Application of Intelligent Sprinkling System in Modern Agriculture——Taking Shijiazhuang Tongfu Smart Farm as an Example

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Abstract: China is a great power in population and agriculture. The crop yield is crucial to food security and national security, while the wide application of plant protection technology is an important means of improving the grain output and therefore can guarantee high and stable crop yield. It is important to pay attention to the integrated pest management in the crop growth process, especially the scientific sprinkling mode of pesticides. At present, most sprinkling devices still depend on on-site manual operation because of the low degree of automation and intellectualization. Besides, the accompanied volatilization of pesticides often threatens the physical health of the operator. In fact, the development of information communication and intelligent equipment and technology is accelerating the transformation of mechanical and automatic agricultural production into smart agriculture featured with "information perception, quantitative decision-making, smart control, accurate input" and the transformation of traditional pesticide spraying into intelligent spraying mode. With the development of science and technology, the intelligent sprinkling system is widely used in production practice. The study takes the intelligent sprinkling system for vegetable cultivation from Tongfu Group as an example to investigate its operating principle, structure, functional characteristics and explore the science and technology principle and development direction of the system and discuss the marketing of the system.

Keywords: Smart sprinkling system; Crop-dusting; Information agriculture; Smart agriculture

I. Overview of intelligent sprinkling system and its application

(1) Overview of intelligent sprinkling system

In modern agriculture, the intelligent sprinkling system mainly consists of hardware (e.g. sensor, UAV for sprinkling device) and software (high-speed Internet, cloud database, app). In the agricultural operating environment, the intelligent sprinkling system can send related instructions through computer processing based on the collected data by the sensor and then sprinkle the pesticides in a stipulated region in a fixed amount and time as per predetermined speed. On the one hand, the system can adjust its operating status based on actual conditions to achieve the ideal sprinkling effect. On the other hand, the system can realize automatic control and satisfy specific demands of agricultural production to achieve a better operating effect without manual control [1]. A set of mature intelligent sprinkling systems can not only greatly improve the agricultural operating efficiency, and achieve high productivity, but also reduce agricultural pollution and promote the development of green agriculture.

(2) Application of foreign and domestic intelligent sprinkling systems

In recent years, the intelligent sprinkling system has not been used frequently in China where the single sprinkling device is mainly used and a set of a complete intelligent system is lacking. With the development of

science and technology and high-quality agricultural development, the intelligent sprinkling system has a wide market prospect. At present, the frequently used sprinkling devices in rural areas of China are still backpack-type manual sprayers and backpack-type automatic sprayers which are not advanced in structural form and technical performance. In the process of pesticide application, the "bubbling and dripping" may result in a serious intoxicating phenomenon. The fragile components, low pesticide utilization for machines and tools and only 20%-30% [2] of pesticide utilization for manual sprayers may lead to serious waste and poisoning of operators. Besides, the poor quality of sprayer, nonuniform pressure, bad atomization effect and low pesticide effect may lead to serious land pollution and low power. The UAV for plant protection is widely used in plain areas and some hilly and mountainous areas in Heilongjiang, Xinjiang, Jiangsu and Henan. By the end of 2018, the registered agricultural UAVs were about 31,500 and the total operation area for flight defense reached 20 million hm^2/time in China. In 2020, China saw a boom in the UAV market. By 6 May 2020, DJI Technology sold over 20,000 UAVs for plant protection, which even exceeded the sales volume of the previous year [3]. The data reveals that China's plant protection field is developing in the direction of intellectualization, but there is a long way to go to apply a complete and large-scale intelligent sprinkling system.

It is worthwhile to learn from foreign experiences in the intelligent sprinkling field. In developed countries, air sprayers are mainly used to spray the pesticide, bactericides, leaf fertilizers and herbicides in agricultural production, for example, the fertilization robot from the USA and weeding robot from Germany can realize accurate recognition in the intelligent spraying operation and achieve remote operation and control. When detecting weeds, the Weed Seeker sprinkling system from USA Patchen can spray pesticides for weeds in a targeted direction through controlling the spray nozzle to complete the accurate sprinkling and directional pesticides application process. The device is mainly used for spraying pesticides for weeds between the ridges, along the ditch and on both sides of the road.

Depending on the high degree of automation and intellectualization, Japanese sprinkling devices always play a leading role in UAV plant protection. In 1990, the Japanese Shanye Company launched the first unmanned helicopter for spraying pesticides in the world, which was featured with high efficiency and safety and without topographical limitation. As a result, the UAV realized fast development. In addition, Japan also launched the cable-induced unmanned sprinkling device which could generate a magnetic field when the cable was laid along the operating line after power-on. The sensor detects the magnetic field and walks along the magnetic field to complete the unmanned spraying work. It is widely used in integrated pest management for the orchard garden because it can improve the efficiency for over two times and thoroughly solve pesticide poisoning and noise hazard. Although the foreign intelligent sprinkling device was developed early, there were still problems. Due to the high price (about tens of or even dozens of dollars), the device could not be widely used in agricultural production in the world.

Fig. 1 UAV crop-dusting

II. Application investigation for the intelligent sprinkling system of Tongfu Group

(1) Operating principle

The intelligent sprinkling system from Tongfu Group can utilize the collected data and database information for comparison and analysis to obtain the diagnosis results; and utilize the GPRS communication technology to send the control instructions (e.g. related pesticides concentration, duration and position) to the main controller. Then the main controller executes analysis and processing based on the accepted instructions, displays the flow velocity, position level and surplus pesticides, and controls the connection and disconnection of the related relay to control pesticide spraying for the designated area.

Specifically, the spray concentration value is set based on environmental factors and crop characteristics in the system working process. The crop position is determined based on the predefined distance between the sprayer and the system. The spraying concentration and velocity are calculated based on the environmental parameters and air velocity. The sensor will output a "start work" signal when detecting the concentration. The screen is used as the HMI interface and the micro-processor will control the peripheral equipment such as the stepping motor and lamp via I/O control based on the collected environmental information [4]. The receiving terminal will determine the related control through comparing the setting value and actual measurement value. The operating system of the smart spraying includes the visual digital screen which displays wind power, sunlight exposure, crop analysis and other indexes.

(2) Hardware and software and online application in the intelligent sprinkling system

1. Hardware

The hardware of the intelligent sprinkling system mainly includes a detection device, control device and sprinkling device. The detection device from Tongfu Group mainly includes an infrared sensor, soil temperature and humidity sensor, illumination sensor, wind speed sensor and rain sensor. These sensors are placed in the farmland to monitor the crop growing environment. Through the feedback of real-time data, the gateway uploads the collected data to the server via the wireless network (4G/5G) to provide accurate monitoring and a scientific basis for crop growth and realize data transmission of smart agriculture.

With the functions of remote warning, remote switch, and remote upgrade, the control module in the system can integrate the communication module to upload the data in real time. The hardware encryption for the communication chip can ensure the security of the data transmission. In case of serious abnormal operation (e.g. current power of water pump beyond the rated load, water pump flow beyond the abnormal value, overvoltage, undervoltage, default phase, electric leakage, overcurrent), the integrated control module can automatically switch off the power supply module to ensure personal safety, device and property safety. In case of general abnormal conditions (e.g. failed GPS positioning, offline communication), the system will send a prompt, but the water utilization will not be affected.

Fig. 3 Farmland monitoring information of Tongfu Smart Farm

Fig. 4 Control mainboard of the smart farm

The sprinkling system is mainly provided with XAG XP2020 agricultural UAV, SUPER3 Pro RTK vehicle-control system and the industrial top high-pressure fan with outlet air velocity up to 160m/s. The high-speed airstream from the duct can carry the frog drop to the target area to realize more accurate spraying. The smart cloud platform can realize all-round tracking and spraying; the embedded gyroscope can keep the spraying angle automatically and realize 360-degree all-round tracking and spraying at a fixed point flexibly. The spraying mode includes air route mode, round-trip mode, following mode, and remote-control mode. The system can be controlled via the XAG ACS2 single-hand joystick or driven automatically in the XAG Agriculture APP directly.

Fig. 6 XAG XP2020 Agricultural UAV

2. Software

Tongfu Group realized the network transmission via 3G/4G/5G and observed the crop data via computer or mobile client. The administrator can control the crops based on the data, which is simple and convenient. By means of the XAG Agricultural Service APP, Tongfu Group can directly operate and control the crop-dusting UAV and monitor the farm information in real time via software in the console room. The overall design solution includes the initialization subprogram module, keypress subprogram module, and man-machine interaction subprogram module, etc. The overall system initialization includes clock initialization and peripheral initialization (e.g. display and DHT11 initialization), data (environmental temperature and humidity from DHT11) reading, and data update on the display. If the keypress is pressed, the data can be cleared.

3. IoT application

In Tongfu Group, the IoT system consists of the data service center, industrial data transfer unit (DTC), farmland information acquisition system, and ZigBee underlying data transfer. The GPRS (General Packet Radio Service, providing the end-to-end and wide-area wireless IP connection) technology for IoT communication is a mobile data service that can be provided for GSM (Global System for Mobile Communications) mobile phone users. Extended from GSM[5], GPRS is different from the previous transmission mode of circuit switching in the channel and transmitted in the form of a packet. The user costs are calculated by the transmitted data traffic, instead of the whole channel. Theoretically, the mode is cheaper and the data transmission speed of WAP is not comparable to the GPRS[6].

III. Analysis of feasibility and limitations in marketing and application of the intelligent sprinkling system

(1) Feasibility

With the refining and intensive development of agriculture, the role of intelligent agricultural machinery is gradually prominent. The intelligent sprinkling system can provide a complete production solution for farmers, including intelligent equipment, the IoT system platform and agricultural production management system. As an important defender of the new-era agriculture, the intelligent sprinkling system attracts attention in technical exploration and market prospects, being a new star in the field of modern agriculture. The intelligent sprinkling system is highly efficient, convenient, accurate and environmental. Generally, the small-scale systems are applicable to various landforms and plots because they can be operated simply and carried conveniently. In recent years, the system has been recognized and accepted by planting and agricultural technicians. In China, the UAVs for pest control develop fast and become the standard configuration for the product due to their appropriate price and strong power. As a result, many leading scientific products spring up, for example, DJI UAVs have developed well in the international market.

With the accurate GIS (Geographic Information System), the intelligent sprinkling system can collect, store, manage, operate and analyze the geographical distribution data in the atmospheric space for the whole or partial earth surface, which is consistent with the requirements of accurate agriculture. The intelligent sprinkling system uses high-definition cameras in different areas to collect the crop growth data in real time and transmit the data to the upper computer. The upper computer analyzes and diagnoses the growth data, compares the data with the database information, and determines the pests in the crop growth process and the necessity of nutrient solution. Based on the analysis and diagnosis results, the upper computer sends the related control instructions to the main controller through GIS technology and communication technology. The above technologies are used to ensure accurate demands for pesticides and microelements and realize accurate spraying and application. As a result, it is possible to ensure healthy crop growth and reduce the influences on the soil and environment.

With high accuracy, short time of single operation, large spraying area per day and high efficiency, the intelligent sprinkling system has high requirements for the planting type and area. In China, agriculture is based on the single-family contract system. Although the farm-type intensive production is formed in the process of land transfer, the quantity and area are not enough and the land distribution is scattered, as a result, the scale effect cannot be formed for the plants. The intelligent sprinkling system is highly efficient, convenient, accurate and environmental. Generally, the small-scale systems are applicable to various landforms and plots because they can be operated simply and carried conveniently.

In some part of rural China the drones can grasp the situation of crop pests and diseases in advance, and can accurately select pesticide types and determine the amount of pesticides according to the actual occurrence of pests and diseases in the field.This will speed up and upgrade all aspects of agricultural production.This not only makes farming more accurate, but also solves the problems of high human labor intensity and labor shortage. The intelligent spraying system automatically adjusts the nozzles according to flight speed, height, crop type, and severity of pests and weeds to achieve variable and accurate spraying.

(2) Limitations

Despite the various development opportunities and good scientific and technical foundation for wide development, the intelligent sprinkling system still has some problems. At present, it is urgent to solve the following problems for industrial development:

1. Loss of standards. Being in the early stage of development, the intelligent sprinkling system still has some problems with national standards, industry norms and specifications.

2. High comprehensive costs. At present, the high price of intelligent sprinkling systems, supporting services and maintenance costs lead to low market penetration of the UAVs for plant protection.

3. Lack of product universality. The domestic intelligent sprinkling system is mainly used in the northeast and the North China plain. Due to the complex terrain and topography, intensive agriculture and small scale,

and scattered land distribution, the UAVs cannot be used in many regions, which accelerates the research and development of universal products.

     4. Lack of professional talents. As a piece of new agricultural machinery, the intelligent sprinkling system has high technical and professional requirements for the operator. As a result, the common farmers cannot operate the system independently, which requires the support of professional talents.

IV. Prospect forecast for the application of intelligent sprinkling system

     It is necessary to establish an effective crop monitoring system to ensure the sustainability of integrated pest management in modern agriculture. The traditional chemistry or physics-based control method cannot satisfy the demand for timely monitoring and control of plant diseases and pests. A safer, more economical and efficient strategy must be implemented to reduce the losses due to plant diseases and pests.

     Among the hardware equipment of the intelligent sprinkling system, the sensors include optical components, the pyroelectric infrared detector and the pressure sensor, which are used for detection from the ground to the crop surface and transmission of sensing information to the remote computer. Based on the obtained mass information, after collection and processing, it is possible to accurately control the present crop status and spray pesticides in appropriate time nodes to realize highly efficient and high-quality pest control. Although China has made some advances in the field, the intelligent sprinkling system is frequently used in the demonstration district and teaching base at present. With the increase of proportion for the benefit improvement in China's agricultural production due to scientific progress, the intelligent sprinkling system will be used gradually in the wide arable lands in China to achieve perfect integration of modern science and technology into agriculture. In consequence, the system has a wide market prospect.

     In addition, the application potential of the intelligent sprinkling system is also reflected in another important field, that is, the influences of pesticides on environmental protection and human health can be reduced. All over the world, the OP compound is one of the most important chemical constituents in the pesticides, which can seriously threaten human health. Now, there are over 100 OP compounds that are approved for production. Due to the high proportion of the traditional pest control mode, the bad health effects from pesticides mainly occur in developing countries. On the one hand, the intelligent sprinkling system can control the sprayed pesticides to an appropriate range, which can avoid excessive application of the pesticides. On the other hand, a system with a high degree of automation can greatly reduce the frequency of direct contact between humans and pesticides to effectively solve environmental pollution and human health problem. The agricultural pollution problem is becoming increasingly serious in China as the largest developing country in the world, while the intelligent sprinkling system is an important breakthrough point, and the wide application of which provides a new idea for pollution control.

     With complete functions, the intelligent sprinkling system from Tongfu Group has high economic benefits and use values. Through interaction between hardware and software in the whole system, the

intelligent sprinkling system can realize automation, refinement and intellectualization. Compared to the traditional sprinkling technology, the system can achieve high efficiency and greatly save human costs. According to the data from Tongfu Group, when the intelligent sprinkling system is applied, the occurrence rate of pests is decreased by 20%-30% and the amount of pesticides is decreased by over 15% compared to the traditional sprinkling mode, leading to yield improvement for over 30%. Therefore, it is urgent to reduce costs and improve system stability due to high research and development costs and maintenance costs.

China's Ministry of Agriculture and Rural Development has formulated standards and supporting policies on the digital construction of agricultural modernization, focusing on the main direction of agricultural modernization, facing the major needs of rural revitalization, closely focusing on promoting the deep integration of digital technology and agriculture and rural areas, focusing on promoting the construction of information infrastructure, convergence and sharing of data resources, digital upgrading of the whole agricultural industry chain, and expanding digital support application scenarios.

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