Research on Tea Planting Technology Based on Intelligent Agricultural Internet of Things

Zhongdong Wang[1], Jiale Guo[1,*], Ang Xue[2], Yuqi He[1]
[1]Smart Agriculture College (Internet of Things Engineering College), Guangxi Science & Technology Normal University, Laibin 546199, Guangxi, China
[2]School of Environmental and Energy Engineering, Beijing University of Civil Engineering and Architecture, Beijing 100010, China
*Corresponding Author.

Abstract: Based on the intelligent agricultural Internet of Things technology, this paper discusses the application principles and advantages of intelligent agricultural Internet of Things technology in environmental monitoring, intelligent irrigation and fertilization, and disease and pest monitoring and early warning in the tea planting process, aiming at the problems of environmental factors interference, low resource utilization efficiency and difficult disease and pest control in the traditional tea planting process. At the same time, the problems faced by the application of this technology were discussed, and corresponding solutions were proposed, aiming at promoting the intelligent development of tea planting and providing theoretical support and practical reference for improving the quality and yield of tea.

Keywords: Smart Agriculture; Internet of Things Technology; Tea Cultivation; Environmental Monitoring; Intelligent Irrigation and Fertilization; Disease and Pest Monitoring and Early Warning

1. Introduction

As an important cash crop, tea occupies an important position in the global agricultural economic system, but also has a rich variety and a long history. In traditional tea planting methods, most tea farmers rely on their own experience to plant, and lack scientific and quantitative management methods in the planting process. Therefore, in the process of tea planting, the accuracy is often low, such as in fertilization and irrigation, often can not grasp the best time and dosage; Resource utilization efficiency is low, it is difficult to achieve efficient transformation of water resources and fertilizers, and a lot of resources are wasted. In the face of complex and changeable environment, the ability to cope is far from enough, and when extreme weather and climate change come, it will have a greater impact on the yield and quality of tea. However, with the cross-era development of intelligent technologies such as the Internet of Things, sensors, and big data, intelligent agricultural Internet of Things technology provides an opportunity for the modernization of tea industry planting. With comprehensive real-time monitoring and high-precision regulation, the technology is deeply embedded in all aspects of the tea industry, from the growing environment of tea, resource utilization, to the prevention of diseases and pests, all of which can achieve dynamic tracking and scientific management. This not only effectively optimizes the planting process of the tea industry, but also greatly improves the quality and yield of tea, enabling it to significantly enhance its comprehensive competitiveness in the market with stable and high-quality product characteristics.

2. Challenges Facing the Tea Industry

2.1 Environmental Factors Interfere Greatly

The growth of tea is greatly disturbed by environmental factors, which requires appropriate temperature and humidity, light, soil pH and nutrient content, etc. Any abnormality will easily affect the quality and yield of tea. Take light and soil pH as an example.

2.1.1 Light plays a decisive role in shaping the quality of tea

Tea is a shade-loving and shade-tolerant plant. Diffuse light is the best light for tea growth,

and the best tea quality is produced when the light is blocked by 30% to 40%. When tea trees grow under full light conditions, the tea produced will have the disadvantages of small leaf shape, thick leaves, short inter node and hard and brittle leaves. The tea tree grown under the condition of shading has large leaf shape, thin leaves, long inter node and soft leaf quality, and the content of nitrogenous compounds, caffeine, amino acids, chlorophyll and nitrogenous aromatic substances are increased, and the tender retention is good. At the same time, the carbohydrate is reduced, the poly phenol content of tea is reduced, and the astringency of tea is weakened [1].

2.1.2 Soil pH is the foundation of tea growth

Acidic soil is a necessary condition for the growth of tea trees, and the pH of the soil suitable for tea trees is roughly 4.0 to 5.5. Tea plants grow under suitable pH conditions, the content of chlorophyll in the leaves produced by tea plants is relatively high, so the photosynthesis capacity is also strong, compared with the respiratory consumption is weak, and the synthesis and accumulation of organic matter is large. However, when the tea tree grows under too acidic or alkaline conditions, the leaf color of its output will be yellow, resulting in weak photosynthesis, but strong respiration, at this time consumption is greater than synthesis, and finally the accumulation of organic matter is very little, and the growth is abnormal. At the same time, when the soil pH is suitable, the tea tree has a stronger ability to absorb nutrients. On the contrary, even if a lot of fertilizer, tea trees are difficult to absorb and use. Therefore, it is necessary to provide suitable soil pH for tea plants [2].

However, it is difficult for traditional planting methods to achieve real-time and accurate detection and management of these environmental factors. Tea farmers, for the most part, rely on their own experience, observing the appearance of tea plants, changes in the weather and seasons. However, there are obvious limitations in this way, and it is impossible to analyze environmental factors scientifically and quantitatively. In the face of climate change and complex and diverse soil conditions, it is difficult for traditional planting methods to detect and take effective measures in time. This makes tea production unstable, and the quality of the tea produced is also uneven, which cannot meet the growing demand for high-quality tea in the market.

2.2 Resource Utilization Efficiency is Low

In the traditional tea planting mode, the problem of low resource utilization efficiency is very serious, especially in irrigation and fertilization.

The traditional irrigation method is generally judged by the experience of tea farmers, and lacks accurate measurement and scientific planning, which is easy to cause the problem of insufficient or excessive irrigation.

2.2.1 Under irrigation

Due to the lack of accurate detection of soil conditions and water requirements of tea trees, tea farmers cannot timely detect the water needs of tea trees, especially in the dry season, when tea trees are in urgent need of water to maintain growth and metabolism, if the irrigation is insufficient, the physiological activities of tea trees will be severely inhibited. As a result, the growth rate of new shoots of tea plants slows down, the leaves cannot fully unfold, become thin and yellow, and the photosynthesis efficiency is reduced, thus affecting the yield and quality of tea. Moreover, long-term water shortage will also lead to the reduction of the resistance of tea trees, making it more susceptible to the attack of diseases and pests, greatly increasing the difficulty and cost of tea garden management.

2.2.2 Over irrigation

In the traditional irrigation mode, over-irrigation often occurs, which leads to a large amount of water resources being wasted, and also produces a series of negative effects on the growth of tea trees. When the soil is saturated with water for a long time, the air permeability will be damaged, and then the soil will begin to harden, destroying the original excellent aggregate structure of the soil, thus affecting the normal respiration and growth of tea roots. In addition, with a large amount of water washing, nutrients in the soil will also be lost, which will greatly reduce the nutrients available for the growth of tea trees.

In addition to irrigation problems, there are also many unreasonable places in fertilization. When applying fertilizer, tea farmers rarely apply fertilizer precisely according to the actual needs of different growth stages of tea trees, resulting in frequent excessive fertilization. This leads to a significant increase

in production costs, and the excess fertilizer will flow into the surrounding water and soil environment along with the erosion of rain or soil infiltration, causing environmental pollution in the nearby area and affecting the ecological balance.

Statistics show that in the traditional tea planting process, the waste rate of water resources is as high as 30%-50%, while the utilization rate of fertilizer is only 30%-40%. Water resources have not been rationally utilized, fertilizers have not been fully absorbed, and a large amount of water resources and fertilizers have been wasted, which not only increases the planting cost, but also has an impact on the surrounding environment. This has seriously affected the sustainable development of the tea industry.

2.3 Pest Control is Difficult

With the rapid development of the current tea industry, the types of tea plant diseases and pests began to increase, and the degree of harm was becoming more and more serious, which seriously affected the healthy growth of tea plant. In the traditional pest control methods, tea farmers often use chemical pesticides, which can quickly control pests and diseases and ensure tea production, but frequent and large use of chemical pesticides will bring a series of serious problems.

First of all, excessive use of chemical pesticides will lead to excessive pesticide residues. Relevant studies have shown that some tea producing areas due to a large number of large-scale use and abuse, and chemical pesticides are non-degradable, pesticides cause serious pollution to the tea garden, the pesticide residue of the tea produced far exceeds the national standard, affecting the quality of the tea, so that the original fragrant tea with chemical odor. At the same time, these excessive pesticides not only pollute the soil, but also enter the human body with the food chain, endangering health.

Secondly, overuse of chemical pesticides will destroy the ecological balance. The heavy use of pesticides will kill many beneficial organisms while eliminating diseases and pests, thus destroying the ecological balance, making pests further multiply due to the lack of natural enemies, resulting in more and more serious diseases and pests. The improper use of pesticides has destroyed the ecological balance

of nature and caused a large number of diseases and pests that did not pose serious harm in the past. In addition, over time, pests and diseases have gradually developed resistance to chemical pesticides. According to statistics, the resistance of some diseases and pests to commonly used chemical pesticides has increased several times or even tens of times. This also means that in order to achieve the same control effect, the use of pesticides needs to increase the dose, thus falling into a vicious circle, not only aggravated the damage to the ecological environment, but also greatly increased the difficulty of pest control [3].

With the increase of people's awareness of food safety and ecological environmental protection, the traditional way of relying on chemical pesticides to control pests and diseases has become outdated, so more green and sustainable pest control strategies need to be used.

3. Application of Smart Agricultural Internet of Things Technology in tea Planting

Smart agriculture Internet of Things technology in the tea industry planting includes environmental monitoring, intelligent irrigation and fertilization and disease and pest monitoring and early warning three parts, through the joint action of the three to improve the growth environment of tea trees, promote the healthy growth of tea trees, improve tea quality and yield. The concept diagram is shown in Figure 1.
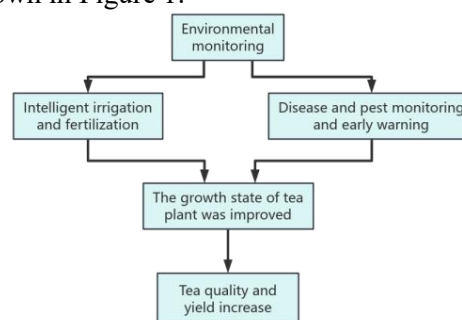

Figure 1. Smart Agriculture IoT Technology Application Link Concept Map

3.1 Environmental Monitoring

3.1.1 Sensor deployment

In order to improve the intelligence and refinement level of tea garden management, various sensors are rationally arranged and deployed in different functional areas of the tea

garden according to scientific planning and accurate calculation, and then a comprehensive and efficient monitoring system is built.

Temperature and humidity sensors are the key detection equipment for the microclimate of tea gardens, and generally need to be arranged near the tea canopy to ensure real-time, dynamic and accurate acquisition of changes in air temperature and humidity inside the tea garden. Data acquisition by these sensors provides continuous and reliable environmental data for tea garden management and provides a basis for the formulation of subsequent planting strategies.

The installation of light sensors requires careful consideration and design to achieve accurate measurement of light intensity and light duration. The sensor needs to accurately record the light data of different periods in the morning, middle and evening, and provide the data to the tea garden manager, so that the tea garden manager can regulate the shading facilities and implement the light supplement measures according to the light exposure of tea trees in different periods.

Soil moisture sensors can detect soil moisture in the ground. Buried in soil at different depths around tea roots, they can monitor and collect soil moisture content data at all times. When soil moisture deviates from the range required for tea growth, abnormal data will be immediately fed back to the management system. Through these abnormal data, the tea garden managers can adjust the irrigation amount, which can effectively avoid the problem of insufficient or excessive irrigation caused by the wrong judgment based on experience [4].

Soil pH sensor is an important monitoring equipment for soil quality. The equipment continuously and stably detects the pH value of the soil, and sets the threshold value according to the requirements of the tea tree for soil pH, so as to maintain the stability and suitability of the soil environment in the tea garden. When the deviation from the threshold occurs, the manager can take improvement measures on the soil based on the data feedback in a timely manner to ensure that the soil environment is always in a state suitable for the growth of tea trees.

Weather station is a comprehensive platform for collecting meteorological information of tea garden. The facility is usually built in an open, well-ventilated and representative place, and it can collect meteorological data on wind speed, wind direction, rainfall and other aspects. At the same time, weather stations can not only provide managers with current meteorological information, but also predict weather trends in the future based on historical data analysis and big data algorithms, so that managers can plan in advance and take corresponding preventive measures to deal with possible weather changes.

In addition to the sensors introduced above, there are many types of sensors that can also be applied to the intelligent management of tea gardens. All kinds of sensors working together can build a comprehensive, multi-level and three-dimensional monitoring network of tea gardens, providing a strong data basis for the intelligent management of tea gardens, so that managers can make scientific and reasonable decisions on the basis of these data. Then promote the improvement of tea yield and quality, and promote the sustainable development of tea industry.

3.1.2 Data acquisition and transmission

In the tea industry planting of smart agricultural Internet of Things system, sensors play the role of data acquisition. Various sensors such as temperature and humidity sensors, light sensors, soil moisture sensors and soil pH sensors collect data of environmental information in the tea garden, and then transmit these data efficiently to the gateway through the wireless sensor network. After receiving the data collected by the sensor, the gateway will collect the data. The initial processing and packaging of raw data is done quickly so that it has the format required for secure and efficient transmission. Then it is uploaded to the cloud server through 4G/5G network or the Internet, and the data is stored and analyzed in the cloud server, which further provides a strong basis for the intelligent management of the tea garden.[5]

Among them, the system supports a variety of communication methods, can adopt multiple signal output at the same time, and without any change, can use more than two communication methods at the same time, and can use one communication method to achieve a number of functions, and support the connection and communication with multiple environmental monitoring centers [6]. The system structure is shown in Figure 2.
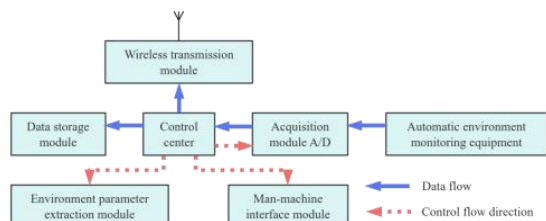
Figure 2. Data Acquisition and Transmission System Composition

3.1.3 Data analysis and decision support
Based on advanced big data analysis technology, the cloud server analyzes all kinds of environmental data collected by the sensor, and integrates and cross-analyzes all kinds of data through precise algorithms. At the same time, a tea tree growth model is built based on a large number of scientific studies, field visits and past data, which contains the optimal range of parameters required by tea trees for environmental factors at each growth stage. Then, the cloud server compares the data collected in real time with the growth model, so as to determine whether the current tea tree is in the best condition for tea tree growth. If the comparison data shows that the current environmental parameters deviate from the appropriate range, the system will issue corresponding response measures according to the abnormal data, and put forward reasonable rectification suggestions for the manager and prepare for the next step [7].

Through this intelligent environmental monitoring mode, under the condition of allowing managers to visualize environmental data, it also provides managers with comprehensive, scientific and forward-looking tea garden management suggestions to help tea gardens achieve fine management and ensure that tea trees are always in a good and suitable growth environment, so as to improve the yield and quality of tea and promote the intelligent and efficient development of the tea industry.

3.2 Intelligent Irrigation and Fertilization
3.2.1 Intelligent irrigation system
Under the intelligent environmental monitoring mode, the intelligent irrigation system is supported by strong data. According to the water demand of tea plants at different stages, the system implements intelligent management of irrigation facilities based on the data of temperature, humidity and soil conditions in environmental monitoring data, and reasonably controls the switching time and water output of irrigation facilities.

At the same time, the irrigation facilities adopt advanced technologies such as drip irrigation and micro-sprinkler irrigation to transport water to the roots of tea trees that are really short of water and need water, greatly improving the utilization efficiency of water resources. At the same time, the manager can also remotely control the irrigation system according to the needs of the mobile phone app and other ways, no matter where the operation status of the system can be checked at any time and the relevant parameters can be adjusted, so as to realize the rationalization, intelligence and high efficiency of tea garden irrigation [8].

3.2.2 Precision fertilization system
Precise fertilization system is an important part of fine management in tea industry. The system combines the soil conditions collected by environmental monitoring and the specific needs of tea trees at the current stage to analyze, make a reasonable ratio of fertilizer, dynamically track the content of various elements in the soil and the requirements required for the growth of tea trees during the fertilization process, and timely change the fertilization plan.

At the same time, the system can be used in conjunction with the irrigation system, and the fertilizer is accurately transported to the root of the tea tree with the irrigation and watering, which not only ensures the efficient absorption of nutrients by the tea tree, but also greatly improves the utilization efficiency of the fertilizer. Studies have shown that compared with traditional fertilization methods, the fertilizer utilization efficiency of the precision fertilization system has increased by 20%-30%, and the number of fertilization has been reduced, avoiding the problems of soil compaction and nearby environmental pollution caused by excessive fertilization, and laying a solid foundation for green and efficient tea gardens.

3.3 Disease and Pest Monitoring and Early Warning
This part consists of two parts: the pest monitoring system and the early warning system. The data collected by the pest monitoring system is transmitted to the cloud for data analysis, and then it is determined whether the alarm threshold is reached. After reaching the alarm threshold, the early warning

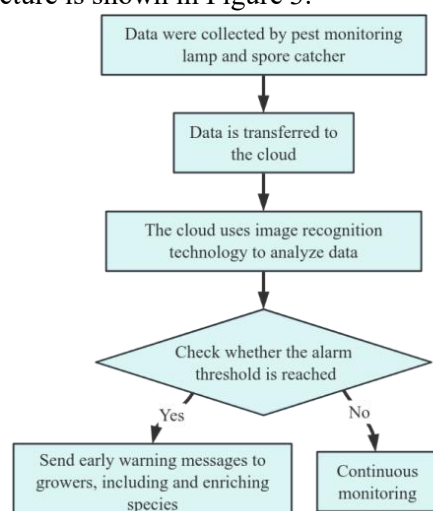information is sent to the growers. The system structure is shown in Figure 3.

Figure 3. Pest and Disease Warning Flow Chart

3.3.1 Pest monitoring system

The pest monitoring system is mainly composed of bug situation monitoring module, pathogen spore monitoring module and remote video monitoring module of pests and pests. Through the Internet of Things information acquisition terminal, the pest, disease and tea garden video information are collected to monitor the growth of tea trees in real time [9].

The worm situation monitoring module mainly realizes the worm situation monitoring function. This module displays the insect situation information such as the total number of pests in a certain period and a specific area, insect images and the occurrence number of certain pests in the form of lists, and displays the trend of insect situation changes in the form of statistical charts. In addition, the module also intuitively reflected the pest occurrence area and pest density on the map by making thematic maps, so that the occurrence of pest in the tea garden can be visualized.

The main function of pathogen spore monitoring module is to monitor pathogen spore. The system provides a screening and query function for the number of pathogen spores, which can be accurately queried according to the time period, monitoring point and other conditions. At the same time, it also shows the development trend of pathogen spores over time in the form of statistical charts, and compares data from different regions and different growth stages, so that managers can have a more comprehensive understanding of the change law of pathogen

spores. In addition, the module also intuitively reflected the disease occurrence area on the map by making thematic maps, so that the occurrence of disease in the tea garden can be visualized.

The remote video monitoring module includes real-time monitoring, historical video, picture center and so on. Among them, the real-time monitoring provides the multi-channel screen display of the tea garden camera and the control function of the head, which realizes the remote online viewing of the growth of tea plants and the occurrence and infringement of diseases and pests, and provides a reference basis for the staff to judge the types and development degree of diseases and pests.[9]

3.3.2 Early warning system

The early warning system mainly monitors the environmental factors (such as temperature, humidity, light, etc.) and the occurrence characteristics of diseases and pests in the tea garden in real time, and uses mathematical models, statistical methods and artificial intelligence technology to predict the occurrence trend of diseases and pests in the future period of time. To provide scientific basis for pest control in tea garden.

The occurrence of diseases and pests is closely related to climate and environment. Therefore, a threshold value can be set on the system for environmental parameters such as air temperature and humidity and soil temperature and humidity in the range prone to diseases and pests. When the environmental monitoring data exceeds the threshold value, the system will issue an early warning information on the probability of diseases and pests occurrence. The warning information will then be displayed on the map, and the system will automatically send a message to the staff and farmers to remind them. In addition, the staff of the tea garden can also use manual analysis to predict the occurrence of diseases and pests by viewing the environment and pest monitoring data within the system, and use the system warning function to manually send early warning information to farmers and other relevant personnel [9].

4. Problems Facing the Application of Smart Agriculture Internet of Things Technology

Although smart agricultural Internet of Things technology Outlines a promising prospect for

the development of the tea industry, it is faced with a series of difficult problems in the actual promotion and application.

4.1 Higher Cost
In order to realize the implementation of smart agricultural Internet of Things technology, there are great challenges in terms of funding. The purchase of a large number of sensor facilities, intelligent devices, and the construction of Internet of Things communication systems require high initial capital in the pre-construction process. The costs of equipment maintenance, data storage and analysis continue during subsequent operations. For small-scale tea growers and enterprises, these expenses are an unbearable financial pressure. Therefore, the high economic cost restricts the popularization of this technology.

4.2 Skilled Personnel Shortage
Smart agriculture Internet of Things technology integrates the knowledge of agriculture, Internet of things, information technology and other disciplines, and requires professionals with relevant knowledge and skills. But at present, there is a shortage of smart agricultural talents in China, especially in emerging technologies and cross-disciplinary talents. As the development of smart agriculture is not mature enough, enterprises are faced with certain market risks and uncertainties, resulting in the loss of some talents. This also brings certain challenges to the development of smart agriculture.

4.3 System Compatibility and Stability Need to be Improved
Because of the different formats and structures of data collected by different devices and sensors, data fusion is difficult and consumes a lot of time and resources. At present, there is still a lack of a complete set of standardized and automated data fusion schemes. At the same time, the environment of the tea garden is complex, and adverse factors such as temperature and humidity and electromagnetic interference will lead to instability of the equipment, resulting in data transmission interruption, equipment failure and other problems, which seriously affect the normal operation of the smart agriculture Internet of Things system.

5. Solution Strategy

5.1 Reduce Cost
In order to effectively solve the cost problem of the promotion of smart agricultural Internet of Things technology in the tea industry, efforts can be made from multiple dimensions.
In terms of technology research and development, increase investment in the research and development of hardware such as sensors and intelligent devices, encourage innovation, and strive to introduce low-cost, high-performance sensors, improve equipment integration and versatility, and reduce costs from the source.
In terms of policy support, the government should introduce targeted policies to give financial subsidies and tax incentives to tea growers and enterprises that adopt this technology to reduce the burden of its application.
In terms of industrial development, enterprises can be encouraged to scale production and application to dilute unit costs, and cooperation with financial institutions can be explored to ease the financial pressure of enterprises with the help of financial services such as financial leasing, and all-round promotion of smart agricultural Internet of Things technology in the tea industry.

5.2 Strengthen Personnel Training and Technical Training
In order to fill the talent gap of smart agriculture Internet of Things technology, colleges and vocational colleges should optimize the professional layout, vigorously strengthen the interdisciplinary construction of agriculture and Internet of things, improve the curriculum system and practical teaching links, and accurately train composite talents that meet the development needs of smart agriculture.
At the same time, the government, enterprises and scientific research institutions need to work together to build a training mechanism for agricultural iot talents, accelerate the training of professional and composite technical talents, and enhance the ability of technological innovation and promotion and application. With the help of the conditions and teaching staff of colleges and universities, open up the cross-training direction of the

Internet of Things field and the agricultural field; Joint agricultural product production enterprises and breeding and breeding large households, promote the deep combination of production, university and research, explore the theory with practice of personnel training mode, strengthen the production and sales of front-line technical personnel training. In addition, it is also necessary to establish a talent incentive mechanism, stabilize and expand the talent team, and meet the talent needs of the development of agricultural Internet of Things [10].

5.3 Improve System Compatibility and Stability

Vigorously promote the research of key technologies in the process of technology research and development, achievement transformation and promotion and application, actively digest and absorb international advanced experience, develop high-reliability, low-cost and adapt to the harsh environment of agricultural resources, environment, crop growth dynamic information acquisition sensors and animal behavior information sensors, and develop micro-sensor energy self-excitation supply and energy-saving control technology. New data storage and processing technologies such as cloud computing and big data are introduced to provide technical support for system integration and large-scale application of agricultural Internet of Things technology products [10].

Organize relevant experts and scholars to study the basic and universal standards of agricultural Internet of Things, and formulate iot standards suitable for the actual needs of agricultural production as soon as possible. Including the research and development of agricultural sensors and identification equipment function, performance, interface standards, field data transmission communication protocol standards, agricultural multi-source data fusion analysis and processing standards, agricultural Internet of things implementation specifications, etc., to promote the overall development and scale application of agricultural Internet of things in China with standardization guidance.

6. Conclusion

The integration of smart agricultural Internet of Things technology has opened up a new road for the modern and intelligent development of the tea industry, and has brought unlimited bases and challenges. By monitoring the environment system, the manager can grasp the environment of the tea garden in real time, and create the best climate and soil conditions for the growth of tea trees. Intelligent irrigation and fertilization make reasonable use of water resources and fertilizers to avoid resource waste. Pest monitoring and early warning may reduce the occurrence of pests and diseases. These functions not only improve the quality and yield of tea, but also optimize the efficiency of resource utilization and greatly enhance the production efficiency of the tea industry.

In short, the application of smart agricultural Internet of Things technology in the field of tea planting has broad application prospects and huge development potential. Through the realization of functions such as intelligent monitoring and control system, precise fertilization and irrigation system, disease and pest warning and control system, and tea traceability and quality management system, intelligent agricultural iot technology can optimize tea production management, improve tea quality and safety, and promote the sustainable development of tea industry. With the continuous development and improvement of Internet of Things technology, smart agricultural Internet of Things technology will become an important trend and direction of tea planting in the future.

References

[1] Jiang Beibei, Wei Xingzhang, Huang Chunyong, et al. Brief Analysis of Key Technologies for Ecological Tea Garden Construction. Seed Science and Technology, 2022, 40(08): 24-27.

[2] Liu Baoshun. The Natural Ecological

Environment and Quality of Wuyi Rock Tea. China Tea, 2017, 39(08): 36-37.

[3] Zi Qiang, Zhang Long, Zhang Jian. Analysis of the Current Situation and Control Methods of Eucalyptus Pests and Diseases in Guangxi. Southern Agriculture, 2023, 17(06): 71-73+77. DOI: 10.19415/j.cnki.1673-890x.2023.06.023.

[4] Ge Xiang, Tan Chengwei, Xue Yayong, et al. Deployment and Scheduling Algorithm for Wireless Sensor Network Coverage. Journal of Jilin University (Information Science Edition), 2024, 42(03): 400-405. DOI: 10.19292/j.cnki.jdxxp.2024.03.001.

[5] Zhang Hong. Research and Design of Cloud Platform for Facility Agriculture Internet of Things Based on Distributed Computing. Nanjing Agricultural University, 2017.

[6] Wang Xianfeng. Design and Function Implementation of Environmental Automatic Monitoring Data Acquisition and Transmission System Architecture Based on Internet of Things. China Environmental Management, 2013, 5(04): 53-57.

[7] Cao Jianshu, Zhai Jingbo. Application Research of Intelligent Agricultural Technology in Crop Growth Monitoring and Management. Digital Agriculture and Intelligent Agricultural Machinery, 2023, (12): 30-32.

[8] Zhao Yanlin, Zhang Yufeng, Zhang Jingbo. Research on Agricultural Intelligent Irrigation System Based on Internet of Things Technology. Modern Rural Science and Technology, 2024, (12): 73-74.

[9] Zhao Xiaojuan, Ye Yun, Ran Yaohu. Design and Implementation of Tea Tree Pest and Disease Monitoring and Early Warning System Based on Internet of Things. China Agricultural Information, 2019, 31(06): 107-115.

[10] Wang Xiaojuan, Liu Caifeng, Xie Hong, et al. Current Situation, Existing Problems and Countermeasures of Agricultural Internet of Things Development in China. Journal of Anhui Agricultural Sciences, 2017, 45(01): 215-217.