Research and Application of Meteorological Support Service System for Bean Dan (*Clanis bilineata* tsingtauica) Rearing

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Abstract Bean Dan (*Clanis bilineata* tsingtauica) rearing has become one of the characteristic agricultural projects actively promoted in Guanyun County. One of the important basic conditions affecting the growth and development of Bean Dan, especially its seasonal yield and quality, is the natural climatic resources or the artificially created microclimate environment. Accordingly, Guanyun Meteorological Bureau has designated the "Research and Application of Meteorological Support Service Technologies for Bean Dan Rearing" as a key project for meteorological services in agriculture in recent years. The core of the meteorological support system construction is to fully utilize the achievements of meteorological system modernization, employ the existing monitoring, forecasting, early warning, and service systems, and establish a comprehensive agricultural meteorological indicator system for Bean Dan rearing. This enables intelligent meteorological support services for Bean Dan rearing, thereby safeguarding the development of the local industrial economy.

Key words Bean Dan; *Clanis bilineata* tsingtauica; Guanyun County; Meteorological support service system

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Clanis bilineata tsingtauica belongs to Sphingidae in Lepidoptera. Its larva is commonly referred to as "Bean Dan", a term frequently used in academic literature and also adopted in this paper. According to a comprehensive review of literature at home and abroad, the species has only been documented in China and India. It is native to China and is mainly distributed in the Huang - Huai River Basin, the Yangtze River Basin, and South China, but has a very limited distribution in India. Among these regions, the climatic resources of the Huang - Huai River Basin in China are the most suitable for its growth and reproduction, making it the most densely distributed area and the species' place of origin. The primary host plants of Bean Dan include soybean, Robinia, Chinese wisteria, Pueraria, and Mucuna, among other leguminous plants. Its main target of damage is soybean. The 1st to 2nd instar larvae have a small activity radius and mainly feed on the tender leaves at the top of soybean plants. The 3rd to 4th instar larvae have a larger activity range, and begin to move between plants, which significantly increases their leaf consumption. By the 5th instar, the larvae have grown large and plump, and their feeding amount surges. According to data analysis, their consumption accounts for approximately 90% of the total food intake during the entire larval stage. A large number of Bean Dan can rapidly consume entire leaves, leaving only leaf veins or stems, directly leading to reduced soybean yield or quality, and even complete crop failure. Therefore, controlling or mitigating the impact of Bean Dan on soybean production has long been one of the key agricultural management measures studied in soybean-growing regions of the Huai River Basin.

Insects first appeared on Earth during the Devonian period of the Paleozoic era, approximately 350 - 370 million years ago[1-2]. Through a long process of evolution, various insect groups gradually adapted to the environmental conditions of different climatic regions around the world. However, in the long course of biological evolution, insects seem to have only evolved to adapt to their surroundings, without moving upward in the biological chain, leaving them at a lower level. In other words, insects have effectively become prey for many other organisms. The landmark event that distinguished humans from other organisms during evolution was the ability to create and use tools. This fundamental change meant that survival and evolution were no longer determined solely by food availability. Humans will never be like the anteater, which, despite having appeared as early as 25 million years ago, evolved specifically to meet the ecological demand of feeding on ants and termites, that is, relying on insects as its core food source. In contrast, insects have long become just one item on the human menu. Especially in China, with the development of agricultural civilization, food processing capabilities have increased exponentially, and eating insects has become a matter of seeking benefits and enjoyment rather than necessity. For example, people eat locusts to prevent them from causing crop damage, and consume silkworm pupae to help regulate physical weakness. Therefore, eating insects has been driven by the need to prevent insect damage and to treat illnesses, rather than by food demand per se[3-4].

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This has led to distinct regional characteristics in insect consumption in China, with different areas favoring different insects. For example, in Jiangsu Province, Xuyi is known for eating crayfish, Suzhou for eating crabs, and Guanyun for eating Bean Dan.

From the above analysis, it is evident that insect consumption has become a characteristic regional culinary tradition. Accordingly, the study of edible insects has emerged as an important branch of food research worldwide. Some even believe that insect protein is one of the three main future sources of protein for humans, and advocate for the large-scale development of insect farming as a specialized agricultural sector[5-10]. Many people in Guanyun hope to replicate the "crayfish miracle" of Xuyi by creating a similar success with farmed Bean Dan. Consequently, artificial cultivation of Bean Dan has naturally become one of the important topics of daily concern for the people of Guanyun[11-14].

In summary, the cultivation of Bean Dan has become one of the characteristic agricultural projects actively promoted in Guanyun County. As an insect, whether grown naturally or artificially, one of the important basic conditions affecting its growth and development, especially seasonal yield and quality, is the natural climatic resources or the artificially created microclimate environment. Therefore, in recent years, Guanyun Meteorological Bureau has designated the "Research and Application of Meteorological Support Services for Bean Dan Rearing" as a key project for weather services in agriculture. We have primarily been responsible for the research and development of these meteorological support technologies. To facilitate the exchange of experience and to provide reference information for meteorological support services for other specialized cultivation or breeding projects, the following is an introduction to the research and application of meteorological support services for Bean Dan cultivation in Guanyun County.

Materials and Methods

Study object

The main species cultivated for Bean Dan in Guanyun County is the 5th instar larva of the bean hawkmoth (*Clanis bilineata* tsingtauica), hereinafter referred to as "Bean Dan". The growth progress of Bean Dan during cultivation and the corresponding meteorological conditions during the same period were collected as the study subject.

Data collection

Collection of bean dan growth data The data collection for Bean Dan growth and development followed the standards of GB/T 15804.12009 *Guidelines for the Forecasting and Investigation of Crop Pests – Part* 1: *General Principles*. In addition, considering market quality requirements for Bean Dan cultivation, specific standards were determined and observations were organized by the cultivation department. The main collected indicators included: physical indicators (body length, body weight, color), physicochemical indicators (protein, fat, trace elements, pesticide residues), and food quality indicators (color, texture, taste).

Collection of meteorological data The collection of meteorological data followed the technical standards of GB/T 337032017 *Specifications Observating for Automatic Weather Station* and GB/T 401532021 *Classification and Coding of Meteorological Data*, as outlined in the *Specifications for Meteorological Observation Data Collection and Processing*. Specific observation items were determined and observed by professional technical personnel from the meteorological department. The main collected indicators included: hourly air and soil temperature, air and soil humidity, precipitation, and sunshine duration.

Data collection period Bean Dan cultivation in Guanyun County is carried out by two methods: greenhouse cultivation and open-field rearing. For both methods, the observation and data collection period corresponds to the actual rearing period of each respective method each year.

Data processing

The statistical analysis of characteristic values for Bean Dan and meteorological elements was conducted using statistical methods and completed with a selfdeveloped statistical software. The analysis of the relationship between Bean Dan yield and quality elements and meteorological elements was carried out using the indicator system of agrometeorological support services[15-17].

Results and Analysis

Main meteorological indicator system for the growth and development of Bean Dan

Based on a comprehensive statistical analysis of the collected growth and development data of Bean Dan during the rearing period, together with the corresponding meteorological element data, and combined with a systematic analysis of literature sources, the meteorological indicator system for Bean Dan cultivation in Guanyun County was established as shown in the following table (detailed collected data and calculation processes are omitted).

Table 1 Meteorological indicator system for support services in Bean Dan rearing in Guanyun County

Developmental stage	1st instar larva	2nd instar larva	3rd instar larva	4th instar larva	5th instar larva
Duration (d)	3 – 5	3 – 4	4 – 5	5 – 7	8 – 10
Average temperature (℃/h)	Suitable: 25 – 30; unsuitable: ≤20 or ≥33			Suitable: 25 – 30; unsuitable: ≤15 or ≥35	
Precipitation intensity (mm/d)	≥25				
Relative humidity (%/h)	Suitable: air humidity 60% – 70%, soil humidity 70% – 80%; unsuitable: air humidity <40% or >85%, soil humidity ≤ 40% or ≥90%				
Sunshine percentage (%/d)	Suitable: 50 – 60%; unsuitable: ≤30% or ≥80%				

Content of the meteorological support service system for Bean Dan rearing

The meteorological support service system for Bean Dan rearing in Guanyun County was designed and constructed based on four modules: monitoring, forecasting, early warning, and service[18-22]. The specific construction content is as follows.

Construction of the monitoring system Using hourly automatic weather station data from the existing national meteorological monitoring network, a dynamic analysis of the comprehensive indicators corresponding to the cultivation meteorological indicator system for Bean Dan at different growth stages was performed automatically on an hourly basis. Analysis product reports (document files) were generated accordingly.

Construction of the forecasting system Using hourly numerical forecast products from the existing national meteorological forecasting system, the specific meteorological elements of the rearing meteorological indicator system corresponding to the growth stage of Bean Dan in Guanyun were interpreted and applied. This resulted in the generation of specialized meteorological element forecast products (document files).

Construction of the early warning system Through the full utilization of numerical products generated by the monitoring and forecasting systems, along with the recent achievements in smart meteorological construction (as described in "Construction of the forecasting system"), intelligent early warning products (document files) were automatically generated.

Construction of the service system By fully utilizing the achievements in meteorological early warning service construction and using the existing meteorological system as a carrier, the meteorological service products for Bean Dan rearing are promptly delivered to government agencies, management departments, business operators, and producers. This ensures that these products fully play a reference role in production management.

Main service products

Publication of the *Guanyun Meteorological Service Technical Manual for Bean Dan* The *Guanyun Meteorological Service Technical Manual for Bean Dan* covers three main aspects: "Overview of Bean Dan Production in Guanyun County and Climatic Characteristics", "Meteorological Service Techniques for Bean Dan", and "Major Meteorological Disasters During Bean Dan Growth and Their Defense Measures". (1) It systematically assesses the climatic adaptability of Guanyun County's climate resources for Bean Dan rearing and provides guidance on how to rationally utilize climatic conditions for scientific breeding. (2) It systematically introduces the main meteorological support service products available from the meteorological department during the preproduction, production, and postproduction stages of Bean Dan rearing in Guanyun County, as well as the technical channels for accessing these products, thereby offering an index for management, production, and operational personnel. (3) It proposes scientific prevention plans for possible meteorological disasters during the rearing process, providing decisionmaking reference information for effective disaster prevention.

Compilation of the *Annual Plan for Meteorological Support Services* Each year, based on the new service needs of the current year and the current status of the meteorological department's service capacity building, the *Annual Plan for Meteorological Support Services* is compiled and distributed to service recipients and relevant operational departments. This ensures that both service providers and recipients have a clear set of guidelines to follow. Taking the 2025 "Plan" as an example, the annual meteorological support services for Bean Dan rearing were meticulously planned in terms of "service period, service recipients, service products, service formats, and service priorities at each stage", thereby providing technical support for routine operational meteorological support services for Bean Dan rearing.

Timely issuance of monitoring, forecasting, and early warning products During the Bean Dan rearing period, specialized monitoring, forecasting, and early warning products for meteorological support of Bean Dan rearing are issued daily. The content of these products follows the format of agricultural weather forecasts, with three core components: "weather and climate forecast, assessment of weather and climate impacts, and recommendations for agricultural production management measures"[23]. The products are available in data formats compatible with "SMS, WeChat, public WeChat accounts, and fax".

Conclusion and Discussion

Based on the comprehensive analysis, the following conclusions are drawn:

(1) The climatic resources of Guanyun County, China, make it one of the most suitable regions for the natural reproduction, growth, and development of Bean Dan. Consequently, Guanyun County has always been a primary habitat area for Bean Dan.

(2) It is a major pest in local soybean production. When weather and climate conditions in a given year are favorable for its outbreak, the pest can proliferate massively, severely affecting soybean yield and quality. For example, *Yongzheng Andong County Gazetteer* (1727) records in Volume 17 *Miscellaneous Affairs* that Andong County (whose jurisdiction at the time covered areas east of Huai'an, north of Yancheng, and south of Lianyungang, with today's Guanyun County at its core) documented the pest's damage as follows: "… The county cultivates soybean over a large area. During the fifth and sixth lunar months, when drought occurs, dou teng (here annotated as Bean Dan) appears, causing the most severe damage. … At the time when the soybean flowers are about to form pods, the pest is at its peak of destruction. … Hundreds or thousands of hectares are devastated, as if scorched by fire. …" To prevent the damage caused by Bean Dan to soybean production, people had to take action by eating Bean Dan, much like how northerners ate locusts. In other words, the original purpose of eating Bean Dan was to control crop damage, not for culinary enjoyment or pleasure.

(3) While people obtain natural nutrients by eating insects,

they also face significant risks, and eating Bean Dan is no exception. The *Miscellaneous Affairs* also records the toxic effects of Bean Dan on humans, stating: "… Occasionally, some try to cut the pest, but within a short time, they are infected by its poison, causing facial swelling, dizziness, and a feeling of suffocation approaching death …". According to literature reviews and online collections, the only reported risk associated with its consumption to date is allergic reactions. For example, on November 6, 2006, the DXY biomedical network reported a case in which a 36-year-old man experienced whole-body skin redness approximately one minute after consuming Bean Dan, accompanied by mild chest tightness. He was diagnosed with a Bean Dan allergy and immediately treated with oxygen inhalation, intravenous injection of dexamethasone, intramuscular injection of phenergan, and intravenous injection of glucose with vitamin C. One hour later, his symptoms disappeared, and he was discharged from the hospital. In fact, the risk of eating Bean Dan is far lower than that of Jiangsu's delicious pufferfish. However, through the efforts of people in Hai'an, Jiangsu, pufferfish have been made nontoxic by developing detoxification aquaculture techniques, enabling their nationwide popularity. Among these efforts, meteorological personnel in Hai'an contributed to the development of meteorological support services for nontoxic pufferfish farming, thereby boosting the pufferfish industry[24]. This has prompted meteorological professionals in Guanyun to consider how to develop meteorological support services for nontoxic Bean Dan rearing. They must contemplate a key task for the coming period: investigating the relationship between toxin development in Bean Dan and environmental conditions, and then regulating the microclimate of their rearing environment to reduce toxin content, thereby making Bean Dan a safe food for consumers.

(4) At present, factoryscale rearing of Bean Dan has not yet been achieved. Current artificial rearing essentially involves transplanting its host plant, soybean, from the field indoors, but it still fundamentally consists of artificially growing soybean and allowing Bean Dan to grow naturally on it. This necessarily requires us to consider soybean varieties and the impact of soybean growth and development on Bean Dan yield and quality. That is, meteorological support services may need to target not only Bean Dan, but also the climatic conditions for both outdoor and indoor soybean cultivation, as well as provide support services for the entire soybean growth and development process. This requires us to further improve meteorological plans and procedures, optimize the service system, and achieve full coverage of meteorological support services.

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