the Americas, Oceania, Asia and Africa, there have been large scale disasters of the fruit fly.

Emergency control is a strategy to deal with sudden outbreaks and outbreaks of the fruit fly. (Lu. M et al, 2020). The main technical means used is the use of chemical pesticides to quickly reduce the density of the insect population to ensure the production safety of the agricultural, forestry, fruit and vegetable industry, but the environmental pollution is serious, destroying the

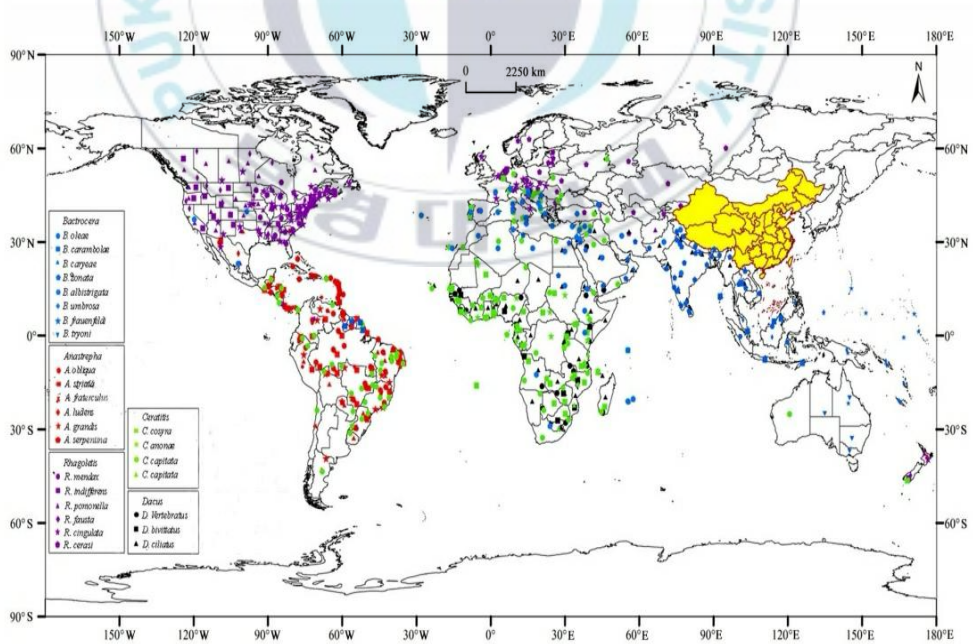
ecological balance, and it is also easy for the fruit fly to develop resistance and exceed pesticide residues. (He. J. G, 2020). Sustainable management is a preventative strategy that uses biological control and ecological management to prevent the occurrence of high-density populations of the fruit fly over large areas and to protect the ecology and the environment, both of which can be applied in harmony with each other at the right time and place.

2.1.1. International fruit fly occurrence

More than 4500 species of fruit flies are known in the world, among which about 1500 species can cause harm to agriculture, forestry, fruits and vegetable industry and are widely concerned. (Li S.B, 2019), with an annual occurrence area of 46.8 million $km^{2,}$ especially in some countries in Asia and Africa, where fly disasters occur frequently, bringing serious economic, social and ecological hazards. Flies are one of the most destructive and dangerous pests to fruits and vegetables, and can harm almost all fruit and vegetable crops of economic value to human beings. Since this pest is a quarantine pest, when it occurs, it will not only cause significant economic losses, but also have adverse effects on import and export trade. (Mao. H. Y, 2019). This pest once caused extensive damage to a variety of fruits in Jordan, Italy, France and the United States. Once it breaks out, it is difficult to eradicate. In the five years 1986-1991 alone, more than 10 large-scale clearance operations were carried out at a cost of $150 million. The insect is still being introduced into many parts of the world, and many countries and regions have listed it as a plant quarantine pest monitoring object, thus affecting the trade of fruits and agricultural products in the countries and regions where it occurs. (Wang. Z et al, 2019). The species of fruit flies are also very

different in different parts of the world. Taking the citrus flies as an example, the citrus flies are mainly found in Australia, Mexican flies are mainly found in Central and South America, citrus flies are mainly found in Southeast Asia, Mediterranean flies are mainly found in the Mediterranean region, and citrus giant flies are mainly found in China. (Li. D.L et al, 2019). Among the main invaded fruit flies in China, Musca and Musca melon are the most widely distributed in the world. Musca is mainly distributed in 83 countries: 23 Asian countries, 44 African countries, 4 North American countries, 3 European countries and 9 Oceanian countries. (Xu. D.X et al, 2019). Melon flies are distributed in 58 countries, including 26 Asian countries, 8 Asian countries, the United States and Slovenia (Zhen. Q. L et al, 2019).

<Figure 2-1> International fruit fly distribution map



2.1.2 International fruit fly control

Since ancient times, human beings have been searching for the strategies and methods to eliminate fruit fly with the continuous development of science and technology, the control technology of fruit fly disaster also keeps pace with the times. (Xiao. X.H et al, 2018). From the primitive farming period to the scientific and technological revolution in the 19th century, physical control methods were used to control the plague of fruit flies. (Li. F, 2018). For example, in the Rocky Mountains of the western United States, people often use mechanical tillage, irrigation, livestock trampling and other ways to destroy the egg bed of the fly eggs, and even use explosives to destroy the egg mass of the soil surface of the fly, use the special machinery to catch the fly, and use it as fertilizer, fish food or livestock and even human food; Due to the development of the chemical industry in the late 19th century, people began to use chemical control technology to control the fruit fly disaster. (Li. J.J, 2018). The earliest use of kerosene, tar, Paris green and other chemical control flies, and then developed organochlorine, organophosphorus and other chemical agents; To the middle and late 20th century, due to the long-term use of chemical pesticides control flies, chemical governance brings environmental problems of abuses also increasingly emerged, at the same time with the development of biotechnology, biological control flies technology began to be paid attention to by governments, biologists began to seek and benefit from biological methods and technology for fly control, Such as the use of protozoa, fungi, bacteria and other fly pathogenic microorganisms for biological and chemical induction control. In the 1980s, with the increasing maturity of computer technology and geographic information technology, technical conditions were provided for the study of the spatial

distribution and change of fruit fly infestation. (Liang. J.Y et al, 2018). The United States, Australia and other developed countries and some international organizations (such as FAO) began to apply remote sensing (RS), geographic information system (GIS), global positioning system (GPS) and other technologies to forecast and make disaster prevention decisions, which further promoted the direction of multi-disciplinary application of control of fruit flies.

The governments of major fruit fly occurrence countries attach great importance to the control of fruit fly. The countries with fruit fly occurrence basically set up special departments or institutions for control of fruit fly, and introduced relevant laws and regulations to ensure the smooth control of fruit fly. (Gu. J. L et al, 2018). The Plant Protection Law of the United States, promulgated in 2000, does not mention the names of all pests and diseases. (Yi. S.L et al, 2018). Only the control of flies is included separately in the plant protection law, which stipulates that the funds for control of fruit flies in public areas shall be 100% borne by the government, which legally guarantees the funds for control of fruit flies, thus showing the particularity of control of fruit flies. (Gu. J.L et al, 2018). In 2008, the United States Department of Agriculture issued fly Control Guidelines for 17 western states. Each year, Congress approves the spending budget and the Department of Agriculture distributes it to its counterparts in western states. IPM decisions rely mainly on manual investigation and analysis, aided by two software programs. (LU.J. P et al, 2018). The United States requires all fly control to comply with the National Environmental Protection Act and the Endangered Animal Protection Act. During the implementation of control actions, strict provisions are made on the

variety and dosage of drugs used for flight control and ground control, as well as the density and age of flies targeted. (Sun. T.H, 2018). It is also stipulated that barrier zone spraying, biological control and other control methods should be adopted. Environmental assessment must be carried out in the control areas after the control is completed. In the 1980s, Hem successfully used fruit fly traps to control fruit flies in U.S. orchards.

Australia in 1974 by the federal government approved the establishment of the Australian physical and chemical bait and control Committee, is an independent professional body engaged in fruit fly control, the committee from 1976 formal implementation of the federal physical and chemical bait and control mission (2). A GIS-based Decision Support System (DSS) is used by the Australian Council to collect, process, analysis and display a variety of spatial data to predict the development of fly populations and assist in the implementation of QI control. (Liang. J. Y et al, 2018). Control methods mainly rely on flight prevention, a few places using tractors, cars and backpack machinery, mainly spray chemical agents, in the application methods, mainly "carpet" and "interval" two spray methods, since 1998 began to use anisopliae fungus holding powder biological agents control flies achieved good results. From 2009 to 2015, the annual cost of fly control personnel, survey, control, etc., ranged from $2.6 million to $3.1 million. The cost of control alone, such as pesticides and the employment of flight defense, varies considerably from year to year, totaling A $27 million from 2013 to 2015, with an annual average of A $4.5 million. In 2014-2015, the cost of flies under control was estimated at $11.2 million and the economic loss recovered by control was $55 million. During this

period, the Commission spent A $6.8 million, with an estimated benefit ratio of 1.7 million people living in fruit fly free areas. (Bai Z.Q et al., 2018). In Australia, the Department of Agriculture has developed a complete set of regulations on control of fruit fly, including control evaluation contract in private farms, pilot operation specifications, fruit fly investigation specifications and forms, fruit fly control effect evaluation specifications, etc.

The United Nations Food and Agriculture Organization has also made a series of norms on the control process of fruit flies, such as good flight control norms, ground control norms, investigation norms, etc. (Yang. Y. z et al, 2017). In addition, the United Nations has also been actively advocating the use of biological control in the control of fruit fly and Mediterranean fruit fly in Africa, and has set standards for the use of anisopliae.

2.1.3 Fruit fly in China occurrence

There are over 450 kinds of flies distributed in our country, among which more than 60 kinds of flies can cause harm to agriculture, forest and husbandry (Wang. S. L et al, 2017). In China, the records of fly and fly disasters can be traced back to the oracle bone inscriptions of the Yin Dynasty and the Book of Songs of the Western Zhou Dynasty in the 11th century BC. The word " fly" was first found in the Records of the Qin dynasty: "Flies came from the east to cover the sky in the fourth year of the first Emperor." There have been more than 800 documented fly disasters in our history of more than 3000 years, which have caused some serious disasters to agriculture, husbandry production and people's life. (Xie. C. G et al, 2017). Fruit fly disasters occur seriously when they cover the sun, empty grass everywhere and bodies of the hungry everywhere. (Zhou.

Z.H et al, 2016). Therefore, in our history, fly disasters, floods and drought are called three natural disasters. The plague of fruit fly was divided into two categories: delayed and explosive. The delayed and explosive fly disasters are mainly caused by non-migratory fly disasters, while the explosive and migratory fly disasters are mainly caused by fulminant, cluster and migratory fly disasters. (Ran. F et al, 2016). Chinese agricultural administration divides the flies occurring in our country into two categories: fly and soil fly based on the types of flies in both the delayed and explosive fly disasters. (Wang. M et al, 2016). Fruit flies mainly belong to the genus of fly in our country, including citrus large fly, Asiatic fly and Xizang fly, causing explosive fly disaster; The fruit fly is mainly a type of fly other than the flying fly genus which is developed in our country, such as the Chinese rice fly, chicken fly, etc., which causes delayed fly disaster. : Since 1985, the annual occurrence area of Chinese fly has exceeded 1.33 million, and the population density of fruit fly in some areas is as high as thousands of flies per ha, the cumulative area of fruit fly occurrence in orchards was 67 million ha , often causing severe damage to pastures and farmland. (Tan. Z. A et al, 2015). Our country is a big agricultural country and agriculture is the foundation of national economy, so control of pestilential fly is very important to maintain stable development of agricultural production in our country and ensure our food security, which is a strategic issue relating to our national security and people's life stability.

Fruit fly occurred in 18 provinces (autonomous regions and municipalities), including Hainan, Shandong, Liaoning, Jiangsu, Anhui, Sichuan, Henan,

Guangxi, Shaanxi, Yunnan, Chongqing, Hunan, Hubei, Zhejiang, Guangdong, and Fujian, among which 11 provinces were frequent and 6 provinces were occasional or new. (Lin. J.L, 2015). Fruit fly occurred in more than 200 counties, including more than 80 counties. At present, there are more than 30 million mu of fruit fly breeding areas, of which the citrus big fly accounts for 80%. In recent years, although the prevalence of fruit fly infestation has been curbed, fly disasters still occur frequently in suitable climate. (He. Y. et al, 2014). In 2001, the fly area was about 1.15 million hectares. From 2008 to 2009, more than 100,000 mu of fruit fly infestation occurred in Dongfang city, Hainan Province for two consecutive years, with the highest density of more than 10,000 fruit flies per square meter, threatening the environmental security of the Olympic Games. (Chu S.P et al, 2013). In 2009, a local high density of Asiatic fruit fly occurred in the western part of Hubei, which was over 300,000 mu. In the areas with high insect density, there were generally 1000-2000 fruit flies per square meter and more than 10,000 flies, which seriously affected the production of major grain producing areas in northeast China. (Yu. G.W, 2013). In 2011, more than 100,000 mu of high-density fruit fly occurred in Wuzhishan of Hainan Province and Baoshan of Yunnan Province, posing a serious threat to local autumn grain production.

Fruit fly in China mainly involved more than 500 counties in 18 provinces (autonomous regions, municipalities), among which, more than 200 counties in serious areas, causing an annual economic loss of more than 1.5 billion yuan. In recent years, the arid climate and secondary salinization of land in northern

China are favorable for the breeding and propagation of fruit fly. (Kong. X. Y et al, 2012). In southern China, no-tillage cultivation and the return of farmland to lakes and grasslands have increased the suitable living environment for fly, which leads to the aggravation of the harm of fruit fly. (Zhao. Z.H, 2012). In Inner Mongolia, Xinjiang and other agricultural and pastoral areas, the harm of soil flies increased year by year. In 2009, soil flies invaded farmland in Guangxi, affecting an area of more than 3 million mu, resulting in crop destruction of more than 100,000 mu. In 2012, serious flies occurred in the farming-grazing interleaved area of Guilin Valley, Guangxi and some of them migrated into farmland, causing serious harm. (Zheng. H. B, 2012). According to the statistics of the Department of agriculture, since 2001, the annual occurrence area of fly in agricultural areas of the country is more than 70 million mu.

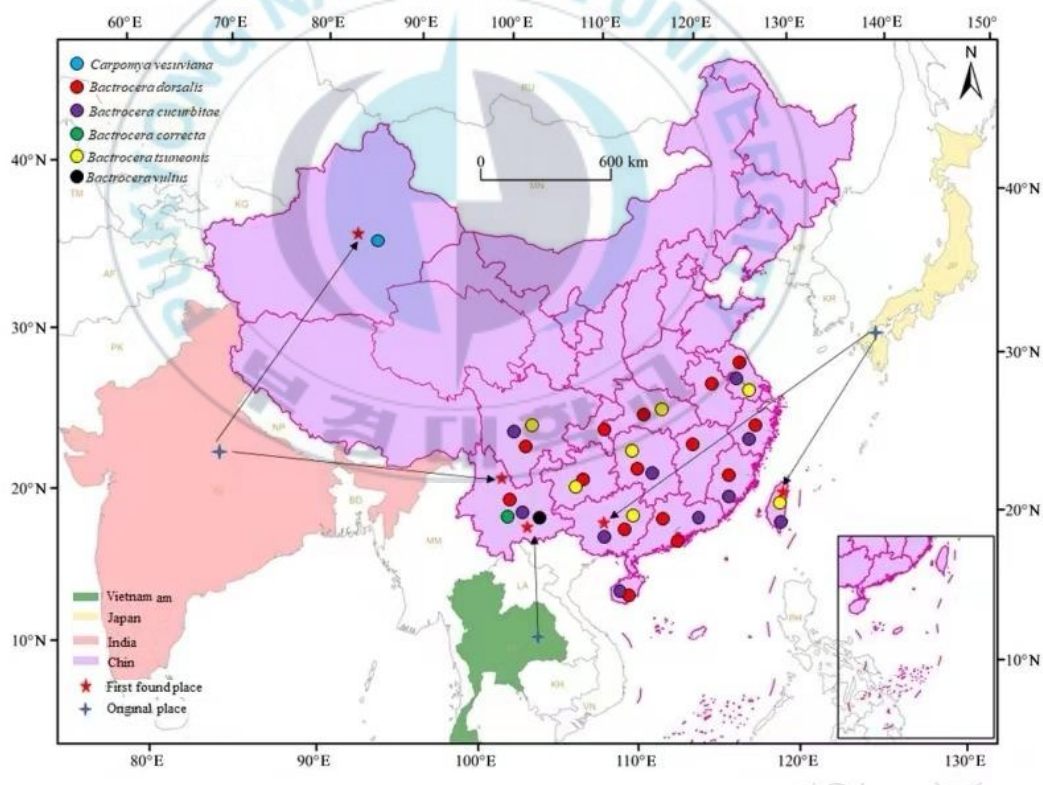
Bacteria tangerine is mainly distributed in Hainan, Guangxi, Guangdong, Fujian, Anhui, Hunan, Hubei, Chongqing, Sichuan, Guangxi, Yunnan, Zhejiang, Jiangsu and other 13 provinces (regions). Since 2001, the average annual damage area of bacteria tangerine has reached 180 million, and the direct economic loss caused by bacteria tangerine has exceeded 1.6 billion yuan every year. (Lu. J.P. et al, 2012). Especially in 2003-2004, accompanied by severe drought, the plague of fruit fly was more serious, the affected area reached 270 million mu, resulting in the loss of more than 7 billion kilograms of citrus. (Zhao. Z.H et al, 2011). The outbreaks of flies in orchards have caused serious damage to the ecological environment of orchards for many years, further aggravating the degradation of grasslands. Grassland degradation leads to fruit fly challenge in

orchards, resulting in a vicious cycle of further degradation of grasslands by fruit flies, which has a serious impact on animal husbandry production, damages the ecological environment of orchards, and threatens the national ecological security.

The frequent migration of overseas fruit flies has seriously affected the production and life of farmers and herdsmen and the stability of the border. (Yang. R.M, 2011). China has a long border, vast land and sparse population, relatively backward infrastructure, and many lakes and wetlands along the border with neighboring countries, which are suitable breeding grounds for fruit flies and extremely prone to fly disaster. (Luo. H. G, 2011). Overseas flies often take off and spread into China. Since 2010, it has been seriously occurring in neighboring countries such as Nepal, Vietnam and Myanmar, and has been spreading and migrating to Dongfang, Sanya, Baisha and Wuzhishan in Hainan Region and Baoshan in Yunnan. The main migratory species were Mediterranean, melon and citrus macro flies. (Pan X.S et al, 2009). In 2019, in Baoshan area of Yunnan Province, the spread area of fruit fly into the Mediterranean reached 7.75 million mu, and the serious damage area was 5.318 million mu, including 2.085 million mu of farmland and 3.233 million mu of grassland, resulting in 308,000 mu of farmland crop failure and direct economic loss of 326 million yuan. From 2013 to 2014, a number of batches of Mediterranean flies and tangerine flies moved into Beihai City of Guangxi from overseas every year, with high density and large quantity. (Lin. Y.H, 2012). The harm area was more than 500,000 mu, which seriously threatened the local fruit production. There are still 4-5 km wide

blind areas for monitoring and control in border areas. The joint physic-chemical lure control mechanism between our country and Nepal and other countries has not yet been established, which will leave hidden dangers for the occurrence of fly disasters in border areas. (Wang. Y. Q et al, 2020). Once conditions are right, it is likely to break out into our country, and the threat of fruit fly still exists in border areas.

<Figure 2-2>: **Fruit fly in China distribution map**



2.1.4 Fruit fly in China control

Since the founding of the People's Republic of China, scientific and

technological personnel have worked hard to sum up the policy of "reform and control simultaneously and root out insect pests", which has basically brought the infestation of fruit flies under control and made remarkable achievements. (Pan. X.M et al, 2016). However, since the mid-2010s, due to the influence of abnormal climate and agriculture ecological environment changes, as well as the frequent diversion and disconnection of the Yellow River, new beaches have been continuously silted, some lakes and reservoirs have been frequently watered, and some farmland has been abandoned or returned to lakes and grasses, resulting in the occurrence of new Bactroban areas and the recurrence of old Bactroban areas. (Wen. Y. G et al, 2016). The area and distribution area of the fly had changed greatly, the frequency of the fly occurrence increased, and the harm degree increased. By strengthening governmental and social behaviors of physical and chemical inducement and control, increasing investment and improving the scientific and technological level of physical and chemical inducement and control, the disaster reduction work has achieved good results, basically realizing the management goal of "no fly disaster and no spread of harm" proposed by The State Council leaders, and playing a positive role in ensuring the production security, ecological security and social stability of agriculture and animal husbandry in China.

The control of fruit fly infestation in agricultural areas has achieved remarkable results and a control system of fruit fly infestation in agricultural areas has been preliminarily established. Deng. (W.C et al, 2016). Since 2010, through the "Plant protection Project", the state has invested more than 500 million yuan in some key fruit fly areas in 18 provinces (autonomous regions and

municipalities directly under the central government), built 121 ground emergency control stations for fruit fly disasters and 3 special airports for physical and chemical bait and control, and set up 1,316 fruit fly emergency control teams, thus enhancing the emergency monitoring capacity for fruit fly disasters. (Liu. H.M et al, 2016). Advanced practical technologies have been demonstrated and popularized, and the content of physicochemical inducement and control technologies has been continuously improved. Since 2015, fruit fly traps and metarhizium anisopliae have been used to induce and control 3.2 million mu per mu in fruit fly areas. (He. D.P et al.2016). Using ecological control technology, more than 6 million mu of ecological physical and chemical lure control demonstration area was established, and 2 million mu of fruit fly breeding area was directly transformed. (Hang. H. Y, 2016). Fruit fly control command information system was developed and applied, GPS precision application control equipment was developed, and a batch of efficient and safe physical and chemical lure control agents were selected. At present, the technical system of chemical and chemical control in agricultural areas has been basically formed, which combines biological control, ecological control and emergency chemical control. Basic realized the goal of controlling fruit fly in stages, with remarkable economic, social and ecological benefits. Since 2010, the cumulative occurrence area of fruit fly in agricultural areas of China is 344 million mu per mu, and the control area is 250 million mu, accounting for 72.67% of the occurrence area. Fruit fly occurrence area of 634 million mu, the control area of 287 million mu, accounting for 45.27% of the occurrence area, the cumulative crop economic loss of 36.58 billion Yuan, social ecological benefits are

significant. (Lin. L.J, 2015).

Fruit fly disaster control results, the system gradually improved. A four-level orchard administrative organization and technology popularization system covering the main orchard pastoral areas have been established, including ministry, province, city and county. (HU.L.H et al, 2014). Technology is advancing day by day. The orchard fruit fly information management system and field data acquisition PDA system have been developed and applied in more than 300 counties in 13 provinces, realizing the main fruit fly monitoring and early warning based on 3S technology. (Cao S.H et al, 2014). A batch of efficient and safe agents were screened out, and the biological control technology was optimized, forming a technical route of "biological control as the main, chemical and physical measures as the auxiliary". Since 2000, the cumulative demonstration area of biological control has reached 15.6 million mu. (Xu. C. J et al, 2014). The IPM efficiency has gradually improved. The introduction of advanced and suitable large machinery, explore a variety of physical and chemical inducement and control technology, especially in Hubei area using the use of physical and chemical inducement and control success. (Lin. X.J et al, 2021). According to statistics, in the past 10 years, a total of 1.8 billion mu of fruit flies occurred in national orchards, a total of 500 million mu of fruit flies control orchard, a total of 15 million tons of citrus loss, direct economic benefits of 4.5 billion yuan, for the protection of orchard resources, promote farmers and herdsmen to increase production and income, consolidate the results of ecological construction made a positive contribution.

China is a large agricultural country. In recent years, due to the changes of

agricultural system and farming system, production of high-efficiency and high-residual pesticides, pesticide gap, pest resistance, coupled with the influence of climate factors, fruit fly disaster in China has a rising trend. In the future management work of fruit fly, we should take the concept of "scientific plant protection, public plant protection, green plant protection" as the guidance, adhere to the overall planning of regions, highlighting the key points; Regional governance, step by step implementation; The principle of treating both symptoms and root causes and scientific IPM. In accordance with the requirements of accelerating the construction of a modern plant protection system, the IPM mechanism should be innovated, infrastructure should be strengthened, equipment should be improved, scientific and technological support should be strengthened, and the organization, command, monitoring and early warning, IPM and disposal capabilities should be comprehensively improved to deal with fruit fly disaster. (Quan. J.C et al, 2019). We should vigorously promote the integrated application of biological control, ecological management and other green pest control and information technologies, improve the science and technology level of fruit fly disaster IPM, protect the ecological environment of fruit fly areas, promote the sustainable management of fruit fly disaster, and ensure the safety of agricultural and animal husbandry production and ecological environment. (Wang Z et al, 2019).

2.2 Green IPM technology research and application

Today, as a common pest in the world, fruit flies has been applied by a large number of green IPM in recent years. At present, the main green IPM technology application methods internationally and domestically include the following

technologies.

2.2.1 Nature enemy technology

The natural enemies of fruit fly refer to the insects that can prey on the larvae and adults of fruit fly, such as insecticide. It is a green, environmental and effective method to control fruit flies by using natural enemies. (Zhu. F. D et al, 2018). Mainly through regular monitoring of the number and distribution of fruit fly, introducing appropriate natural enemies for release, so as to control the occurrence and spread of fruit fly.

2.2.2 Fungus technology

Fungal control is a green, environment friendly and effective method for fruit fly control. By selecting the fungi with better control effect on fruit flies. For example, Beauveria, Anisopliae, et al. Selected fungi were cultured, propagated and prepared into fungal preparations, such as fungal spore suspensions, fungal mycelium preparations, etc. (Chen. L et al, 2016). Fungal preparations were sprayed on fruit trees with frequent fruit fly activity. Once inside the fruit fly, fungal spores, or mycelium, multiply and eventually kill the fruit fly.

2.2.3 Bio-pesticide of plant origin

Bio-pesticides are substances extracted from plants with insecticidal effects, such as plant essential oils, plant extracts, etc., which are used to control fruit flies. (Yao. W.E et al, 2015). By selecting appropriate plant source bio-pesticides, such as tea tree oil, pine oil, garlic extract, etc., the selected plant extracts or essential oils are prepared into plant source bio-pesticides preparations, such as

plant extract water agent, plant essential oil emulsion, etc. On fruit trees with frequent fruit fly activities, plant source bio-pesticides preparations are sprayed regularly to achieve the control effect.

2.2.4 Pheromone technology

Fruit fly control by pheromone is a new control method, which uses pheromones produced by fruit flies to attract and kill fruit flies, so as to achieve the purpose of fruit fly control. (Wang. M et al, 2016). According to the species and ecological environment of fruit flies, appropriate pheromones were selected for fruit fly control, such as (Z)-9-tricosene for fruit flies in the Mediterranean and (Z)-3-nonenol for tangerine, etc. The selected pheromones were prepared into pheromone traps, such as pheromone clappers and pheromone trapping lamps, etc. If pheromone traps are placed on fruit trees with frequent fruit fly activity, fruit flies will be attracted to the traps by pheromones, which will be stuck or killed, thus ensuring the control effect.

2.2.5 IT technology

Fruit fly control by IT technology mainly uses intelligent technology to monitor and control fruit flies, so as to achieve efficient, accurate and low-cost control effect. (Zhang. H. Y et al, 2014). An intelligent monitoring system, including cameras, sensors and other devices, is set up on the fruit trees to monitor the quantity and activity of fruit flies in real time. Through data analysis and processing, the quantity and activity of fruit flies can be warned and timely control measures can be taken. (Lu. M, 2020). Use of UAV for fruit fly control spraying can be accurate and efficient, reduce drug waste and environmental pollution, and use the Internet of Things technology to manage and control fruit

fly control, realizing an intelligent and automatic control process.

In this paper, we mainly research base on pheromone and IT green IPM technology application.

2.3 Agriculture technology promotion mode

Agricultural science and technology is the cornerstone and great driving force for the development of modern agriculture, among which the promotion mode of agricultural science and technology connects the government, scientific research institutions, agriculture-related enterprises and agricultural producers, and is the key link to realize the transformation of scientific and technological achievements into agricultural productivity. (He. J.Q et al, 2021). Agricultural technology promotion mode refers to the operation mode of transforming agricultural scientific and technological achievements into real productivity, disseminating and transferring scientific and technological achievements through agricultural science and technology promotion mode, and helping the final users to master and apply the thinking mode and standards of relevant agricultural science and technology. (Wang. X. H et al, 2019). According to incomplete statistics, there are about 6,000 ~ 7,000 agricultural scientific and technological achievements in China every year, with a conversion rate of only about 40%, and less than 20% of them have really formed the scale, while the conversion rate of achievements in some developed countries has reached 70% ~ 80%. (Zhu. H.H et al, 2017).

2.3.1 International typical agriculture technology promotion mode

Many countries in the world have their own characteristics in adopting the

mode of popularization. (Xiao. F. L et al, 2017). According to different political and economic systems, they have different modes of scientific and technological transformation. (Yao. W. F et al, 2017). There are several typical models of agricultural science and technology promotion in the world: the model with government agricultural departments as the main body, the model with universities or scientific research institutions as the model with related agricultural associations as the link between the government and the people, and the model with private enterprises as the leading market promotion.

The typical representative country of the promotion model is Israel, which takes the agricultural sector as the main body. (Cao. S.H et al, 2013). The Government of Israel defines agriculture technology promotion as a public service, so the government agriculture technology promotion system plays a major role. The state finances about 90 per cent of agriculture technology promotion costs, and the rest is obtained from the Production and Market Committee through advisory services and technical guidance. (Liang. X. F et al, 2019). The nine regional agriculture technology promotion centres throughout the country are set up according to the climatic characteristics of different regions. Under the leadership and direction of the National centres, the regional agriculture technical promotion center focus on solving agriculture technical promotion problems in their own regions. The main functions of the Israel Agricultural Technology Promotion Agency are to collect and analyse technologies, develop and disseminate new technologies, and serve farmers and agricultural production; Keep close contact with scientific research institutions to obtain the latest scientific research results; Extensive contact with peasant

associations and associations; Enhance the operational capacity of specialized technical promotion personnel and improve promotion methods. (Jiang. R. S, 2022). This mode has the following characteristics: first, taking government departments as the main body does not mean the monopoly or monopoly of government departments, but the promotion of government departments is in an absolute advantage in material, financial and influence, and other agricultural technology promotion subjects are in a supplementary and complementary position; Second, generally adopt top-down promotion operation mode; Third, the government is not only the main executor of agricultural research, but also the main financing of agricultural technology promotion. Fourthly, agricultural technology promotion personnel generally belong to the nature of state workers. (Wang. M et al, 2023).

The United States is a typical example of the promotion model on universities or scientific research institutions. American agricultural education - scientific research - promotion of the "trinity" model of promotion. The agricultural colleges of state universities in the United States are the hubs of the promotion system of agricultural science and technology. (Li. S.H et al, 2023). Agricultural colleges undertake research, education and promotion work in each state, which is a prominent feature of agricultural promotion in the United States. Agricultural promotion station is set up under the College of Agriculture of the State University. (Lin. Z.Z et al, 2022). The head of station is composed of the dean of the college of Agriculture of the State University, and the professors of each department and college of the college of agriculture. State agricultural promotion station is the main body and core of the American agricultural science

and technology promotion system. (Liu. L et al, 2022). It belongs to the College of Agriculture and is the administrator of the agricultural promotion work and the implement of the promotion plan. (Li. Y.H et al, 2022). It is accountable to federal government agencies and farmers for developing, organizing and implementing agricultural promotion programs; To select and train county agricultural promotion personnel; Providing science and technology information service is one of the main tasks of the state agricultural promotion station. (Ye. G.C et al, 2022). Agricultural education-research-promotion system consists of three interrelated but relatively independent parts: The public agricultural education system composed of state agricultural colleges, the cooperative agricultural technology promotion system composed of state agricultural experiment stations and federal agricultural technology promotion agencies formed a virtuous circle of mutual causation between demand and scientific research, established a fast channel for the transformation of scientific research results, and ensured the rapid development of agricultural production. (Liang. F. J et al, 2022). The biggest advantage of this model is that it can timely transform agricultural technology into agricultural productivity. (Huang. Z et al, 2022). However, the American Trinity mode of promotion has its special preconditions for adaptation, including perfect legal protection, stable source of funds, professional promotion personnel and so on.

Japan is a typical country in which the government helps the people by combining the promotion model with the agricultural association. (Yu. J. Y et al, 2022). A system of agricultural improvement popularization system established by the government and promotion organizations of farmers' groups jointly

providing agricultural technology promotion services. (Wang. H. S, 2022). The National Ministry of Agriculture, Forestry and Fisheries shall, on the basis of the opinions of the governments at all levels, formulate the national agricultural technology popularization guidelines, and the governments at all levels shall, on the basis of the guidelines, formulate specific popularization plans, and the regional popularization and improvement shall be responsible for the organization and implementation of the plans. (Wang. H. s, 2022). Agricultural Cooperative organization is a folk organization to carry out comprehensive service work in rural areas. It plays an extremely important role in the promotion of agricultural technology in Japan, and has distinct characteristics at the same time. (Shao. S. f et al, 2022). There are three characteristics of agricultural technology promotion mode organization in Japan: first, there are relatively perfect agricultural technology promotion service organization; Second, there is a wide range of agricultural technology promotion services; Third, there is a perfect agricultural technology promotion service personnel appointment training system (1) In addition, the agricultural association is also equipped with nutrition instructors, with the government promotion, according to the actual situation of the farmers, research and development of agricultural production and management plan, and give specific guidance, such as help farmers to develop the introduction of low-cost, high-benefit agricultural science and technology achievements, Promoting new varieties and new crop cultivation agricultural technology, formulating reasonable farming system, helping farmers design agricultural management plans aiming at operating income, and providing information and technical guidance to farmers are the forces that cannot be

ignored in the promotion of agricultural science and technology in Japan. In addition, Japan has sufficient funds for the popularization of agricultural science and technology. (Gao. B. L et al, 2022). The government is responsible for the agricultural science and technology popularization system. The central government pays funds for the cooperative agricultural science and technology popularization to all prefectures and counties, and the local government provides a certain proportion of supporting funds to jointly serve as the funds for the local government's popularization and maintain the operation of the agricultural science and technology popularization system.

The Netherlands is the typical representative country of the market-oriented promotion model led by private enterprises. (Ye. Z.C et al, 2022). Private enterprise plays an important role in agricultural promotion. The Dutch agricultural promotion system consists of four parts: national promotion organization, social organization promotion agent, private enterprise promotion agent and farmer cooperative promotion agent. Private promotion agencies refer to some specialized consulting enterprises, technical service departments of enterprises of means of production, etc. In the Netherlands, private promotion agencies employ about 2,000 promotion workers whose main task is to provide agricultural high-tech and professional advice. (Zhu. C. W et al, 2022). The production of flowers and vegetables in the Netherlands accounts for a large proportion of agricultural production. However, the production of such agricultural products requires very complex technologies. In order to win the competition, it is necessary to constantly acquire new technologies and maintain high quality, which is one of the reasons why Dutch farmers can accept private

consulting enterprises. (Chen. J.Y et al, 2021). In the Netherlands, for example, 50 per cent of agricultural production is supplied, which provides its consumers and members with technical information such as the cultivation technique of the seeds sold, their characteristics, the amount and time of application of a particular pesticide, etc.

2.3.2 Chinese agriculture technology promotion mode

At present, the main party of the agricultural technology promotion in our country adopts the professional promotion institution sponsored by the government and a multi-level model of agricultural technology promotion. (Lin. J et al, 2021). In 1993, the implementation of Law of the People's Republic of China on the promotion of Agricultural techniques made Chinese agricultural science and technology promotion career on the legal and enforceable administration track. A non-profit agricultural technology promotion service system dominated by the agricultural sector has taken shape. (Ye. Z.C, 2021). The establishment of the national Promotion Service for Agricultural science and technology in 1995 was the great development of the promotion system construction of agricultural technology. (Peng. S.H et al, 2021). So far, our country has formed the national agricultural technology promotion, provincial, municipal, county agricultural technology promotion, township agricultural technology promotion station five-level agricultural technology promotion organization. Its main characteristics are: first, agricultural technology popularization under the direct leadership of the government; Secondly, agricultural technical popularization institutions at all levels are not only under the leadership of agricultural administrative departments at the same level, but

also under the business guidance of higher promotion institutions. Third, the national agricultural technology promotion institutions, the cooperation of various departments. (Xiang. D et al, 2021).

Agricultural technology promotion mode mainly includes: government-industry-education cooperation promotion mode, science and technology demonstration project and demonstration garden promotion mode, scientific research project driven promotion mode, farmer specialized cooperative promotion mode, etc. (Kong. D. Y et al, 2021).

The government-industry-academia cooperation and promotion model is a model in which the government, enterprises and research institutes work together to transform scientific research results. (Tan. K. J et al, 2020). Chinese agricultural science and technology base and economic base are relatively weak, the degree of industrial is low, and the links between industry, academia and research have not yet been realized, so to successfully transform an agricultural science and technology achievement requires strong government support. (Quan. J.C et al, 2020). Firstly, the government should create a favourable environment for the transformation of scientific and technological achievements by formulating policies, improving the management system, improving project funding and improving the basic environment for attracting investment in science and technology. Secondly, in addition to giving policy preferences to projects with good social benefits, the government also gives direct economic support to those scientific research projects that have obvious social benefits, make significant contributions to the country's economic development and can drive the economic development of a party.

The government-industry-academia cooperation model is one of the effective models for the industrial of agricultural science and technology, and plays an important role in supporting leading agricultural enterprises and real agricultural industrial. (Sun T.H et al, 2020). The three parties in this model are each doing their part, combining the favourable factors of policy, market, management and scientific research, so that many of the links between scientific and technological achievements and their application in the market are smoothly connected, and therefore the success rate of transformation is high.

In recent years, China has invested in many successful agricultural modern demonstration bases and high-tech agricultural science and technology parks, the purpose of which is to incubate, demonstrate and promote the achievements of agricultural science and technology, thus driving farmers to take the road of increasing their income through science and technology. (Wang. Z. l et al, 2020). The aim is to incubate, demonstrate and promote the achievements of agricultural science and technology, thus driving farmers to increase their income through science and technology. (Zhao. Y et al, 2019).In addition, since 2004, the Ministry of Agriculture has organised the "National Agricultural Science and Technology Household Demonstration Project", which is a national agricultural science and technology promotion and demonstration initiative led by the government and organised by experts to deliver science and technology to villages and households and to provide practical science and technology services to farmers, which will certainly have a significant impact on the progress of agricultural science and technology in China. (Huang. X.L et al, 2019). This will have a significant impact on the progress of agricultural science and technology

in China.

The research project-driven promotion model is based on the experts' own scientific research achievements and common problems in rural production, with scientific research projects as the carrier to carry out agricultural technology innovation, technology demonstration and technology promotion work, the project funding sources are government special funds, enterprise research and development funds. The main forms of expression are "experts 10 projects + enterprises" and "experts + projects + farmers". (Ning. J.C et al, 2019).

Cooperative is a new type of rural cooperative economic organise established by farmers engaged in the production and operation of similar agricultural products in order to maintain and their common interests, in accordance with the principles of voluntary mutual benefit and democratic consultation. (Li. S. S et al, 2018). Agricultural cooperatives are a common way to transform agricultural science and technology in foreign countries. (Hou. B.H et al, 2018). With its own unique private, cooperative and professional nature, it provides its members with pre-production, production and post-production services throughout the whole process, solving the problems that the collective economic organise of the community does not get up, that the state economic and technical departments cannot cover, and that the farmers cannot solve alone, and promoting the effect of transformation and agricultural science and technology achievements.

Chinese agricultural science and technology promotion system is a single government-based promotion system based on the agricultural sector formed under the conditions of the planned economy. (Ding. S.M et al, 2018). The

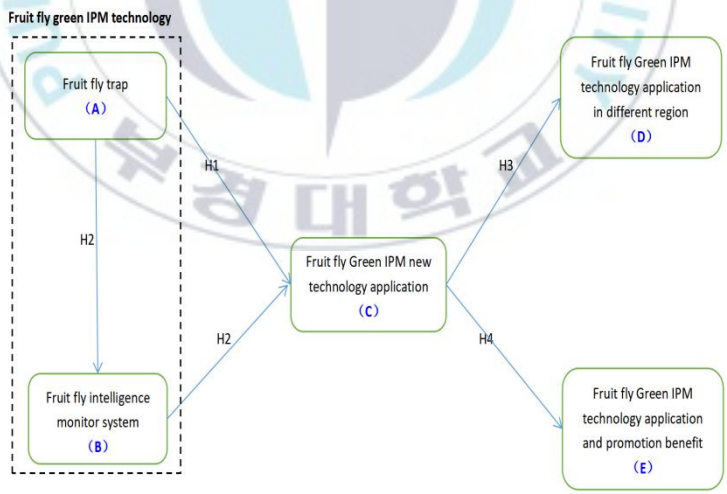
transformation of agricultural science and technology achievements is influenced by the planned economic system, which mainly adopts a plan-based promotion model, with the market playing a minor role in its operation. (Wen. Y et al, 2017). Agricultural technology promotion is in a single form, the means are backward, the mode of operation of the agricultural technology promotion system has not got rid of the administrative compulsory promotion under the era of planned economy, the promotion departments at higher levels to the promotion departments at lower levels, technical guidance in the form of administrative orders, the lack of effective incentive mechanism for the progress of agricultural science and technology, the agricultural technology promotion mechanism is not active, with the development of the socialist market economy, in the face of the new situation and new tasks China's agricultural science and technology promotion mode should also be innovated accordingly to meet the needs of the new era.

III. Research Model and Research Hypothesis

3.1 Research Model

According to our research direction and outline structure,Using a mediation model to modeling the relationship between the five modules, including Fruit fly trap and Fruit fly intelligent monitoring system as independent variables, green IPM technology application as intermediary variables, Fruit fly green IPM technology application in different regions and Fruit fly green IPM technology application benefit as the dependent variable. The specific model is as Figure 3-1.

<Figure 3-1> Research model



In this research model, (1). Fruit fly trap and Fruit fly intelligent monitoring system as independent variables, Impact on Fruit fly green IPM technology

application in different regions and Fruit fly green IPM technology application benefit. Fruit fly trap and Fruit fly intelligent monitoring system through control the number and distribution situation of fruit flies, for subsequent IPM measures to provide basic data and guidance, Thus affecting the implementation and effect of Fruit fly green IPM technology application in different regions and Fruit fly green IPM technology application benefit. (2). Green IPM technology application as intermediary variables, connect the independent variable and dependent variable. Green IPM technology application by providing green fruit flies IPM technology of application solutions and technology to realize to control the number and distribution situation of fruit flies and control effects of ascension, Thus affect Fruit fly green IPM technology application in different regions and Fruit fly green IPM technology application benefit.（3). Fruit fly green IPM technology application in different regions and Fruit fly green IPM technology application benefit as dependent variable, Affected by independent and mediating variables. Fruit fly green IPM technology application in different regions is affected by the intermediary variable and independent variables and, through summarizing the suits in different parts of the control scheme and technical, to realize the green fruit flies IPM technology in different parts of the application. Fruit fly green IPM technology application benefit is affected by the intermediary variable and independent variables and, by evaluating and comparing the control effect and cost-effectiveness, and prove that the application of the green fruit flies control technology to promote economic, social and ecological benefits.

"A" stands for Fruit fly trap, "B" stands for fruit fly intelligent monitor

system, "C" stands for fruit fly green IPM technology application, "D" stands for fruit fly green IPM technology application in different regions, "E" stands for fruit fly green IPM technology application and promotion benefit, and the formula of the mediation model is determined as follows:

$$D = \beta 1 \times A + \beta 2 \times B + \beta 3 \times C + \varepsilon 1$$

$$E = \beta 4 \times A + \beta 5 \times B + \beta 6 \times C + \varepsilon 2$$

Here, β1 to β6 are regression coefficients, and ε1 and ε2 are error terms.

3.2 Research hypothesis

Base on study of Fruit fly in China green IPM technology application, designed the above research model, then raise the below research question and research hypothesis.

3.2.1 Hypothesis green IPM product

a. Lack of mature and highly efficient products

The traditional physical control products used for green IPM in China are mainly insecticidal lamps, yellow and blue boards and sticky tapes, while biological pesticides are mainly emulsion oils, wet powders, powders, granules, water, baits, mother liquids and mother powders, etc.

Since the introduction of insect traps into China around 2000, the research and development and promotion of various pest traps based on insect pheromones has been repeatedly listed as a key project in the national science and technology plan, and great progress has been made in the application technology of pheromone traps. (Wei. B et al, 2017). However, the types of traps used in the field have been relatively simple, mainly because: (1) traps usually

focus on trapping males, and the basic principle is to reduce the density of the insect population by reducing the chance of mating between males and females, which usually leads to a limited trapping effect and a slow decline in the density of the insect population, and the trapping effect is not obvious; (2) the original liquid of the pheromone trap core is not pure enough, which leads to an inconspicuous trapping effect on the pest; ((3) The choice of slow-release carriers is mainly based on vulcanization rubber with a short slow-release cycle, which often misses the best trapping time because of the inability to grasp the time for pests, resulting in poor trapping effects. Although these traps have been effective in green IPM, they are not effective in trapping, are not mature and efficient, and have limitations in terms of the types of pests they can control and the areas in which they can be used, so they do not form a relatively mature, stable and efficient product specifically for fruit flies.

b. The product cannot be stored and transported at room temperature

The pheromone in a trap is a polymer compound that is suitable for storage in a frozen environment. Because of its product characteristics, the pheromone is prone to volatility in storage and transport, which has been an important factor limiting the development of a large number of trap products, including fruit fly traps, and applications. (He. Y. B et al, 2017). As the pheromone itself is active, temperature, humidity, light, rainfall and wind can all have an impact on it, which in turn can cause the activity of the pheromone trap core to decline and lose its effectiveness. During the period of occurrence of the fruit fly, the appropriate temperature for its growth and reproduction is within the range of 20-35 degrees. However, the pheromone traps can lose their activity if stored at

room temperature for a number of reasons, so the original pheromone trap solution is usually stored frozen (-10 to -20 degrees). For field application, the pheromone cartridges should be removed from the freezer and placed in the trap for use. As the period of fruit fly control is mostly in the summer, the need to keep the stock solution frozen makes transporting it a lot more difficult. In addition, as pheromone traps should not be stored at room temperature for long periods of time, this also causes inconvenience to the user and restricts the application of the traps over long distances and large areas.

c. Product production standards for fruit fly traps need to be developed

Product standards are the basis for guiding the production and operation of products. (Liu. A et al, 2017). In China, national, industry and local standards are issued to specify the technical requirements and test methods for various products, and where these standards are not yet available, enterprise standards should be developed in accordance with relevant laws and regulations. (Yao. M. Y et al, 2017). Each trap product has specific quality indicators according to its performance, such as purity of pheromones, trap characteristics, specificity, storage stability, etc.

The common domestic fruit fly trap is a new type of fruit fly green control product, although it has entered the pilot mass production stage and has been developed product enterprise standards, but there has not been a set of product standards after the technical supervision department for the record.

d. Fruit fly trap products need enter into market

According to the Pesticide Law of the People's Republic of China, the production and operation of pesticides, veterinary drugs, feed and feed additives,

fertilizers, seeds, agricultural machinery and other agricultural production materials that may endanger the safety of humans and animals shall be subject to a registration or licensing system in accordance with the relevant laws and administrative regulation. (Li. D.Q et al, 2017). At present, the Ministry of Agriculture and Rural Development has a record-keeping system for trap products until formal national registration regulations are in place. As the development of the application of fruit fly traps has been at the stage of experimental demonstration and pilot production, and the degree of market is low, patent applications and trademark registration should be strengthened to carry out the process of commercial development of the products.

H1: Fruit fly trap as a kind of fruit fly green IPM technology has positive effect for fruit fly green IPM.

3.2.2 Hypothesis on intelligent monitoring system

The main problems in Fruit fly in China monitoring are backward survey means, non-standard data reporting and poor accuracy. The current monitoring and investigation mean and equipment cannot effectively solve the problem of backward survey means of wild fruit fly situation. It could not standardize and unify the field information questionnaire and effectively solve the problem of non-standard information data among the county, city, province and national fruit fly control department (Li. L et al, 2017). The data collection system of fly information can't effectively solve the problem of poor accuracy of fly information. It can't solve the problem of information management in the process of physical and chemical bait and control, form a perfect control

system of fruit flies, effectively locate the occurrence of fruit flies, quickly obtain the area and degree of the occurrence of fruit flies, and provide decision support for the selection of appropriate control opportunities and methods. Specific problems are described as follows.

a. The means of field investigation are backward

The traditional methods of investigating the occurrence of fruit flies mainly rely on manual collection and document management. (Wang. T et al, 2016). Investigators need to fill out paper investigation forms in the field, record the insect situation information, input the data into the computer, and report it to the superior authorities through email. It is necessary to carry a large number of paper forms during field investigation. It is easy to fill in the information of fruit fly occurrence area, which will cause confusion and heavy workload at the grass-roots level. The lack of effective means of information collection of fruit fly is not conducive to simple, timely and accurate reporting of fruit fly occurrence and control information. The delay of the optimal control time will affect the control effect, and is not conducive to the timely and effective exchange of information, allocation of resources and prevention of fruit fly infestation in the whole country.

b. The reported data is abnormal

Fruit fly in China occurrence area is large and widely distributed,

involving more than 20 provinces and more than 700 counties. (Gao. Y. H et al, 2016). In addition, the principle of territorial management and hierarchical responsibility leads to the fact that the fruit fly areas and provinces are independent. The collection and reporting of fruit fly information has not formed a relatively unified standard format, and there are often non-standard data reported by different people and different regions, and the standardization of information is low. (Wu. L. et al, 2016). The information transmission and sharing among county, city, province and national fruit fly control were severely restricted. Although some provinces and regions have a certain number of monitoring and investigation norms for fruit fly pests, due to the lack of unified customized report formats, the degree of freedom of monitoring and investigation is relatively large, which affects the breadth, depth, quality, interest rate and comparability of data collection, affects the utilization efficiency of monitoring and early warning data, and makes it difficult to realize information sharing and interconnection, which is not conducive to improving the timeliness of fruit fly control. And to achieve the national fruit fly control work top-down unified management.

c. The reported data is inaccurate

The accuracy of the reported data of the survey of fruit flies is poor, and the geographical location information is missing, including the occurrence area of flies in the jurisdiction, the specific location of fruit flies, and the obstacles in the occurrence area, etc. Due to the inability to accurately grasp

the geographical information data and distribution of fruit flies in the region, it is difficult to timely grasp the change situation of fruit flies in the region, and realize the occurrence situation of fruit flies and the dynamic monitoring of fruit flies in the region. (Li. L et al, 2016).

Fruit Flies have the characteristics of strong migration, sudden and fulminant occurrence. (Li. C et al, 2016). Many major fruit fly areas have adopted flight control and large vehicle spraying equipment to carry out control work. Due to the strong mobility of fruit flying control and vehicles, the geographical information of fruit fly area is particularly important in the control work, which can avoid the occurrence of leakage and repeated spraying and reduce the use of pesticides and pollution to non-targets.

H2：Fruit fly intelligent monitor system as technology has positive effect for fruit fly green IPM.

3.2.3 Hypothesis on green IPM technology application in different region

a. Single usage mode

In recent years, China has developed a variety of green IPM technologies such as ecological control, biological control, natural enemy protection and utilization, but only using a single technology mode, the control effect is not ideal. (Tang. J. Q et al, 2016). For example, although the artificial protection and utilization of parasitic wasps to attract fruit flies in Guangxi have achieved

certain control effects, due to the rich species of parasitic wasps, if the selected parasitic wasps do not match the pest species of fruit flies, the parasitic wasps may fly out of fruit fly epidemic area, resulting in the loss of control of local fruit flies.

b. The use is not targeted

The geographical situation of pestilence region of fruit fly is complicated. The ecological environment and the occurrence characteristics of fruit fly in some main fruit fly areas are different, and the personnel, technical strength and the facilities for control of fruit fly in different areas also have great differences. (LI.D.Q et al, 2016). It is necessary to organically integrate and assemble existing green control technologies, such as new bio-pesticides, behaviour control products and information systems, according to the characteristics of different fly regions, and establish regional green fly control technology models according to local conditions, so as to improve control efficiency and achieve sustainable control of fly pests in China.

c. The scale of use is not large

At present, due to the low enthusiasm of users, the defects of the technology or the difficulties in application, some green technologies for control and prevention of fruit flies are difficult to be applied in production, and the scale of promotion is not large. (Zhang. X. M et al, 2015). For example, the ecological control technology of planting plants that the flies do not like to eat is applied to control the occurrence of fruit flies by reforming the breeding ground of fruit flies. However, the ecological control technology is difficult to be widely applied due to the high cost and technical difficulty.

d. Not much attention

Although new green IPM technologies such as physical and chemical control, ecological control, biological control, and natural enemies protection and utilization have been popularized in recent years, local governments still do not pay enough attention to green IPM technologies, coupled with the lack of sustained policy and financial support, leading to slow progress in green IPM. (Guo. X.Q, 2022). The green IPM area in some fruit fly epidemic areas accounts for less than 20% of the total control area.

H3: Fruit fly green IPM technology application has positive effect in Chinese different region.

3.2.4 Hypothesis on green IPM technology application and promotion benefit

a. Lack of cohesion between research and promotion

China is a traditionally agricultural country and the country attaches great importance to agricultural science and technology research at all levels, from central to local governments. (Zheng. W. Y et al, 2018). According to incomplete statistics, since the reform and opening up of China, from 1979 to 1998 alone, more than 50,000 scientific and technological achievements have been validated by the central government and the provinces, autonomous regions and municipalities directly under the Central Government, and these achievements have played a huge role in helping China's economic development. (Ran. L. Y et al, 2014). At the same time, however, not enough attention has been paid to the promotion of agricultural science and technology, especially the

"last mile" of the results, which is lacking. At present, the funding for agricultural science and technology promotion in China is only 0.125% of the total agricultural output value, and the ratio of promotion funding to research funding is 1:2, far below the World Bank's standard recommendation that "agricultural science and technology promotion funding in less developed countries should account for 1-2% of the total agricultural output value, and promotion funding should be higher than research funding".

In addition, the general problems of agricultural scientific research in China are: the selection of scientific research topics is not highly targeted, the direction of research objectives is relatively single, the scope of research is narrow, and the exploration and improvement of theoretical science and technology are pursued too much, but the practical technology research at the application level is often neglected, resulting in a disconnect between agricultural scientific research and technology application and promotion, the interface between scientific research objectives and the needs of the market is not This has resulted in a disconnect between agricultural scientific research and technology application and promotion, and a lack of connection between the objectives of scientific research and the needs of the market. (Liu. D. Z et al, 2022). In addition, agricultural technology promotion departments usually fail to provide timely and accurate feedback to scientific research departments on the practical scientific and technological information urgently needed in the production line, which also leads to a serious disconnect between scientific research and promotion and application.

b. Weakness of fruit fly green IPM technology promotion power and

participant uncultured

Fruit fly green IPM technology promotion as one of agricultural technology promotion, force and the quality of agricultural technology promotion practitioners is one of the basic elements that directly affects the effectiveness of agricultural technology promotion, and is also fundamental to good agricultural technology promotion work. (Gong. B. Y et al, 2019). At present, the construction of agricultural technology extension teams in most of China's agricultural regions, there are still many problems, even after the reform and opening up, the rapid economic development of more than 40 years, the construction of agricultural science and technology extension system is also repeatedly frustrated, although the state has repeatedly issued a notice requiring the stabilization of the agricultural technology extension system, but the influence of economic interests and the special nature of the work engaged in agricultural extension The situation of "broken threads, broken nets and scattered people" has not been able to change substantially. In particular, in the vast rural areas, because of the small number of front-line agricultural extension personnel, poor quality and low skills, and because of the imbalance in geographical economic development, which has led to an extremely unreasonable distribution of personnel directly engaged in agricultural extension, with more practitioners at the upper and middle levels and fewer at the grassroots level, showing an inverted pyramid structure of practitioners, resulting in the phenomenon of one person and one station at the township level agricultural extension station is quite common, resulting in agricultural technology The last kilometre of the promotion process is not implemented frequently. (LI.Y.F et al, 2019). In addition, from the

perspective of the comprehensive quality of agricultural extension personnel, due to the unbalanced distribution system in the past decades, resulting in a large proportion of low-education practitioners, a considerable number of front-line agricultural extension personnel generally have narrow knowledge, serious aging knowledge and untimely updates, difficult to adapt to the challenges of economic and technological development in the new era, it is difficult to take up the task of disseminating and promoting advanced agricultural technology knowledge, which will inevitably This is bound to seriously affect the development of agricultural technology extension work at the grassroots level and the transformation of new technical achievements on the ground.

c.Inadequate service of fruit fly green IPM technology promotion

Chinese agriculture technology promotion mode developed under the planned economic system is mainly a government action, and the promotion of agricultural technology at the grassroots level is often superficial, such as conveying policies and ideas, and does not provide comprehensive agricultural technology services to users. (Xiao. X. H et al, 2018). Fruit fly green IPM technology application and promotion face to same questions. The promotion work only focuses on the technology itself, "seeing things but not people", and scientific researchers rarely participate directly in the application of agricultural technology, resulting in the extension of the promotion cycle of scientific and technological achievements and the time required for information feedback, and the application of new technologies cannot be rapidly and effectively transformed from potential productivity to real productivity, reducing the agricultural productivity of new technologies.(Chen. Z.Z, 2018). This reduces

the agricultural productivity of new technologies and does not fully reflect the value of agricultural science and technology achievements.

d.Simplification of fruit fly green IPM technology promotion mode

Fruit fly green IPM technology promotion as one of agriculture technology promotion work is an important part of applying advanced technological achievements to production and transforming them into real productivity, and is an important measure to promote agriculture through science and technology. It is an important measure to promote agriculture through science and technology. (Xiao. X.H, 2018).The construction of an agricultural technology promotion model is the organizational guarantee for good promotion work and the basis for completing the functional tasks of promotion work.

For a long time, agricultural promotion in China has mainly been carried out in the form of administrative orders issued from top to bottom, with a single form of agricultural extension and backward means. The mode of operation of the agricultural extension system is not free from the administrative compulsions of the planned economic, but with the establishment of the socialist market economy, the agricultural promotion mode has to be innovated to meet the needs of the new era. (Chen. Z. Z et al, 2017). In 2006, the State Council issued the Opinions on Deepening Reform and Strengthening the Construction of Grassroots Agricultural Technology Promotion System, and the Ministry of Agriculture issued the Opinions on Implementing the Opinions of the State Council on Deepening Reform and Strengthening the Construction of Grassroots Agricultural Technology Promotion System, which successively proposed the gradual construction of a "diversified grassroots agricultural technology

promotion system" and the "cultivation of diversified services". "The Ministry of Agriculture issued the Opinions on Implementing the State Council's Opinions on Deepening Reform and Strengthening the Construction of the Grassroots Agricultural Technology Extension System, which put forward the requirements of gradually building a diversified grassroots agricultural technology extension system and fostering diversified service organizations.

H4: Fruit fly green IPM technology promotion has positive effect for Economic, Social and Ecological benefit.

IV. Experimental design and data collection, analysis, verification

4.1 R&D of fruit fly trap products

Fruit fly trap is a kind of effective green IPM products. Through the analysis of the problems faced in the application of the fruit fly trap, the research determined the type and content of pheromones in the fruit fly pheromone trap, and determined the best slow release carrier, and the carriers used were all green products to verify the stability of the fruit fly trap at room temperature; compiled product standards for the fruit fly trap, all technical indicators conform to the relevant national standards and passed the record of the State Technical Supervision Department; compiled patent registration materials for the fruit fly trap, and obtained the patent registration certificate from the State Intellectual Property Office.

The formulation of the pheromone cores in the fruit fly trap was clarified through the design of the formulation, and the cores were tested for indoor activity and field efficacy, both of which achieved satisfactory results, indicating that the pheromone cores used are green products and have no effect on the activity of the fruit fly trap.

4.1.1 Experimental design

A mature fruit fly trap products base on pheromone needs to have the following characteristics:

1). Conform to the light and simplified characteristics of field suspension,

technical simplicity and ease of use;

2). Using as little active ingredient as possible to evenly disperse to the surface or space where the application object is located, so that the full effect of the drug can be achieved and as many adult insects as possible can be trapped;

3). safer use, reduce crop damage, reduce the chance of poisoning of humans, animals and non-target organisms and pollution of the environment;

4). Improved the stability of active ingredients and prolong the efficacy period;

5). Easy to pack, store and transport and sell. (Yi. J. P et al, 2015).

4.1.2 Experimental data collection, analysis

a. Materials and methods

1). Test site

The trial site was Agrodogan Sharing Farm, Qifang Town, Baisha Li Autonomous County, Hainan Province (109.24°E,19.29°N), with an orchard area of 3.6hm, 2-3 years old, clay loam soil, medium fertility and normal management.

2). Test material

The test materials were “Ceranock” fruit fly sex traps (Qingdao Russell Biotechnology Co., Ltd.), fruit fly traps (Qingdao Russell Biotechnology Co., Ltd.), methyl eugenol (Jiangxi Yisenyuan Plant Spice Co., Ltd.) and yellow boards (Ye Chuan Insect Control Technology Co., Ltd.).

3). Experimental method

The experiment was conducted from March 12 to October 29, 2021, with five experimental groups. Group 1: experimental group of “Ceranock” trap cores;

Group 2: “Ceranock” trap cores + barrel traps; Group 3: yellow boards; Group 4: 95% methyl eugenol and barrel traps; Group 5: blank trap cores and barrel traps. The experimental groups were spaced 30 m apart on branches of fruit trees about 80 cm above the ground. three replicates were set up in each group with a spacing of 10 m between each replicate, and the number of orange fruit flies in each trap and on the sticky board was observed and recorded every 7 days, and the sticky board was replaced, and the trap cores were replaced every 30 days.

4). Statistical analysis

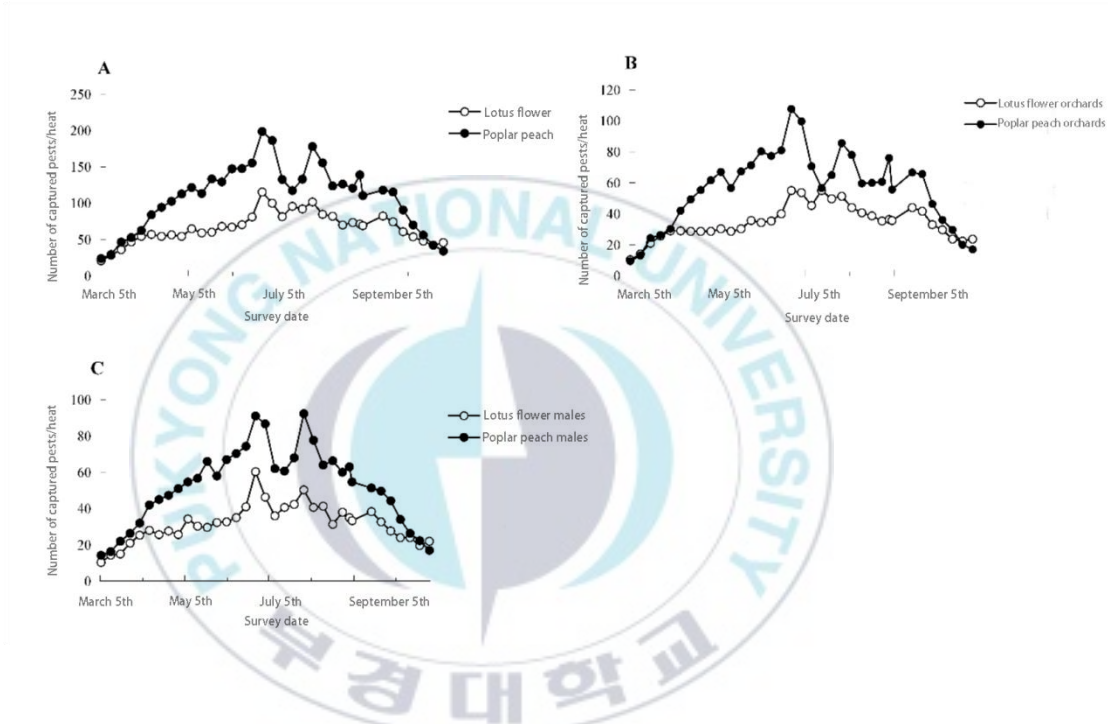
The data were analysis by one-way ANOVA using SPSS21.0 software, and the LSD method was used to test the significance of differences; the dynamic parameters of the orange fly population were plotted using SigmPlot 12.5.

b. Results and analysis

1). Trap dynamics of the orange fly in different orchards

The trapping numbers of Drosophila oranges in the poplar peach and lotus flower orchards of Agrodogan Sharing Farm in Baisha region fluctuated over time, as shown in Figure 1, with three distinct peak periods: the trapping numbers in the poplar peach orchard peaked on June 25, July 30 and September 1, and those in the lotus flower orchard peaked on June 25, July 30 and September 17. The total number of orange fly females and males, as well as the total number of insects trapped in the poplar peach orchard was significantly higher than the total number of female flies trapped in the Wax-apple orchard ($P<0.05$).

<Figure 4-1> Dynamic of attractive effect on *Bactrocera dorsalis* Hendel in carambola garden wax-apple garden



Note: The dynamic of the total trapping amount of *dorsalis* Hendel from March to November, B was the dynamic of the total trapping amount of female *dorsalis* Hendel, C was the dynamic of the total trapping amount of male *dorsalis* Hendel.

<Table 4-1> The trapping effect on Bactrocera (Hendel) and its female and male in carambola garden wax-apple garden

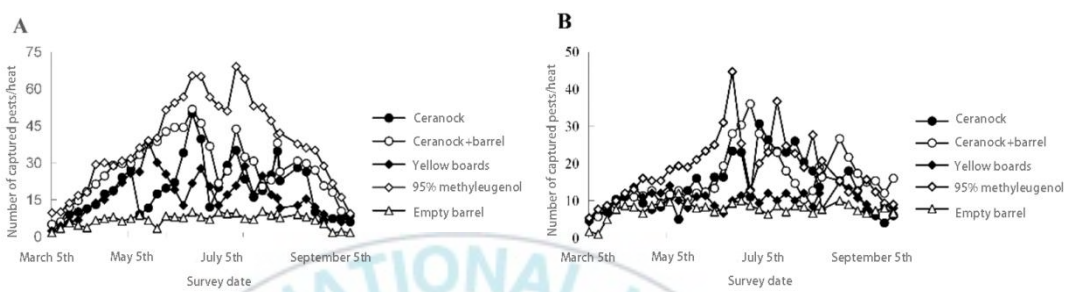
Park type	Total entrapment	Total number of female flies trapped	Total number of male flies trapped	Percentage of females
Carambola garden	108.69±7.60 a	56.27±4.09 a	52.42±3.58 a	51.77%
Wax apple garden	66.30±3.53 b	34.52±1.85 b	31.78±1.75 b	52.07%

Note: The data in the table is an average of 3 replicates. The same letter on the same column in the table shows no significant difference, but the different letters show significant difference (P < 0.05).

2). Trap effect of different treatments on Drosophila melanogaster

The number of fruit flies trapped in the poplar peach orchard population under different treatments fluctuated over time, as shown in Figure 2A. The maximum number of insects trapped was 51 when the “Ceranock” was placed in a barrel trap for combined trapping. A maximum of 51 insects were trapped using yellow boards for orange fly. A maximum of 69 insects were trapped in a combination of 95% methyleugenol and barrel traps. There was no significant peak when trapping with the barrel trap alone.

<Figure 4-2> Dynamic of attractive effect of different cored treatment on *Bactrocera dorsalis* Hendel in carambola garden



Note: A was the dynamic of flies in carambola garden, B was the dynamic of flies in wax-apple garden

The trapping of fruit fly populations in lotus gardens showed fluctuations in the number of traps over time, as shown in Figure 2B, and it was found that the maximum number of traps was 30 when trapping with the “Ceranock” trap. The maximum number of insects trapped was 36 when the “Ceranock” was placed in a barrel trap for combined trapping. Up to 15 insects were trapped using yellow boards for orange fly. A maximum of 44 insects were trapped in a combination of 95% methyleugenol and barrel traps for Drosophila melanogaster. There were no significant peaks when trapping with barrel traps alone.

In both the poplar and lotus orchards, there were significant differences in the trapping effect of the different treatments on Drosophila melanogaster (P=0.000), as shown in Table 2, with the 95% methyl eugenol treatment having

the highest traps, “Ceranock” combined with barrel traps having the second highest traps, higher traps than “Ceranock” alone, higher traps than yellow boards and the blank barrel traps having the lowest trap.

<Table 4-2> The trapping effect of different cored treatment on *Bactrocera* Hendel in carambola garden wax-apple garden

Treatment	carambola garden	wax-apple garden
Blank barrel trap	225.67±4.10 e	263.67±1.20 e
Yellow board	557.33±0.67 d	345.33±8.02 d
Ceranock	654.33±4.37 c	469.67±8.57 c
Ceranock+Barrel trap	953.00±12.49 b	549.00±4.04 b
95% Methyleugenol	1287.33±4.98 a	623.00±0.58 a

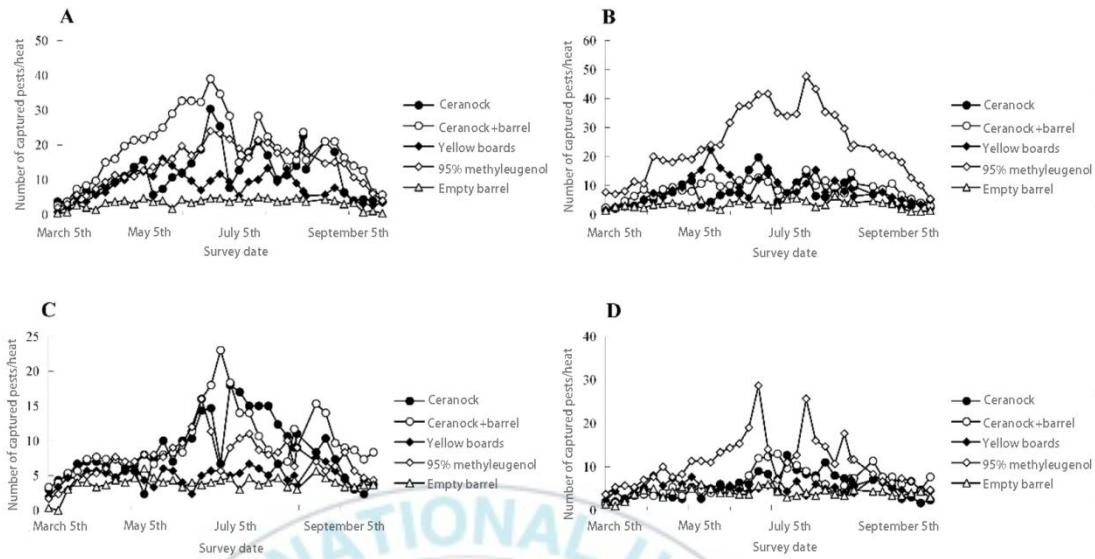
Note: The data in the table is an average of 3 replicates.The same letter on the same column in the table shows no significant difference, but the different letters show significant difference (P < 0.05).

3). Trapping effects of different treatments on male and female orange fruit flies

From March to November 2021, the number of flies trapped fluctuated over time when trapping with the “Ceranock” trap in the popcorn orchard at Agrodogan Shared Farm in the White Sands area, as shown in Figure 3, with a maximum of 30 flies for females and 19 flies for males. The maximum number of flies trapped was 39 for females and 13 for males when the “Ceranock” was placed in a barrel trap for combined trapping. When trapping female Drosophila Hendel fruit flies using yellow boards, the maximum number of flies trapped was

16 for females and 22 for males. When 95% methyleugenol was used in combination with the barrel trap, the maximum number of flies trapped was 24 for females and 47 for males. There were no significant peaks when the barrel trap was used alone for trapping. In the Lotus Garden, the maximum number of flies trapped was 18 for females and 12 for males when trapped in the “Ceranock” trap. Combined trapping with “Ceranock” in barrel traps resulted in a maximum of 23 flies for females and 22 flies for males. When trapping with yellow boards, the maximum number of flies trapped was 7 for females and there was no significant peak for males. When 95% methyl eugenol and barrel traps were used in combination, the maximum number of flies trapped was 16 for females and 28 for males. There were no significant peaks when trapping with the barrel trap alone.

<Figure.4-3> Dynamic of trapping female and male *Bactrocera Dorsalis* Hendel in carambola garden and wax-apple garden with different trapping cores



Note:A was the dynamic of female flies in carambola garden, B was the dynamic of male flies in carambola garden, C was the dynamic of female flies in wax-apple garden, D was the dynamic of male flies in wax-apple garden.

The trapping effect on female Drosophila melanogaster flies was significantly different (p=0.000) in the poplar orchard after different treatments, as shown in Table 3, with “Ceranock” combined with the barrel trap having the highest trapping effect on female Drosophila melanogaster flies and “Ceranock” alone having the second highest trapping effect on female Drosophila melanogaster flies. 95% methyl- eugenol had the highest trapping effect on male fruit flies and 95% methyl eugenol had the second highest trapping effect on male flies. “Ceranock” combined with the barrel trap gave the next highest lure levels for male Drosophila melanogaster. Significant differences were found between “Ceranock”, “Ceranock” combined with barrel traps and 95% methyl

eugenol treatments for both female and male Drosophila, with “Ceranock” and “Ceranock” combined with barrel traps having the highest female trap catches and the highest percentage of females (68.84%) and 95% methyl eugenol having the highest male trap catches and the lowest percentage of females (36.54%).

Significant differences (P=0.000) were found in the trapping levels of female flies in lotus gardens, with “Ceranock” combined with barrel traps having the highest levels of female fruit flies and “Ceranock” alone and 95% methyl eugenol having the second highest levels of female flies. 95% methyleugenol had the highest levels of male flies and “Ceranock” combined with barrel traps had the second highest levels of male flies. The second highest numbers of male flies were trapped with the “Ceranock” combined barrel trap. Significant differences were found between the treatments of “Ceranock”, “Ceranock” combined with barrel traps, 95% methyleugenol and blank barrel traps for both female and male flies of Drosophila Helen, with “Ceranock” combined with barrel traps having the highest female traps with the highest percentage of females (60.84%), 95% methyleugenol having the highest male traps and the yellow board treatment having the lowest percentage of females (48.36%) .

<Table. 4-3> Trapping effect and proportion of female and male *Bactrocera* Hendel in carambola garden wax-apple garden

Treatment	carambola garden			wax-apple garden		
	Female	male	(♂/♀) Sex ratio	female	male	(♂/♀) Sex ratio
Blank barrel trap	111.00±1.15Ad	114.67±2.96Ac	49.19%	128.67±0.67Ac	135.00±1.53Bc	48.80%
Yellow board	266.44±11.95Ac	290.89±11.84Ab	47.81%	167.00±5.51Ac	178.33±9.77Abc	48.36%
Ceranock	405.67±20.27Ab	248.67±15.90Bb	62.00%	288.67±15.71Ab	181.00±8.39Bbc	61.46%
Ceranock+Barrel trap	656.00±37.99Aa	297.00±28.62Bb	68.84%	334.00±14.64Aa	215.00±16.09Bb	60.84%
95% Methyleugenol	470.33±50.77Ab	817.00±51.08Ba	36.54%	251.33±23.02Ab	371.67±23.47Ba	59.66%

Note: The data in the table is an average of 3 replicate. The same letters in the same column showed no significant difference, while different letters showed significant difference ($p < 0.01$). Lowercase letters indicate differences in the same set of different letters, and low case letters indicate differences between females and males treated with the same lure.

4.1.3 Experimental verification

From March to November 2021, three generations of Drosophila occurred in both poplar peach and lotus flower gardens, with the number of insects trapped in both poplar peach and lotus flower gardens reaching a peak around 25 June. The dynamics of the female population of Drosophila showed similar fluctuations to those of the total population of Drosophila, and the use of “Ceranock” in the gardens is of great importance in controlling the population base of the next generation and the large number of infestations of Drosophila.

Different treatments showed different trapping patterns for both male and

female flies in different orchards. In the poppy orchard, after different core treatments, “Ceranock” combined with the barrel trap showed the highest trapping rate and the best trapping effect on the female flies. The trapping effect of “Ceranock” alone was lower than that of 95% methyleugenol for female flies and was the second most effective. Yellow boards were more effective than barrel traps alone. Ceranock in combination with the barrel trap had the highest percentage of females and better control of the next population base of Drosophila. The highest trapping rate and the best trapping effect were achieved with 95% methyleugenol for male fruit flies, followed by “Ceranock” combined with barrel traps and yellow boards. In lotus gardens the “Ceranock” combined with barrel traps had the highest trap load and the best trapping effect on the female orange fly. “Ceranock” alone was the second most effective, and 95% methyl eugenol was more effective than yellow boards and more effective than blank barrel traps. The male flies of Drosophila were trapped in the highest quantity with 95% methyleugenol, followed by “Ceranock” in combination with barrel trap, which was better than the yellow board and better than blank barrel trap.

In the daily production process, “Ceranock”, whether used alone or in combination with barrel traps, has almost no contact with people and fruit, and does not cause any pesticide residues, laying a solid foundation for the pollution-free, green and healthy development of tropical fruits. In terms of operation, in terms of trap assembly and hanging, fruit farmers can master and proficiently apply it with simple training or by reading the instructions for use by themselves, which is highly operable, convenient and can be promoted and

applied in a large area.

H1: Hypothesis is true. Fruit fly trap as a kind of fruit fly green IPM technology has positive effect for fruit fly green IPM.

4.2 R&D of intelligent monitor technology

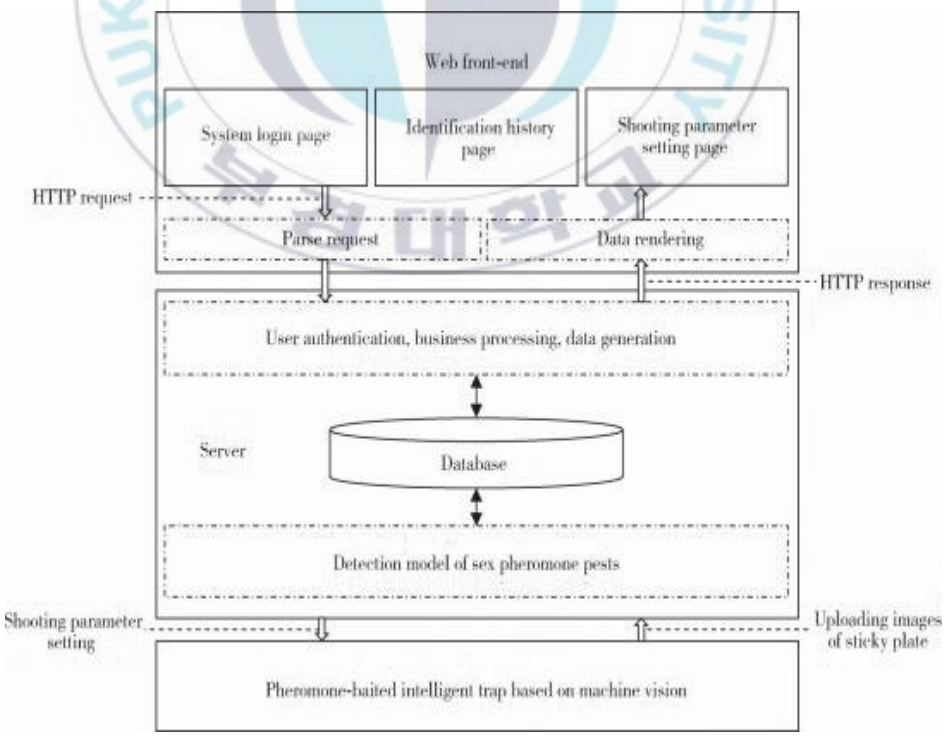
Intelligent monitor technology also is a kind of new green IPM technology was used in fruit fly. By intelligent monitor technology, we can easy to achieve the fruit fly occur situation.

4.2.1 Design of intelligent monitor system

Intelligent monitoring system for fruit fly sex attraction: The intelligent trap based on machine vision takes real-time fly images, and uploads the images to the cloud server through the 4G operator network. After receiving the images, the server calls the fruit fly detection model, saves the detection results to the database, and sends them to the front end of the Web, which is convenient for the detection personnel to view the historical images and model detection results, and realizes the data traceability. In order to facilitate the management of the system and reduce the coupling degree, the front and back separation architecture mode is used for system design. The background of the system is realized by the architecture pattern of MTV and the open Web application framework Django. The database is established by MySQL, the most widely used relational database at present. (Han. T et al, 2022). The front end of the Web is designed with Vue frame, which is conducive to using JavaScript for front-end data interaction and processing, and HTML and CSS for page rendering. The Web front-end applies

to the background for Web data (including login interface, identification history interface, etc. Through Axios network request based on HTTP protocol. After receiving the request, the system back-end conducts background business processing operations such as request parsing and user authentication, and generates response data to return to the Web front-end. The Web front-end analyzes the response data twice and renders it to the browser interface to realize the interface display of the monitoring results of fruit fly sex attraction. The system technical flowchart as below.

<Figure 4-4> Technical flowchart of the pheromone-baited intelligent monitoring system of fruit fly



4.2.2 Intelligent monitor system experimental data collection and analysis

a. Materials and methods

1) Intelligent trap based on machine vision: Intelligent trap based on machine vision mainly includes fixed focus industrial camera, LED surface light source, glue insect board, solar panel and Android tablet equipped with image 4G transmission module. The trap area is designed as a narrow entrance, with a rain shield above to keep out the rain, a trap plate and sex attractant below, and a baffle and rain shield around to prevent pests from entering the trap area and escaping. The camera takes an image of the insect glue board, and the tablet uploads the image to a cloud server. According to the uploaded images, the surveyors check the adhesion of pests on the insect glue board and decide whether to replace the insect glue board.

2) Image data setting: The intelligent trap was installed in the Agrodogan Test base in Baisha County, Hainan province (109.24°E,19.29°N), and the lure core was the sexual attractant of dorsalis (Qingdao Russell Biotechnology Co., LTD.). From 2020 to 2021, a total of 712 images containing sexual pests were collected, with an image size of 3 840 × 2 748 pixels. The images of adult flies were divided into training set and test set in a ratio of 8∶2. The Label annotation tool was used to calibrate the pest in the training set image, and the classification information and coordinate information of the annotation area were saved in the corresponding XML file. Due to the specificity and adhesive effect of sex attractant, in addition to the target insect flies, the insect glue board may also contain some non-lepidopteran insects such as beetles and mosquitoes,

which are very different from the fruit flies, making the background of the insect glue board complicated. At the same time, it may also attract unknown lepidopteran pests such as Spodoptera and other insects, which can easily cause mutual false detection between these pests and fruit flies. In this study, these lepidopteran pests are called disturbance pests.

<Table 4-4> Trapped fruit fly data information

Datasets		Fruit fly	Insect pests of disturbance
Training sets	Number of images	569	238
	Number of insect pests	1627	124
Test sets	Number of images	143	58
	Number of insect pests	413	35
Average number of object insect pests per image		2.87	0.54

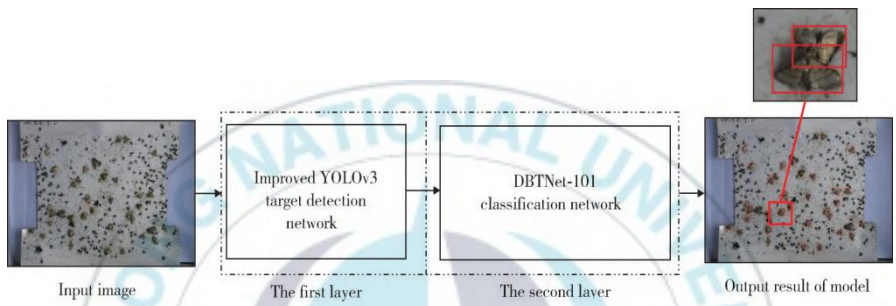
3) Image data enhancement: In order to improve the robustness and generalization ability of the fly detection model, OpenCV algorithm was used to enhance the image data, including four methods: horizontal image inversion, 90° clockwise rotation, image averaging and Gaussian noise addition (Lee, 1980). Training sample size increased by 4 times.

b. Automatic fruit fly detection model

1) Two-layer structure target detection model: The automatic detection model of fruit fly adopts the two-layer network structure. The first layer is the modified YOLOv3 fly detection model. After the images of sexual attraction pests are input into the network, the specific coordinates and classification confidence sets of the regression boxes of fly and disturbance pests are obtained. In order to reduce the mutual misjudgment between target pests and disturbing

pests, a second layer of fine-grained image classification network DBTNet-101 was added to carry out secondary recognition of pest images in the detection box of the first layer, so as to improve the accuracy of fly detection and recognition as Figure 4-5.

<Figure 4-5> Framework of the two-layer network detection model of fruit fly

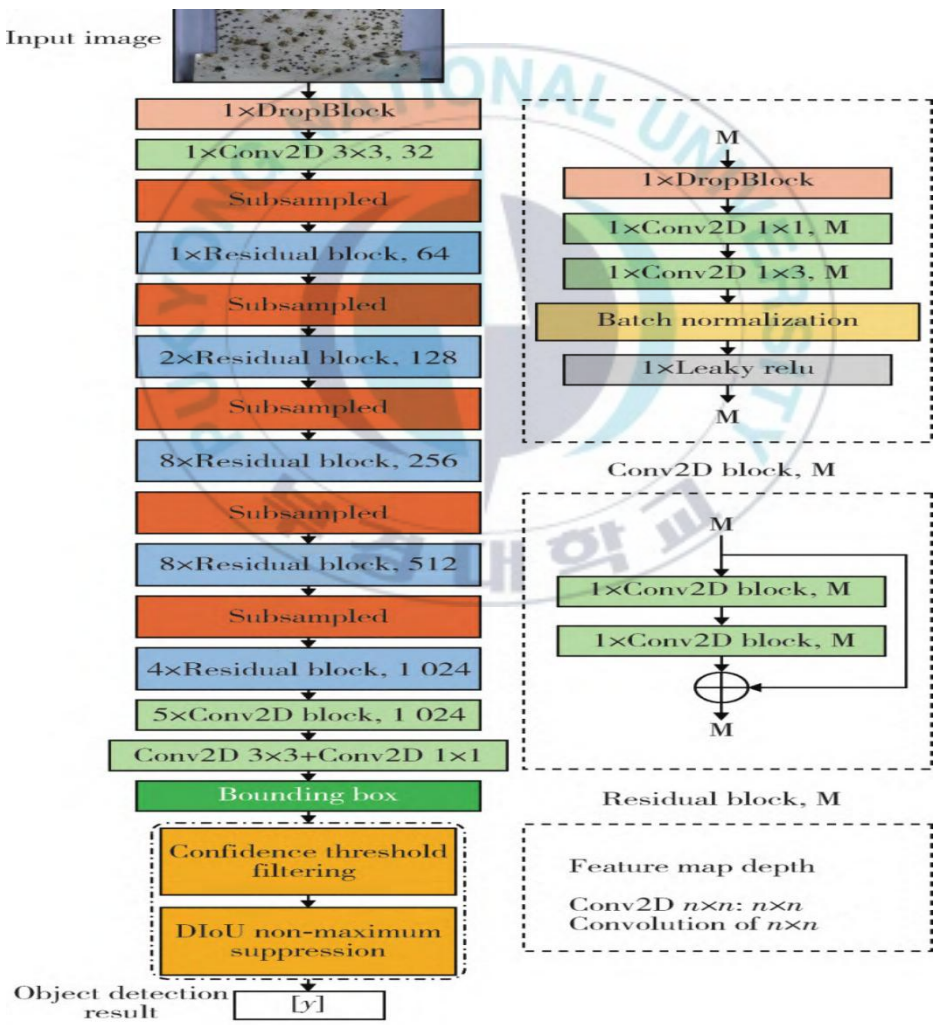


2) Improved YOLOv3 sexual attraction pest detection model: Typical single-stage target detection models include the YOLO line. The YOLOv3 detection model is composed of feature extraction network Darknet-53 and up-sampling feature fusion module. During detection, anchor points, target classification and location information in the anchor point frame are determined through the convolution layer in Darknet-53. The up sampled feature fusion module can output the prediction results at three scales, which can improve the problem of feature loss for small targets at a single scale, and obtain better detection results for larger targets as Figure 4-6.

Due to the complex background of the image of sexual attraction pests, the YOLOv3 model was directly used for the detection of fruit flies, and there were problems of mutual false detection between target pests and interfering insects

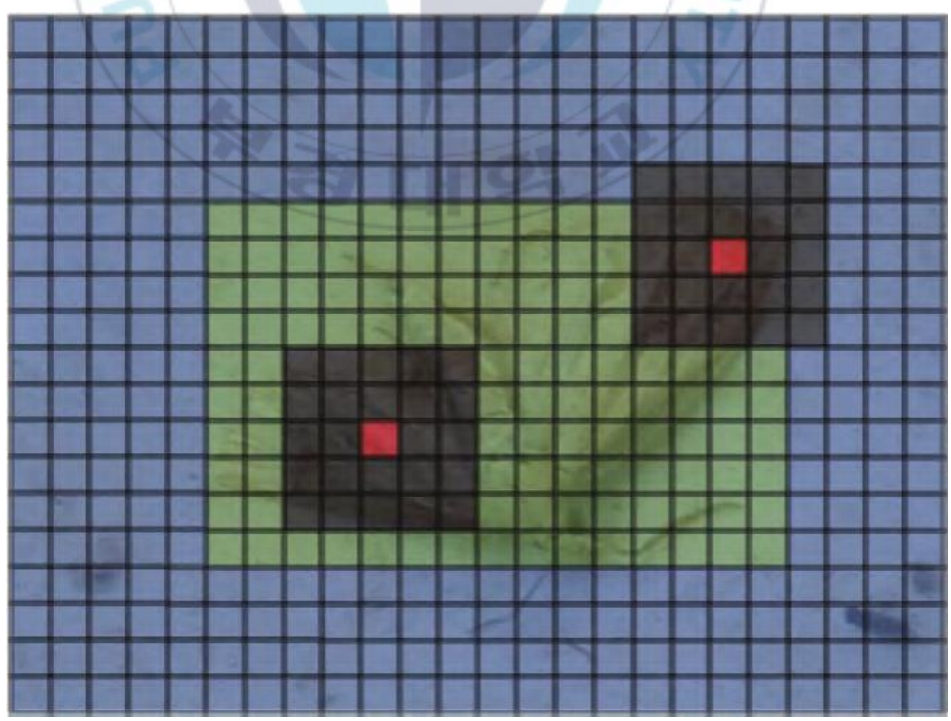
and the loss of the adhesion target prediction frame. To solve these two problems, this study adds Drop Block regularization method to reduce the degree of network over fitting, enhance algorithm robustness, and reduce non-target false detection problems; DIoU-NMS Instead of traditional NMS, non-maximum suppression can effectively reduce the loss of the adhesion target prediction box.

<Figure 4-6> Network framework of the improved YOLOv3 detection model



Common regularization methods include dropout regularization, L1, L2 normal normalization and DropBlock regularization. In order to reduce the degree of over fitting and enhance the robustness of target detection algorithm, the Drop Block regularization method is used in this study. Before the convolution operation, the DropBlock method randomly selects pixel points in the target area in the input layer, sets drop block around the selected point according to the preset block size, and sets all pixel values in the block to zero, as shown in Figure 4-7, where the green area is the target area, and the red point is a random point. The black area is the drop block. After the above algorithm is operated, the image is sent to the network, which increases the difficulty of network training and reduces the dependence of the network on certain local features, so as to avoid over fitting phenomenon.

<Figure 4-7> Schematic diagram of DropBlock



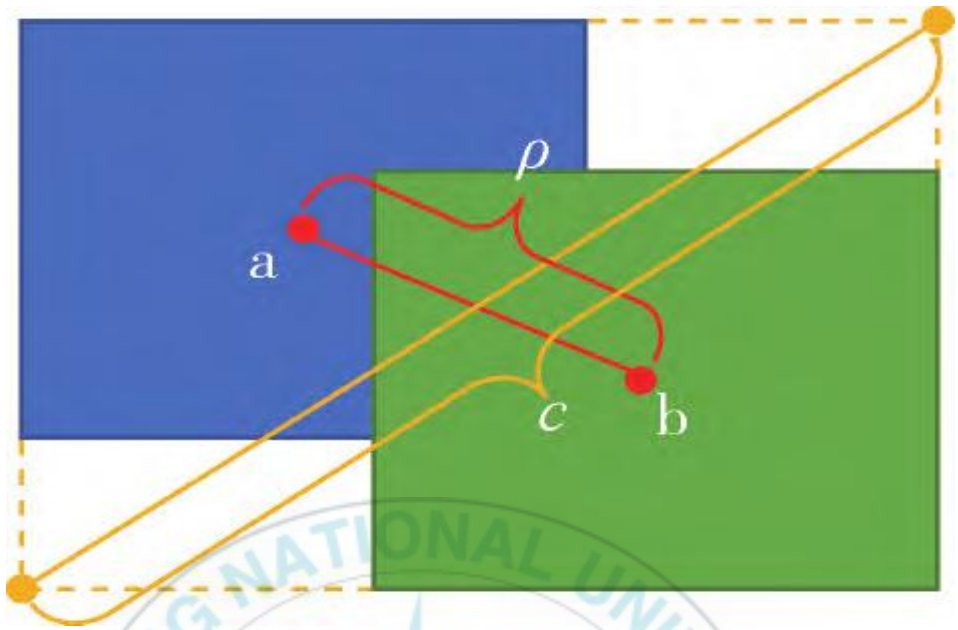
Because the detection results include all the detection boxes that are higher than the confidence threshold, there are many redundant boxes. Therefore, non-maximum suppression (NMS) is required to remove redundant boxes. The traditional non-maximum suppression method uses the intersection ratio (IoU) of two detection boxes as the quantization unit to compare the confidence of the two detection boxes whose intersection ratio is greater than the threshold value. The detection box with higher confidence is retained and the detection box with lower confidence is removed. The traditional non-maximum suppression method is prone to the problem of inaccurate location of the detection box when screening two detection boxes with high overlap, which leads to the omission of target pests. In this study, non-maximum suppression of DIoU-NMS containing distance information was used as a means to remove redundant frames.

The value of DIoU in the diou-NMS is calculated as Formula (1):

$$DIoU = IoU\frac{\rho^2(a,b)}{c^2} \quad (1)$$

In the formula, ρ represents Euclidean distance, a and b respectively represent the center points of the two test frames, and c represents the diagonal Euclidean distance length of the minimum rectangular frame containing two frames.

<Figure 4-8> Schematic diagram of DIoU parameters



ρ: Euclidean distance; a，b: Center point of two detection boxes;
c:Diagonal distance of the rectangular box covering two detection boxes.

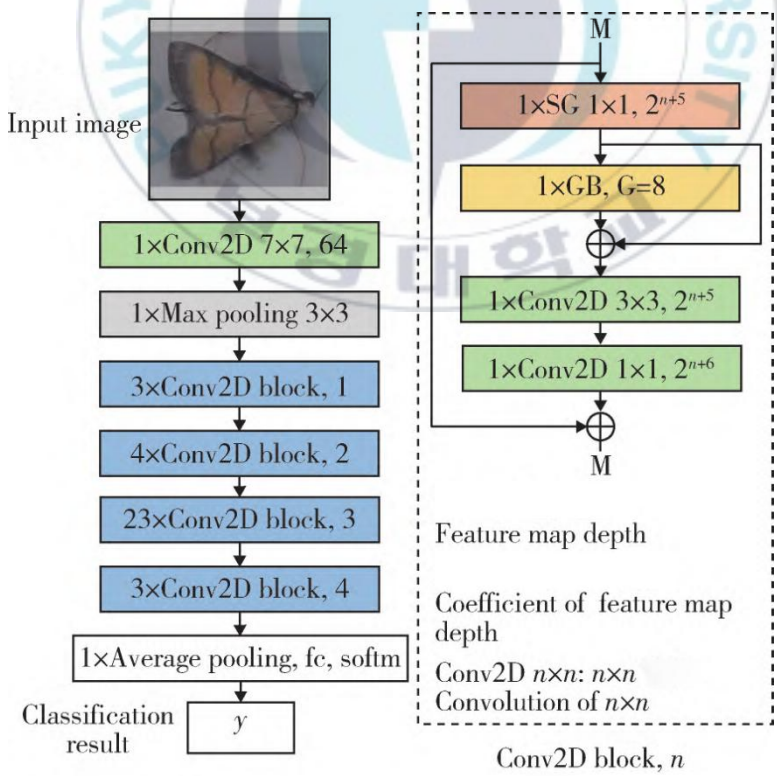
Replacing an NMS with a DioU-NMS can effectively suppress unqualified detection boxes and retain correct detection results to a maximum extent. By obtain the results of two non-maximum inhibition methods for adhesion pests. It can be seen that DioU-NMS can effectively detect two adhesion fruit flies.

3) Deep bilinear transformation network DBTNet-101: In addition to the target insect adult fruit flies, there are often other Lepidoptera interference pests in the insect glue plate image. These pests may have certain similarities with the target pests in body shape or color, resulting in false detection of fruit flies and interference pests in the detection results of the first layer YOLOv3 model. In image recognition tasks, similar species classification tasks are usually classified as fine-grained classification. In order to reduce the mutual false detection

between the target pest and the disturbance pest, and improve the detection rate of the target pest, the second layer of deep bilinear transformation classification network DBTNet-101.

DBTNet-101 was developed on the categorical network ResNet-101, adding a deep bilinear conversion module to perform bilinear calculation operations after grouping the semantic information based on each part of the target, and obtaining rich detailed feature expression of the image without changing the dimension of the convolution feature. DBTNet-101 is composed of one convolutional layer, 33 convolutional region blocks, and one fully connected layer.

<Figure 4-9> Network architecture of DBTNet-101



Here, "1 × SG 1 × 1, 2n + 5" represents the 1 × 1 convolutional layer with the semantic grouping reduction bundle added, and its output depth is 2n + 5. "1 × GB, G = 8" means bilinear calculation operation in convolutional neural network, and the specific calculation is shown in Equation (2).

$$y = T_B(Ax) = \mathrm{vec}\left(\sum_{j=1}^{G} \left((I_j Ax)(I_j Ax)^T\right)\right) \quad (2)$$

Where, x is the input feature matrix, A is the grouping mapping matrix optimized by SG, G is the number of groups, Ij is an identity matrix when corresponding to the JTH group, and the others are 0. After the input features of the DBT convolution block are semantically grouped, the bilinear pooling is performed according to the group, that is, the outer product operation is performed on the feature vectors, and finally the final result is obtained by integrating the features of each group.

In order to objectively evaluate the double-layered fruit fly proposed in this study, The detection performance of the network detection model, using precision, recall and F1 are used as evaluation metrics. Among them, the precision rate table, The proportion of pests identified by the model that were correctly identified as target pests, Recall represents the ratio of pests identified as target pests that are correctly identified. For example, F1 is the comprehensive evaluation of the two, and its calculation formula is as Formula (3). (4) and (5).

$$P(k) = \frac{TP(k)}{TP(k) + FP(k)} \quad (3)$$

$$R(k) = \frac{TP(k)}{TP(k) + FN(k)} \quad (4)$$

$$F_1(k) = 2 \times \frac{P(k) \times R(k)}{P(k) + R(k)} \quad (5)$$

Where, TP(k) represents the number of correctly identified pests of the KTH category

Quantity, FP(k) denotes the number of interfering pests misclassified as the KTH pest class

Quantity, FN(k) denotes the number of pests of type k that are recognized as non-type k pests

Quantity.

C. Results

1) Model checking results

YOLOv3, the improved YOLOv3 and the two-layer network detection model proposed in this study were trained with the same training set and tested on the same test set, and the results showing.

<Table 4-5> Detection results of Fruit fly different models

Detection models	Precision rate (%)	Recall rate (%)	F1 -score (%)
YOLOv3	91. 1	92. 4	91. 8
Improved YOLOv3	94. 0	94. 2	94. 1
Two-layer network detection model	97. 6	98. 6	98. 1

It can be seen from Table 4-5 that the improved YOLOv3 has the

recognition accuracy and recall rate of fruit flies increased by 2.9%and 1.8%respectively, and the F1 score increased by 2.3%. the accuracy and recall rate of fruit fly recognition by the double-layer network detection model are 97.6%and 98.6% respectively, which can meet the needs of intelligent monitoring of fruit flies.

The Web front end of the intelligent monitoring system for fruit fly sexual lure mainly includes user login, intelligent recognition of sexual lure images, equipment management, user management, identification history and other functions. The system can automatically collect the images of the rice leaf borer periodically, accurately detect and count the fruit flies, and users can view the fruit fly detection results through the Web front end, realizing the traceability of monitoring data.

<Figure 4-10> Display of application terminal interface of Fruit fly intelligent monitoring system in Agrodogan, Hainan

4.2.3 Experimental verification

Real-time and accurate acquisition of the species and number of fruit flies is the premise of accurate measurement and prediction of fruit flies. At present, the method of pest sex bait reporting in our country still requires surveyors to regularly go to the field to check the number of fruit flies on the sex trap board, which has some problems such as large workload, low efficiency and difficult data traceability. The use of intelligent measuring and reporting equipment and methods can reduce the workload of measuring and reporting personnel, improve work efficiency, and become an effective means of fruit fly monitoring at present.

H2: Hypothesis is true. Fruit fly intelligent monitor system has positive effect for fruit fly green IPM.

4.3 Green IPM technology application experiment by different region

In this section, mainly studied the specific cases of the application of the technology in several different regions, and proved the effect of the application of the technology in the green IPM of fruit fly through case studies.

4.3.1 Green IPM technology application experiment design

By analyzing the problems existing in the application of the green IPM technology of fruit fly in China, the ecological characteristics, infrastructure and personnel of some major fruit fly occurrence areas in China were investigated and studied, and combined with the local characteristics of fruit fly occurrence,

the technology developed in this paper was assembled and matched with some original green IPM technologies. (Du. X.K et al, 2022). According to local conditions, four green IPM technology modes with regional characteristics were established, namely, the green IPM technology application experiment area in Hainan, Guangxi, Yunnan and Sichuan respectively. Good results were obtained through demonstration and application.

4.3.2 Green IPM technology application data collection and analysis

In the four selected representative pilot areas for the application of green IPM products of fruit fly, case studies on the application of new green IPM technology of fruit fly were carried out mainly according to the following steps. Firstly, the occurrence and characteristics of the fruit flies in the target area were investigated and analyzed, and then the key technologies, technical mode and demonstration applications were summarized and analyzed.

4.3.2.1 Green IPM technology application in Hainan region

The fruit fly region in Hainan is a typical subtropical region, where the dominant species is tangerine, and the main harmful are tropical fruits, including citrus, lychee, mango, wax-apple, etc. Due to its complete infrastructure and good technical foundation for fly control, the characteristics of this region are shown in Table 4-6

<Table 4-6> Fruit fly survey monitor analysis sheet in Hainan region

Main feature	Feature Analysis
Fruit fly zone characteristics	In Hainan Province, which covers tropical and subtropical areas, flies mainly harm tropical fruits and occur all year round

Representative area	Baisha county, Sanya city, Danzhou,etc
Occurrence of fruit fly	It is a major tropical fruit producing area in China, and also there are a large number of tea plantations in the area. The whole area is at risk of infestation by fruit flies
Staffing	More people are equipped to control fruit flies. More than 100 professional IPM teams have been established, and more than 500 people can be mobilized at any time.
Technical force	With many years of fruit fly IPM experience, especially in the field of technical application of green IPM products
Facility	There is a special fruit fly management base in the region, and relevant green IPM equipment and facilities are well equipped, abundant and efficient

a. Key technologies

1) Pheromone traps for fruit flies: The best control period is when dominant species of fruit flies are at the peak of mating and 2-3 weeks before fruit ripens. The number of traps per mu should be 1-2. For areas with serious harm to flies, the number of traps per mu should be 3-4.

2) Fungus technology: Mainly using anisopliae and anisopliae and other fungi to prepare fungal preparations. The control period is the first or second generation of fruit flies. (Ji. Y.X et al, 2022). The dosage of liquid is 1L-1.5L/ mu, and sprayer can be used for ground or flight anti-spraying. Before application, stir well and pour into the sprayer cabinet. If the application conditions cannot reach the ultra-low volume spray standard, water can be mixed at 1:2 and sprayed.

3) Bio-pesticides of plant origin: plant extracts that can repel, kill and disturb the flies, such as Azedarach, chrysanthemum, etc., were mainly selected to prepare preparations. The applied agent was 5% water, and the applied dose was 37.5 ~ 150ml/ mu. Ultra-low volume spray could be diluted with water, and

sprayed every 7-10 days.

4) Natural enemy technology: Mainly according to the living habits and ecological environment of fruit flies, bees and fruit flies are introduced into the breeding area of fruit flies, or artificial means such as "Mini natural enemy factory" are used to increase the number of natural enemies such as ants and spiders.

5) The intelligent system of fruit fly monitoring: it is mainly used for real-time monitoring and data reporting of fruit fly occurrence and control information.

b. Technique mode

Based on the investigation and analysis of the characteristics of Hainan region, fruit fly traps, oil, natural enemy technology, fruit fly monitoring intelligent system, plant pesticide spray technology and so on were integrated and demonstrated in fruit fly occurrence area, forming the green IPM technology mode of Hainan fruit fly.

When the population density is moderate (0.5 ~ 5 flies per mu), fruit fly traps or oil can be used to prevent the development of fruit flies from low density to high density. The main goal is to reduce the outbreak frequency of highly density fruit flies.

When the fruit fly population density was high (more than 5 flies per mu), the fruit fly trap and bio-pesticide could be used in coordination, and the fly trap and preparation could be used alternately in strips with the area ratio of 1:1 (no cross covering). Or mix fruit fly pheromone traps with anisopliae. The aim is to rapidly reduce the density of fruit fly below the economic damage level, protect

natural enemies, and jointly control the population of fruit fly.

<Table 4-7> Fruit fly green IPM technology mode in Hainan region

Fruit fly occurrence processing	**Green IPM technology**	**Direction**
2-3 weeks before fruit ripening	Fruit fly intelligent monitor system	To monitor whether there is activity in the fruit fly, and to provide decision-making basis for IPM in the later stage
During fruit ripening (before picking)	Fruit fly trap, Fungus technology, Bio-pesticides of plant origin, Natural enemy technology, The intelligent monitor system of fruit fly	1)Fruit fly traps should be hung for daily observation. When fruit fly population density is medium or lower (0.5 ~ 5 flies per mu), fruit fly traps can be used separately for monitoring and trapping, and plant-origin bio-pesticides can be sprayed appropriately.
		2)When fruit fly population density is high (more than 5 flies /mu), the application of fruit fly traps can be coordinated with Plant-original bio-pesticides and fungus preparations should be used alternately. During the period when no spraying preparations are used, natural enemies should be released for control and use alternately.
		3)Fruit fly intelligent monitoring system should be used throughout the whole process to observe the fruit fly population density and hazard warning at any time, and report in time
Within 3 weeks of the end of fruit picking	Fruit fly trap, intelligent monitor system	Fruit fly intelligent monitoring system and traps should be used to monitor and observe fruit fly at any time. Once found, control and treatment should be carried out in time.

c. This technology mode has been extended and applied in the fruit fly occurrence area of Hainan Province for two years, with a demonstration area of

30,000 mu. Through this technology mode, the control of the source of occurrence was strengthened, the suitable living environment of occurrence was compressed, the occurrence scale was reduced, the harm degree was reduced, and the occurrence of occurrence in the region was basically controlled. Meanwhile, the water source was not polluted by chemical pesticides, and the ecological environment was protected.

4.3.2.2 Green IPM technology application in Guangxi region

The main characteristics of the region in Guangxi are that it occurs between orchards and farmlands, and the ecosystem is fragile. The dominant species is Mediterranean fruit fly, and the harmful fruits are mainly citrus and banana. The facilities for controlling fruit flies are relatively backward and the technical foundation is weak.

Table 4-8 Fruit fly survey monitor analysis sheet in Guangxi region

Main feature	Feature Analysis
Fruit fly zone characteristics	Guangxi region is a subtropical monsoon climate, mainly mountainous and hilly, fruit crops a year two or three ripened, fruit fly mainly harmful the maturity of fruits and vegetables.
Representative area	Nanning, Guilin city, Hezhou, etc.
Occurrence of fruit fly	Fruits are mainly citrus and sugarcane, etc. The south area is close to the border and has a fragile ecosystem.
Staffing	Inadequate staffing for fly control
Technical force	The technical foundation is weak.
Facility	Fruit fly control facilities are backward, the combination of motor spray and artificial spray, large sprayers and motor sprayers quantity is small

a. Key technologies

1) Fruit fly traps: The best control period is when the dominant species are in the mating stage and fruit maturity stage, and the number of fruit fly traps is 1-2 per mu. Can be directly hung between fruit trees; Change pheromone decoys every 4-5 weeks.

2) Metarhizium oil: The control period is the first or second instar of fruit fly occurrence period. The dosage of liquid is 1L-1.5L/ mu. low capacity sprayer can be used for ground or flight anti-spray. Before application, stir well and pour into the sprayer cabinet. If the application conditions are not up to the ultra-low volume spray standard, spray the fruit by adding water at 1:2.

3) Bio-pesticide preparation: The application is 5% water, the application dose is 37.5 ~ 150ml/ mu, can be diluted with water for ultra-low volume spray.

4) Intelligent system for investigation and monitoring of fruit flies: It mainly implements real-time monitoring and data reporting of the occurrence and control information of flies.

b. Technique mode

Based on the investigation and analysis of the characteristics of Guangxi region, we adopted the strategy of using the new biological control technology of fruit fly traps around the agricultural area and in the orchards, mixed use anisopliae and other biological pesticides in the orchards, and integrated demonstration of the smart system of fruit fly traps, oil and fruit fly investigation and detection in this region. The green IPM technology mode in Guangxi has been formed.

<Table 4-9> Fruit fly green IPM technology mode in Guangxi region

Fruit fly Green IPM Direction

occurrence processing	**technology**	
2-3 weeks before fruit ripening	Fruit fly intelligent monitor system	To monitor whether there is activity in the fruit fly, and to provide decision-making basis for IPM in the later stage
During fruit ripening (before picking)	Fruit fly trap, Fungus technology, Bio-pesticides of plant origin, The intelligent monitor system of fruit fly	1)Fruit fly traps should be hung for daily observation. When fruit fly population density is medium or lower (0.5 ~ 5 flies per mu), fruit fly traps can be used separately for monitoring and trapping, and plant-origin bio-pesticides can be sprayed appropriately.
		2) When fruit fly population density is high (more than 5 flies /mu), the application of fruit fly traps can be coordinated with matrine and Metarhizium oil should be used alternately.
		3)Fruit fly intelligent monitoring system should be used throughout the whole process to observe the fruit fly population density and hazard warning at any time, and report in time
Within 3 weeks of the end of fruit picking	Fruit fly trap, intelligent monitor system	Fruit fly intelligent monitoring system and traps should be used to monitor and observe fruit fly at any time. Survey green IPM effect.

c. Demonstration application

The technology model has been promoted and applied in Nanning City, Guangxi region for 2 years, with a demonstration area of 5000 mu. The control effect reached more than 75%, and it was harmless to the natural enemies of fruit fly, and the demonstration effect was achieved.

4.3.2.3 Green IPM technology application in Yunnan region

Mountain orchards are dominant in Yunnan fruit fly region, and the

dominant species include fructus melon, Fructus tangerine and Mediterranean fly, etc. The vegetation is dominated by citrus, banana and other fruits, and the natural enemies of fructus, such as parasitic wasps, are abundant. The region borders Southeast Asian countries such as Vietnam and Myanmar, respectively, and migratory fructus fruit flies often cross borders to cause harm. The facilities for fruit fly IPM are backward and the technical foundation is weak, which makes it difficult to carry out large-scale artificial control. The characteristics of this region are shown in

<Table 4-10>. **Fruit fly survey monitor analysis sheet in Yunnan region**

Main feature	Feature Analysis
Fruit fly zone characteristics	Fruit flies are mainly found in mountain orchards， bordering Nepal, Myanmar and other countries. Migratory flies often occur in border areas, often causing damage across borders
Representative area	Kunming city, Baoshan city, Dali, Ruili, etc.
Occurrence of fruit fly	The dominant species include the Mediterranean fruit fly, Tangerine fruit fly, melon fruit fly, etc.
Staffing	Inadequate staffing for fly control
Technical force	The technical foundation is weak.
Facility	Fruit fly IPM facilities are backward and artificial control is the main method

a. key technologies

1) Natural enemy protection and utilization technology: to protect local natural enemies - parasitic wasps and predatory natural enemies. In Yunnan Province, there is a wide range of host species, and the infection rate can be as high as 30%, which can effectively control the population of fruit flies in common occurrence years.

2) Fruit fly traps: The best control period is that dominant species of fruit fly are in the mating peak and fruit maturity stage, the number of hung is 1-2 per mu, and the hanging cycle is changed every 3-4 weeks.

3) Matrine preparation: 5% matrine water agent is applied, and the applied dose is 37.5 ~ 150ml per mu, which can be diluted with water for ultra-low volume spray.

4) Intelligent system for investigation and monitoring of flies: It mainly implements real-time monitoring and data reporting of the occurrence and control information of fruit flies.

b. Technique mode

Based on the investigation and analysis of the characteristics of Yunnan region, the regularity of the occurrence and the control effect on the population density of the fruit fly were studied in Baoshan area of Yunnan Province for three consecutive years. (Chen. Y.H, 2022). The strategies and techniques for controlling green fruit flies in Baoshan area of Yunnan province were put forward, which were mainly to protect local natural enemies, parasitic wasps and predatory natural enemies, appropriate use of fruit fly traps, and matrine preparation only when necessary. According to the above characteristics, the green IPM technology mode of Yunnan was formed by integrating the protection and utilization of natural enemies, fruit fly traps, matrine preparation and monitoring intelligent system technology.

<Table 4-11> Fruit fly green IPM technology mode in Yunnan region

Fruit fly occurrence	Green technology	IPM	Direction

processing		
2-3 weeks before fruit ripening	Fruit fly intelligent monitor system	To monitor whether there is activity in the fruit fly, and to provide decision-making basis for IPM in the later stage
During fruit ripening (before picking)	Fruit fly trap, Bio-pesticides matrine, Natural enemy technology,	1)1) Based on the characteristics of local biodiversity, the protection of local natural enemies, including parasitic wasps and predatory natural enemies of flies, should be dominated
		2)Proper use of fly traps
		3) Plant derived bio-pesticides matrine only when necessary
Within 3 weeks of the end of fruit picking	Fruit fly intelligent monitor system	Fruit fly intelligent monitoring system should be used to monitor and observe.

c. Demonstration application

After 2 years of popularization and application in Baoshan area of Yunnan Province, the demonstration area is 5000 mu. The comprehensive ecological environment in the demonstration area was more favorable for the reproduction of natural enemies of fruit fly, and effectively controlled the population density of fruit fly. (Jiang. R.S, 2022). The efficacy of bio-pesticides was gradually recognized by local farmers, and they basically mastered the application methods of bio-pesticides, and the proportion of chemical agents used was significantly reduced.

4.3.2.4 Green IPM technology application in Sichuan region

The main areas of fruit fly occurrence in Sichuan were plateau, mountain and basin orchards in Ganzi area. The average altitude is more than 3000 meters, the dominant species of citrus fruit flies and citrus fruit flies, and the main

harmful crops are citrus. The fruit fly IPM facilities are backward and the technical foundation is weak. The characteristics of this region are shown in Table 4-12.

<Table 4-12> Fruit fly survey monitor analysis sheet in Sichuan

Main feature	Feature Analysis
Fruit fly zone characteristics	Fruit orchards in plateau, mountain and basin are the main fruit flies in Sichuan. The average altitude is over 3,000 meters above sea level
Representative area	Chengdu city, Mianyang city, Guangan, Ganzi state, etc.
Occurrence of fruit fly	The dominant species include citrus macrophyta
Staffing	Inadequate staffing for fly control
Technical force	Weak technical foundation
Facility	Fruit fly IPM facilities are backward and artificial control is the main method

a. Key technologies

1) Fruit fly traps: The best control period is when the dominant species of fruit fly is in the mating period and fruit maturity period, and the number of fruit flies is 1-2 per mu. When the insect population density is large, the fruit fly traps can be suspended by 3-5 per mu and replaced every 3-4 weeks.

2) Oil agent of Metarhizium anisopliae: The control period is the breeding period of 3 ~ 4 instars of fruit flies. The dosage of liquid is 1L ~ 1.5L/ mu. sprayer can be used for ground or flight anti-spray. Before application, stir well and pour into the sprayer cabinet. If the application conditions cannot reach the ultra-low volume spray standard, water can be mixed at 1:2 and sprayed.

3) Matrine bio-pesticide technology: matrine 5% water agent is applied, and

the applied dose is 37.5 ~ 150ml per mu, which can be diluted with water for ultra-low volume spray.

4) Intelligent system for investigation and monitoring of fruit flies: It mainly implements real-time monitoring and data reporting of the occurrence and control information of fruit flies.

b. Technique mode

Based on the investigation and analysis of the characteristics of Sichuan region, integrated the transformation of the ecological environment of practical fruit flies, combined with the use of fruit fly traps, Metarhizia oil agent, practical fruit fly investigation and monitoring intelligent system technology, formed the green IPM technology mode of Sichuan Ganzi citrus fruit fly, covering an area of 3000 mu.

<Table 4-13> Fruit fly green IPM technology mode in Sichuan region

Fruit fly occurrence processing	**Green IPM technology**	**Direction**
2-3 weeks before fruit ripening	Fruit fly intelligent monitor system	To monitor whether there is activity in the fruit fly, and to provide decision-making basis for IPM in the later stage
During fruit ripening (before picking)	Fruit fly trap, Fungus technology, Bio-pesticides Matrine,	Combined application of fly traps, Fungus technology (Metarhizium anisopliae), Bio-pesticide Matrine and other biological control technologies
Within 3 weeks of the end of fruit	Fruit fly intelligent monitor system	Fruit fly intelligent monitoring system and traps should be used to monitor and observe fruit fly at any time. Once found,

picking	control and treatment should be carried out in time.

c. Demonstration application

This technology mode has been popularized and applied in Ganzi area of Sichuan Province for 2 years, with a demonstration area of 3000 mu. In the demonstration area, the use of chemical pesticides has been reduced by more than 35%, the damage loss rate of citrus fly has been controlled below 3%, pesticide residues have been controlled within the permissible range, and the harmless and sustainable control of crop diseases and pests has been promoted, and the local ecological environment has been protected.

4.3.3 Experimental verification

In this section, experiments case on the application of technology of green IPM of fruit fly were carried out in four representative areas of different types of fruit fly occurrence regions. From three dimensions, include the key technology, technical mode and demonstration application effect evaluation were mainly used for green IPM. The Fruit fly green IPM technology application has positive effect in Chinese different region. The hypothesis in the previous study was established.

H3: Hypothesis is true. Fruit fly green IPM technology application has positive effect in Chinese different region.

4.4 Green IPM technology application and promotion mode

benefit experiment

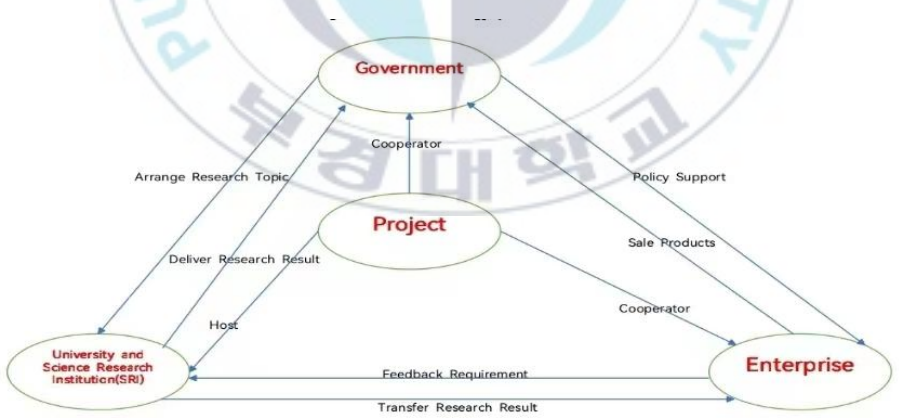
In this section, based on the model of new agricultural technology application and promotion design, the effects and economic, social and ecological benefits of the green IPM technology of fruit fly in China were analyzed and calculated by carrying out field experiments, technical training and technical demonstration. Furthermore, the hypothesis that the promotion and application of the new green IPM technology of fruit fly has a positive correlation with economic, social and ecological benefits was verified in the previous study.

4.4.1 Agriculture technology promotion mode experiment design

Through the promotion and application of new agriculture technology, such as field experiment, conference presentation and technology demonstration, combined with the characteristics of fruit fly green IPM, we explored the promotion and application mode of fruit fly green IPM technology. The mode takes scientific research projects as the link, and the government, universities and enterprises participate in the promotion and application of technology. Government departments subsidize the research and development of new technologies in universities by setting up scientific research projects; Through the formulation of supportive policies to help enterprises to promote the technology. Universities improve the scientific and technological level of government departments by submitting research results to government departments; Through the achievement transformation with enterprises, to realize the industrialization of technology development.(S.M et al, 2023). By feeding back the market demand to the university, the enterprise assists in the research

and development of new products, and by selling products to government departments, it completes the promotion and application of new technologies. The promotion mode of green control technology of fly in China has been gradually formed with the participation of multiple subjects including project, government, science and industry (see Figure 4-6.). The feature of this model is that it takes into account both scientific research and application, which can be applied while researching, and can be promoted and applied quickly and efficiently to realize the transformation of science and technology into productivity.

<Figure 4-11> Green IPM technology promotion mode



The host unit of the project is usually the university and scientific research institute, which takes it as the platform for technological innovation and

development. Through the cooperation between the project and the agricultural technology extension department of the government, the technology developed will be demonstrated and applied by carrying out field experiments and tests and setting up technical demonstration areas, so as to drive the promotion of technology and lay the foundation for the improvement and transformation of technology. Through the cooperation between the project and the enterprise, the link between the scientific research results and the market demand is promoted, and the achievement transformation of technology is accelerated. In this paper, the new technologies for the fruit fly green IPM were all funded by the special scientific research fund of the public welfare industry (agriculture) of the Ministry of Agriculture. (C.X et al, 2022). Driven by the project, the fly trap has been commercially developed, and the intelligent system for the investigation and monitoring of fruit fly has also entered the commercial production stage.

The government agriculture technology extension department is the social public service provider and the decision maker of agricultural economic development. The macro behavior of participating in agriculture technology extension mainly lies in creating a stable agriculture technology environment with the regulatory text such as policy and system. We will create favorable conditions for the transformation of scientific and technological achievements by formulating policies, improving the management system and improving the direction of project funds. In addition to giving preferential policies to some projects with good social benefits, the government also directly gives strong economic support to those scientific research projects with obvious social benefits, significant contribution to the national economic development and

ability to drive the economic development of one side. (S.E.2022). As the new green control technology of fruit fly is an agricultural scientific and technological achievement with public welfare nature, the government extension department has given a lot of policy support in the promotion and application of the trap and intelligent system of fruit fly investigation and monitoring, which promotes the promotion and application of the technology. At the same time, the application of the technology also improves the work efficiency of the government and the level of green control technology.

The strong scientific research and technical strength of the university provides a platform for the research and development of new technologies. (D.G.A et al, 2022). Relying on the advantages of the university in science and technology, talents, disciplines and information resources, the university can solve various technical problems encountered in practical applications for the government, enterprises and users. Promote communication among government officials, industry and universities, and enhance the ability of agricultural technology innovation. (J. M.C et al, 2009). Universities may also publicize and popularize new technologies by conducting training on the use of new technologies, publicity on new technologies, practical operation demonstration and guidance, agricultural science and technology consultation, etc.

The enterprise is responsible for the production and processing of technology, relevant qualification management, product sales and product after-sales service, and is the realization of the application of scientific and technological achievements to the market. At the same time, through practical application, the enterprise can timely feedback the problems found to the

government promotion department and scientific research department, forming a sound development trend.

In the new promotion mode, various parties do their best and perform their own duties. It integrates the favorable factors of policy, market, operation, scientific research and other aspects. (R. K. Peng et al, 2006). It is a diversified promotion system with reasonable division of labor between the central and local governments, close combination of scientific research and education promotion, and joint participation of government departments and private enterprises. Many links between scientific and technological achievements and market application are connected smoothly and good results have been achieved.

4.4.2 Green IPM technology application and promotion data collection and analysis

In view of the existing problems in the promotion of agricultural technology, field experiments, meeting presentations and field demonstrations were used to promote and apply the technology for fruit fly green IPM, and the purpose of the technology demonstration application was tested, which laid the technical foundation for the industrial development and large area application of the technology. (T.T et al, 2021). It is based on this agricultural technology extension mode that the new green IPM technology of fruit flies have been tested. The following is a summary of the specific extension test process and benefit analysis.

a. Field trials of new technologies

In the process of this study, driven by the central guidance of local special fund and the "Science and Technology to help Economy 2020" special fund project, the field test of multiple application modes of the fruit flies trap and the field application test of the intelligent system of fruit flies monitoring were carried out. The feedback obtained from the field tests and tests helped to understand the needs of users, and pointed out the direction for the improvement and perfection of the technology. It lays a foundation for the popularization and application of technology.

1) Design of field experiment

Field experiments on fruit fly traps, intelligent monitoring system and other green IPM measures were carried out in cooperation with plant conservation stations at provincial, municipal and county levels in major fly epidemic areas by applying the new technologies of fly traps and intelligent monitoring system developed in this study, which improved the new field application technology of fruit fly green IPM and realized the sharing of scientific and technological achievements.

<Table 4-14> Fruit fly trap field trial data sheet

Trial content	**Trial region**	**Trial condition**	**Survey content**	**Trial purpose**
Barrel trap	Baisha	Many years rich experience on green IPM;Rain rich	Decrease rate of insect infestation; Trapping effect	Screen for suitable traps and bait

Triangle trap	Guilin,Baoshan	Not enough application experience on green IPM; dry area	Decrease rate of insect infestation; Spread speed	Screen for suitable traps and bait
Tube style trap	Mianyang	Common experience on green IPM; dry area	Decrease rate of insect infestation; Trapping effect	Screen for suitable traps and bait
Boat trap	Kunming	Many years rich experience on green IPM; Rich rain	Decrease rate of insect infestation; Trapping effect	Screen for suitable traps and bait

2) Summary of test results

In the field test of fruit fly traps, the fruit fly population density decreased significantly 7 days after the traps were hung, and the population reduction rate was 31.55%. 14 days after the trap was hung, the population density decreased more significantly, and the population density decreased by 70.69%. This experiment can prove that the method of controlling fruit flies by using the trap is effective.

In the experiment of fruit fly intelligent monitoring system, by monitoring the regularity of fruit fly occurrence and population density, and supporting green IPM measures such as bio-pesticides of plant origin, natural enemy release and fungus spraying, the population density reduction rate was 27.50% and the corrected control effect was 25.81% after 7 days, and the population density reduction rate was 72.50% and the corrected control effect was 70.49% after 16

days. In Hainan Province, 12 days after application, the decrease rate of insect population density was 65.6%, and the control effect reached 72.7%. 24 days after application, the decrease rate of insect population density was 78.6%, and the control effect reached 82.8%. In Guangxi, 12 days after monitoring, the control effect reached 72.7%. 24 days after application, the control effect reached 82.8%; In Yunnan Province, the control effect was 31.97% after 14 days and 74.5 % after 28 days. In the experiment, it was found that the fruit fly traps control the fruit flies, and the weather, vegetation and biodiversity of the test site had certain effects on the drug efficacy. The areas with dry climate, high vegetation coverage and rich species had better control effect.

Through the above field experiments, the comprehensive application effect of the trap and the intelligent monitoring system is 70%, and some areas even reach more than 80%, which fully indicates that the fruit fly series of trap and intelligent monitoring system can be applied to a variety of fruit fly monitoring and trapping environment, and the characteristics of strong specificity, large number of traps and good effects, have broad market prospects.

b. Technique training

The new green IPM technology of fruit flies were publicized and promoted through the form of conference presentation. From 2015 to 2022, it participated in more than 20 national meetings on fruit fly control organized by the National Agricultural Technology Center, prefecture-level meetings on fruit fly control organized by various provinces, municipalities and county-level plant protection

stations, and meetings of the project team for scientific research funds, and trained more than 5,000 plant protection staff and farmers at all levels.

In 2016, he participated in the "Fourth Expert Technical Seminar on Control of fruit fly Cooperation between China and Nepal", and in 2018, he participated in the "World fruit Congress" in Thailand, introducing the new green control technology of fruit fly studied in this paper to the world. The monitoring and intelligent monitoring system of fruit fly have been promoted to Nepal through the China-Nepal International Cooperation Project on fruit fly. Fruit fly trapping technology has been praised by foreign experts for many times.

c. Technology demonstration

Through the cooperation with the national, provincial, municipal and county level plant protection departments, we have carried out on-site demonstration meetings on fruit fly green IPM technology, product promotion meetings, technology demonstration areas, field guidance and other forms, and promoted the green IPM technologies such as fruit fly traps and fruit fly monitoring and investigation intelligent system by means of on-site explanation and demonstration guidance. Through the direct participation of scientific and technological personnel in the extension of agricultural technology, the extension cycle of scientific and technological achievements and the time of information feedback are effectively shortened. Researchers can obtain more new information and constantly open up new research fields. (Liang. F. J et al, 2022). The extension practice is not only the extension and continuation of scientific

research, but also the source of new research topics.

Demonstration zones for new green IPM technologies of fruit fly have been set up in Hainan Province, Shandong Province, Guangxi Autonomous Region, Sichuan Province, Yunnan Province and Hubei Province. By participating in science and technology demonstration and popularization work, we can enhance the perceptual understanding of modern agriculture, which is conducive to combining theory with practice and learning knowledge from production practice.

d. Promotion and application of new green IPM technology of fruit fly

From 2015 to 2022, the fruit fly traps developed in this paper were applied in Sichuan, Hainan, Hunan, Guangxi, Hubei, Yunnan, Guangdong and other provinces, municipalities and autonomous regions. The total area of the traps was 875,000 mu, and the control effect was about 80%, effectively controlling the harm of the flies.

<Table 4-15> Fruit fly trap application and promotion sheet in 2015-2022

Application region	Application area (ten thousand mu)
Hainan	20
Sichuan	19
Yunnan	15
Guangxi	12
Guangdong	10
Hunan	7.5
Hubei	3
Shandong	1
Total	87.5

2015-2022, in Sichuan, Hainan, Hunan, Hubei, Guangxi, Yunnan, Guangdong areas applied fruit fly monitoring intelligent system, applied total area one million mu, could improve the work efficiency by 30%, effectively improved the practical fly monitoring level in our country.

<Table 4-16> Fruit fly intelligent monitor system application and promotion sheet in 2015-2022

Aplication region	Application area (10,000 mu per mu)
Hainan	1800
Yunnan	1000
Hunan	1400
Guangxi	2000
Hubei	2800
Yunnan	200
Guangdong	300
Sichuan	500
Total	10000

4.4.2.1 Economic benefit

The economic benefits of this paper are mainly reflected in the application of fruit fly traps and fly monitoring intelligent system, the demonstration application of fly control in specific demonstration areas and surrounding areas to save the economic loss and cost. It is estimated that the total economic benefit of the two new technologies since 2015 is about 230 million yuan.

The total area of fly pheromone traps used in Sichuan, Henan, Guangxi, Xinjiang, Hainan, Sichuan and other provinces, cities and autonomous regions

is 875,000 mu, and the control effect is about 80%. According to the calculation of planting citrus, the average output value of mu is 600 yuan/mu, and the economic loss is 300 yuan/mu, and the total economic loss is more than 180 million yuan in 4 years (see the calculation formula below).

1). Economic benefit calculation formula

(1) Mu loss value = mu average yield (300 kg) X50% (loss rate) x unit price of citrus (2 yuan/kg)

(2) Total economic loss recovered = (average output value of one mu loss value of one mu) X shrinkage coefficient (0.7) X total promotion area (mu)

2). Economic benefit analysis of fruit fly monitoring intelligent system.

In our country Sichuan, Henan, Guangxi, Hunan, Hainan, Hubei and other provinces, the city, autonomous regions applied flies monitoring intelligent system applied total area 100 million mu, can improve the work efficiency of 30%, saving cost 0.6 yuan/mu, according to each mu of the fly investigation cost is 2 yuan calculated. A total of 48 million yuan was saved (see below for the calculation formula).

Economic benefit calculation formula

(1) Cost saving value per mu = survey cost per mu (2 yuan) X30% (cost saving rate)

(2) Total cost saved = cost saved per mu X shrinkage coefficient (0.8) X total number of applied mu

2) Total economic benefit

After four years of popularization and application of the technology developed in this paper, the cumulative economic losses and cost savings totaled 232 million yuan. After deducting the scientific research cost of 1 million yuan and the new cost of applying the technology of 1.175 million yuan, the total economic benefits were about 230 million yuan (see the calculation formula below).

Economic benefit calculation formula

(1) The new cost of applying technology

(2) The total benefit of increased income and reduced expenditure

Total benefits of income increase and expenditure reduction (ten thousand yuan) = economic benefits of fly traps + The economic benefits of fruit fly surveillance system - the cost of scientific research and the additional cost of

applying new technologies.

4.4.2.2 Social benefit

The harm of fruit fly is a worldwide disaster. Historical experience has proved that the outbreak and disaster of fruit fly not only bring losses to agricultural production, but also have a very serious adverse impact on society. (Hu. Z. S, 2019). The sustainable control of fruit fly is of great significance to reduce the negative impact on society.

Fruit fly in China areas cover more than 700 counties, accounting for nearly 43% of the country's administrative counties, involving hundreds of millions of people. The fly control technology studied in this paper can effectively avoid the losses caused by the fruit fly to agricultural production, reduce social panic, and avoid international disputes caused by cross-border hazards. (LI.S.S, 2018). The adoption of green IPM technology has played an important role in ensuring the quality and safety of agricultural products and human health; Some fly areas are inhabited by ethnic minorities in border areas. The application of green IPM inducement and control technology is conducive to maintaining the stability of life and social stability of residents in border areas.

During the completion of this paper, more than 20 training courses on fly green IPM technology were carried out, and plant protection staff and farmers at all levels were trained more than 5000 times, which cultivated talents for the research, demonstration and application of green control technology in China.

The fruit fly green IPM technology developed in this paper has been widely applied in Fruit fly in China IPM work, providing technical support for

sustainable control of fruit fly disaster in China, and playing an important role in ensuring agricultural and animal husbandry production security and social stability, with significant social benefits.

4.4.2.3 Ecological benefit

Most of the fly occurrence areas are near water sources, such as Hainan region, the wet area at the mouth of the Yellow River and the tidal area of the Yellow River. (Zhang. X. Q et al, 2014). The use of chemical pesticides to control the fruit fly in these areas will seriously pollute the water sources, reservoirs and lakes of the Yellow River. Water is source of the life, polluted water will be a serious threat to the health and survival of human beings and aquatic organisms. The research in this paper is based on the green IPM induction and control technology of biological control, which is very safe for the environment, ecology and other non-target organisms. (Hu. J. F, 2012). The use of this technology to control fruit flies reduces the use of chemical pesticides by more than 80%, and the use of chemical pesticides has been reduced by more than 1200 tons in four years. Therefore, it can effectively protect T water source and ecological environment from chemical pesticide pollution, as well as protect natural enemies of fruit fly and other non-target organisms.

The successful development and application of the fruit fly monitoring intelligent system and fruit fly trap can effectively avoid the pollution of non-target areas, such as ponds, rivers, lakes and residential buildings, farmland and crops, and also avoid the killing of non-target organisms, such as birds, fish and natural enemies of the fly, protecting the ecological environment of the fly

area and having good ecological benefits.

4.4.3 Experimental verification

Through the above promotion and application mode based on the new green IPM technology, the project-centered model combining government, industry, education, research and promotion is carried out nationwide, each performing his/her own duties, and the promotion of new green IPM technology is carried out in an all-round way, which has achieved good economic, social and ecological benefits, and the hypothesis proposed in the previous study has also been verified.

H4: Hypothesis is true. Fruit fly green IPM technology promotion has positive effect for Economic, Social and Ecological benefit.

Based on the above summary of the hypothesis verification results, it is concluded that all the hypotheses proposed in this study are true, as shown in Table 4-17:

<Table 4-17> Hypothesis verification conclusion sheet

Research Hypothesis	Verification Result
H1: Fruit fly trap as a kind of fruit fly green IPM technology has positive effect for fruit fly green IPM.	Positive correlation
H2: Fruit fly intelligent monitor system has positive effect for fruit fly green IPM.	Positive correlation
H3: Fruit fly green IPM technology application has positive effect in Chinese different regions.	Positive correlation
H4: Fruit fly green IPM technology application and promotion has positive effect for Economic, Social and Ecological benefits.	Positive correlation

V. Conclusion and Discussion

5.1 Conclusion

Through interdisciplinary methods of biochemistry, information technology and economic management, this study aimed at the problems existing in the IPM technology of fruit fly in China, aiming at high efficiency, low consumption and environmental protection (green). On the basis of the establishment of the research model, according to the fly trap field experiment, drosophila intelligent monitoring system field experiment, Drosophila green IPM technology application in different areas, drosophila green IPM technology promotion and application benefit experiment, put forward the corresponding research hypothesis to carry out the relevant experiments. The conclusion is as follows:

1. Field experiments were conducted on the trapping effect of Bactrocera dorsalis in Starfruit orchard and Lianwu Orchard in Baisha County, Hainan Province. As a non-toxic sex pheromone attractant mainly based on protein attractants, "Ceranock" trap traps trap and kill the female adults of Bactrocera dorsalis by utilizing the characteristic that female adults are in urgent need of protein, sugar and other nutrients before mating and laying eggs, thus reducing the mating and laying rate of bactrocera dorsalis pests. It makes up for the shortage that the general pheromone trap can only trap male adults. At the same time, after different treatments, it was found that the trapping effect of "Ceranock" placed in the barrel trap was higher than that of "Ceranock" alone, and the number of female flies was the highest. It was analyzed that when

"Ceranock" was used alone, due to the influence of hanging position, weather conditions and other factors, the trapping effect of "Ceranock" on Tangerine flies showed great fluctuations. Thus, the trapping effect on Tangerine flies was affected. According to the actual situation, when "Ceranock" is used alone, the quantity of insect attractors fluctuates greatly, and the quantity of insect attractors continues to decrease in October, which may be due to the influence of rainfall. When "Ceranock" is suspended and used, there is no effective rain shelter setting, so the quantity of insect attractors is significantly reduced under the influence of rainfall. Therefore, in the park with more rainfall, Consider placing Ceranock in a barrel trap before conducting a hanging trap. In conclusion, through the test, it can be seen that the "Ceranock" fly trap has a good trapping effect on the IPM of Bactrocera tangerina. The next step is to increase the application and promotion, not only to reduce the application of pesticides, but also to control the occurrence and damage of bactrocera tangerina.

2. In the experimental study of the fruit fly intelligent monitoring system, a two-layer network detection model is established, and the DropBlock regularization method is added to the model to reduce the over-fitting degree of the neural network and reduce the false detection; Dlou-NMS non-stage large value suppression was added to the model to reduce missed detection. The second layer DBTNet-101 classification network is used to calibrate the detection results of the first layer to reduce the false detection of the target pest, the fruit fly. The experimental results show that the accuracy and recall rate of fruit fly detection on the image are 97.6% and 98.6%, respectively, which can meet the needs of intelligent monitoring offruit fly. The intelligent monitoring

system of fruit fly established in this study realizes real-time and intelligent monitoring of fruit fly, reduces the workload of manual monitoring, and the monitoring data is accurate and traceable. The system can be applied to the green control of fruit fly and effectively monitor the occurrence of fruit fly.

3. In Hainan, Guangxi, Yunnan and Sichuan, four representative areas with different regional characteristics of fruit fly occurrence were selected nationwide, and the case test of fruit fly green IPM technology application was carried out. The application effect of green IPM technology is analyzed from three dimensions: key technology, technology mode and demonstration application effect evaluation. The results of different safety tests show that the application of fruit fly green IPM technology in different regions of China has achieved positive results.

4. Based on the promotion and application mode of green IPM technology, implement the mode of combining project-centered, government, industry, education, scientific research and promotion, and each of them perform their own duties to comprehensively promote the application and promotion of green IPM technology. The case analysis and verification show that the promotion of green control technology of fruit fly can achieve good economic, social and ecological benefits.

The conclusion of this study is that the fruit fly green IPM technology is green, easy to operate, practical, and targeted. (Li. H.M, 2011) It is in line with the national sustainable control strategy, and has the characteristics of treating both the symptoms and root causes, safe, efficient and environmentally friendly. It has a broad application prospect.

5.2 Research contribution

In this study, the main research contribution as below.

Theoretical contribution: Firstly, It is verified that the green IPM technology of fruit flies has a positive effect on the green IPM of fruit flies, which provides theoretical support for the application and promotion of green IPM technology of fruit flies; Secondly, Through the effect test of the application of green control technology of fruit fly in different areas of fruit fly in China, it was proved that the green control technology of fruit fly could be applied in a large area in China, which enriched and enriched the theoretical basis for the application and promotion of green control technology of fruit fly; Thirdly, Through the application and popularization of green control technology of fruit fly, it is proved that the application of green control technology of fruit fly can bring obvious economic, social and ecological benefits to agricultural production in China, and provide new support for enriching the application theory of green control technology.

Practical contribution: Firstly, based on the concept of green IPM, a technology and a new product of green IPM of fruit fly, namely, a pheromone trap for fruit fly and an intelligent monitoring system for fruit fly, have been developed and applied effectively, and good economic, social and ecological benefits have been obtained; Secondly, through the organic combination and integration of the novel and original fruit fly green IPM technology, the application and promotion mode of fruit fly green IPM technology with regional characteristics is summarized to help the future application and promotion of fruit fly green IPM technology; Finally, the practical problem of insufficient

product categories in the application of green control technology of fruit fly was solved. By enriching the product categories in the application of green control technology of fruit fly and integrating the application of a variety of green control technology of fruit fly, the practical effect of green control technology of fruit fly could be better solved.

5.3 Limitations and future research

In this study, the limitations include the following aspects: First, due to the limitation of the number of experimental samples, there are many kinds of fruit fly hazards in different regions of China, and the natural conditions of each region and the restriction of fruit fly occurrence cycle, the experimental results obtained through random sampling may not be very accurate in analyzing the application effect of green control technology of fruit fly; Secondly, in this study, the research method of carrying out empirical research is mainly carried out through experimental method and case study. Limited by experimental conditions and the number of case samples, the collection of research sample data is insufficient, which may lead to certain limitations of the research results. In addition, the scientific nature of the research method needs to be further improved. The reliability and effectiveness of the research results on the application of green control technology for fruit fly need to be further improved.

About the future research, First, Threat of fruit fly to agriculture, forestry and vegetable production is long-term, and the control task of fruit fly is permanent. (Shen. S.H, 2007). Despite many years of research on the regularity of fruit fly occurrence, the key factors affecting the occurrence of fruit fly are

still not very clear, and only in-depth study on the regularity of fruit fly outbreak can put forward more reasonable control countermeasures and techniques. (Zhou. H. J, 2005).

Then, there are many species, wide distribution and difficult research of Fruit fly in China control. Many key technical problems of fruit fly control have not been solved, including how to realize AI monitoring and improve the accuracy of forecast, explore new efficient biological control technology, simple ecological control technology, behavior control technology, etc., which need to be further studied.

Finally, Fruit fly IPM infestation is not only a matter of natural science and technology, but also a social systematic engineering. (Wang. D.S, 2002). The construction of good infrastructure, funding channels and talent team is equally important for the smooth progress of control of fruit fly infestation. Based on the existing work foundation, the construction of sustainable IPM system engineering of fruit fly infestation aiming at green IPM is its development trend.

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