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System for Monitoring Crop Growth Environment and Crop Growth Parameters by Wireless Communication

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Keywords: Growth Environment, Wireless Communication Monitoring, Precision Agriculture, Growth Parameters

Abstract: It can provide abundant and accurate real-time growth environment information, such as air humidity temperature, carbon dioxide concentration, crop yield, crop fruit quality, pH value and other information, which is a necessary prerequisite to promote precision agriculture and improve agricultural output. To obtain this information by monitoring crops with a variety of different and modern sensors is the key to the observation of differences in the growing environment and growth parameters of crops, so as to realize the great project of precision agriculture. This paper aims at studying how to collect the growing environment and the growing parameters of crops by wireless communication monitoring system, which is an important subject at present. In this experiment, sensors with different monitoring functions were placed in the experimental range, and then the wireless communication monitoring system was connected to monitor the climate change that could not be directly observed by human, such as temperature, carbon dioxide concentration, soil moisture content and other crop growth environment data. The experimental data showed that the data measured by professional manual and wireless communication monitoring system only existed within the allowable error range, but did not have a large range of error. The manual and wireless communication monitoring data are compared 24 hours a day, which also proves that the wireless communication can guarantee the accuracy all the time. Experiments on different kinds of crops also provide experimental data within the range of error. The experimental data show that the application of wireless communication technology to crops can not only reduce the labor intensity of farmers by more than 66%, but also reduce the production cost by 45%, reduce the complicated work of wiring, and improve the level of intelligent agricultural production in China, which has certain research value and practical significance.

1. Introduction

In traditional agriculture, the farmers by manual measurement for crop growth environment and the growth parameters of data information, and now with the constant renovation improvement of wireless monitoring has been gradually mature, through wireless communication monitoring system access to relevant data such as crop environment will reduce artificial measurement of huge data error, make accurate crop growth environment and growth parameters of data acquisition. Through the wireless communication monitoring equipment arranged by professionals in the farmland, the living habits, growth environment, physiological conditions and disease conditions of agricultural cash crops, economic livestock and poultry can be studied and investigated. Meanwhile, the wireless communication monitoring equipment can also be used for the environmental monitoring of icy road conditions and petroleum damage lithology. In all sorts of all kinds of control systems, wireless monitoring of equipment such as sensors, temperature sensors, pressure sensors, pH value brightness sensor, biosensor, co2 sensor, etc., suitable for monitoring the environment temperature, pressure, pH, light intensity, land, water content and the concentration of carbon dioxide growth environment parameters. Through electronic transmission, the final display in the computer instrument. Moreover, it can be set within the range of automatic control by setting. If there is significant deviation in data, appropriate regulation will be carried out to ensure that crops have a healthy and consistent growth environment.

The core theme of precision agriculture is to obtain the growing environment and growth parameters of crops through scientific and rapid data collection methods, and then guide irrigation and fertilization or management. According to the development requirements of new agriculture in the 21st century, the traditional agricultural management system has been unable to satisfy the modern agriculture in terms of effectiveness and precision. Therefore, the plan to launch a monitoring system for the growth environment and growth parameters of modern crops is extremely critical. There are many ways of wireless data transmission of growth environment and growth parameters. At present, the common way is mobile GPRS or GSM short message transmission. However, due to the slow transmission speed, data delay and even data loss, this will do the opposite harm to the increase of crop yield. Therefore, this paper adopts wireless communication monitoring for long-distance data transmission. It can not only ensure the precision and accuracy of the data of crop growth environment and crop growth parameters, but also ensure the stability of data transportation, which can meet the new agricultural production needs and expand the actual value and operation space of agriculture.

According to the study of Ni P, the detection of uhv dc grounding electrode mostly adopts manual detection, indicating that this method cannot obtain real-time operation data of the grounding electrode [1]. At the same time, labor costs are very high. In order to meet the safety demand of uhvdc transmission system, this paper designs a wireless communication monitoring system for uhvdc grounding pole. The system USES 3Gwireless communication technology and can remotely monitor ground current, observe well water level, and video data around the grounding electrode. Through the analysis of the data, the system has a broad application prospect in fault detection and life evaluation of uhv dc grounding pole. The system has high data accuracy, fast transmission speed and stable field operation. YIN introduces a method of monitoring multiple loads from the front end of a wireless power transmission system without using any wireless communication system [2]. YIN has developed a mathematical method for deriving load conditions based on frequencies near the scan resonance frequency. YIN argues that the proposal only requires input voltage and current information, eliminating the need for feedback control using wireless communication systems. YIN this suggestion has been actually confirmed in the hardware prototype and achieved good results.

To sum up, this paper aims to study how wireless communication monitoring can accurately monitor crop growth environment and crop growth parameter data, which is an important direction to realize precision agriculture. In this experiment, the wireless monitoring equipment of different monitoring data items was placed in the suitable location of the experimental farmland to monitor the growth environment and growth parameter information of crops that could not be accurately monitored by humans. The experimental data show that the environmental data obtained can be basically consistent with the professional manual monitoring data, whether the wireless communication monitoring equipment is used in different crops, all-weather or single-period.

2. Programs Method

2.1. Overview of Wireless Communication Monitoring

(1) Overall framework design of wireless communication monitoring system

The system of crop growth environment and crop growth parameters based on wireless communication mainly consists of the following modules: sensor unit, processing unit, wireless communication unit and power supply unit [3]. The architecture diagram of wireless sensor network node system is shown in figure 1.

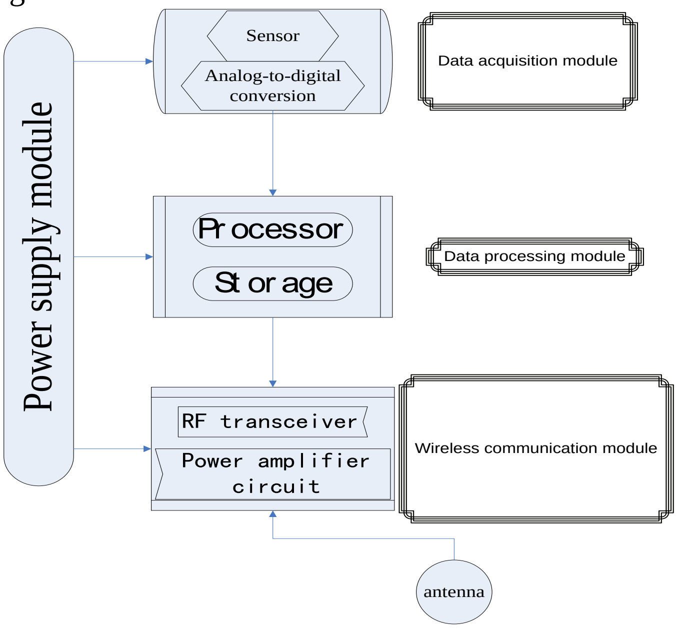

Figure 1. Overall framework of wireless communication monitoring system

The coordination and monitoring of the four modules constitute the wireless communication monitoring network, which can ensure the authenticity and stability of its data. Wireless sensor terminals collect environmental data such as temperature and humidity, light intensity and pH values. When the environment data is collected, it is transmitted to the routing node of the relay station through multiple hops. The routing node is responsible for the exchange of information with the sensor node and the network coordinator. The network coordinator supported by the manager and dispatcher of the wireless communication monitoring system is the data center and control terminal and the data transfer station of the network control center. The growing environment and growth parameters of crops are finally transmitted to the monitoring center, and the data of these crops are stored in the database. Researchers can observe and understand the data of growing environment and growth parameters of crops through computer terminals [4]. In daily life, each node is in a state of dormancy and shutdown. Only when the network coordinator gives instructions, each node will be awakened and work to collect the information of crop growth environment and growth parameters.

(2) Wireless communication monitoring of crop growth environment and the working process of parameter acquisition system

1) The network coordinator energizes the sensor node and wakes the terminal node into working state, waiting for the command to join the wireless communication monitoring network;

2) The gateway sends the driver command to each sensor node in the wireless communication monitoring network;

3) The node will join the network after receiving the start driver command, obtain the address information of the network, configure the local link address, and establish the route;

4) The node collects data according to the pre-set collection cycle of crop growth environment and growth parameters, and transmits related information of crop environment to the network coordinator (gateway) and monitoring equipment in the form of packets. According to the working process of the system, the brief workflow of its data transmission is shown in figure 2.

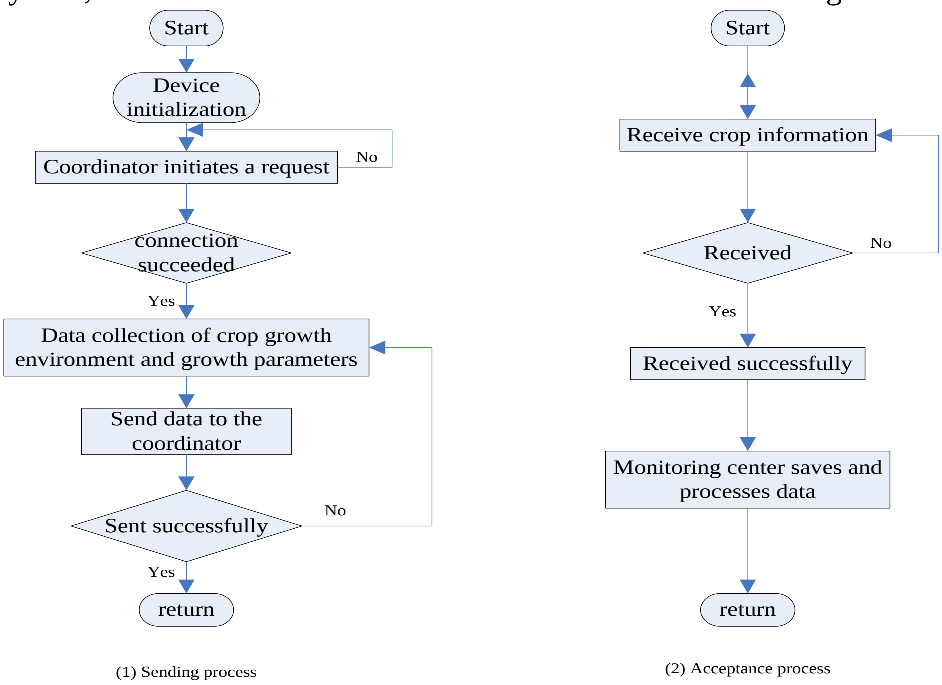

Figure 2. Data transmission workflow

(3) Development characteristics of wireless communication monitoring

1) Systematic economy and energy saving

The biggest advantage of wireless communication monitoring system is energy saving. Simple battery equipment can provide enough energy and can operate normally for 6-20 months. If the situation is stable and data fluctuation is reduced, the battery can last longer [5]. At the same time, wireless communication monitoring system contains sleep state, can choose to make it wake up to work after driving, which can also greatly increase its battery life.

2) Low cost for development and establishment of the system

First, with the maturity of wireless communication monitoring technology, its functional links are simplified, the cost of communication devices is also greatly reduced, and the low cost of networking makes its application range become extensive [6]. Second, wireless communication monitoring system itself is free of copyright fees; farmers do not have to pay more fees.

3) The short time delay

The wireless communication monitoring system has a fast reception speed and excellent acuity. It only takes 10m/s to enter the drive state from the sleep state, and only 15m/s for nodes to connect to the network (it takes 2-7s for bluetooth device nodes to enter the network, and 10s for wi-fi), and the delay is usually only 20-35m/s [7-10].

4) Large capacity

The topology of the wireless monitoring system can be adopted star, tree, and mesh structure, such as a master node number of child nodes, regulation of the upper portion of the master node can also have a parent at the next higher level, can constitute a tree control mode, an area can have multiple network at the same time, as much as possible to cover all the crops growth environment and the growth parameters information area.

5) Good safety performance

The wireless communications monitoring system provides multiple security modes, including non-security Settings, the use of access control lists (acls) to prevent unauthorized access to data, and symmetric passwords using advanced encryption standards (AES128). It also provides data integrity checking and authentication, while allowing individual applications the flexibility to determine their security attributes.

(4) Multi-sensor data application in wireless communication monitoring

The test data of the four sensors are respectively set as

$$\begin{cases} X_1 = \{\chi_{11}, \chi_{12}, \ldots, \chi_{1m}\} \\ X_2 = \{\chi_{21}, \chi_{22}, \ldots, \chi_{2m}\} \\ X_3 = \{\chi_{31}, \chi_{32}, \ldots, \chi_{3m}\} \\ X_4 = \{\chi_{41}, \chi_{42}, \ldots, \chi_{4m}\} \end{cases} \tag{1}$$

Among them

$$m = 3k(k = 1, 2, \ldots, n), \tag{2}$$

χ_{im} Is the m test data for the i sensor.

Since X4 is the sum of the vectors X_1, X_2 and X_3, the data can be divided into two by adding and subtracting vectors

$$\begin{cases} X_{4,1} = \{\chi_{41}, \chi_{44}, \ldots, \chi_{4m-2}\} \\ X_{4,2} = \{\chi_{42}, \chi_{45}, \ldots, \chi_{4m-1}\} \\ X_{4,3} = \{\chi_{43}, \chi_{46}, \ldots, \chi_{4m}\} \end{cases} \tag{3}$$

Using $\mathbf{X}_2$ and $\mathbf{X}_3$ to project the data of $\mathbf{X}_{4,1}$ to the east, $\mathbf{X}_1$ and $\mathbf{X}_3$ to project $\mathbf{X}_{4,2}$ to the north, $\mathbf{X}_1$ and $\mathbf{X}_2$ to project $\mathbf{X}_{4,3}$ to the sky. Through the data settlement of $\mathbf{X}_4$, it can be seen that no matter which sensor 1, 2, 3 or 4 fails, the system can work normally.

Similarly, the $\mathbf{X}_1$ test data is divided into

$$\begin{cases} X_{1,1} = \{\chi_{11}, \chi_{14}, \ldots, \chi_{1m-2}\} \\ X_{1,2} = \{\chi_{12}, \chi_{15}, \ldots, \chi_{1m-1}\} \\ X_{1,3} = \{\chi_{13}, \chi_{16}, \ldots, \chi_{1m}\} \end{cases} \tag{4}$$

And so on, the test data of X_2 is divided into

$$\begin{cases} X_{2,1} = \{\chi_{21}, \chi_{24}, \ldots, \chi_{2m-2}\} \\ X_{2,2} = \{\chi_{22}, \chi_{25}, \ldots, \chi_{2m-1}\} \\ X_{2,3} = \{\chi_{23}, \chi_{26}, \ldots, \chi_{2m}\} \end{cases} \tag{5}$$

Divide the test data for X_3 into

$$\begin{cases} X_{3,1} = \{\chi_{31}, \chi_{34}, \ldots, \chi_{3m-2}\} \\ X_{3,2} = \{\chi_{32}, \chi_{35}, \ldots, \chi_{3m-1}\} \\ X_{3,3} = \{\chi_{33}, \chi_{36}, \ldots, \chi_{3m}\} \end{cases} \tag{6}$$

$\mathbf{X}_{1,1}$,$\mathbf{X}_{1,2}$ and $\mathbf{X}_{1,3}$ are of equal precision, and likewise, $\mathbf{X}_{2,1}$,$\mathbf{X}_{2,2}$ and $\mathbf{X}_{2,3}$ is of equal precision, $\mathbf{X}_{3,1}$,$\mathbf{X}_{3,2}$ and $\mathbf{X}_{3,3}$ is of equal precision. Through such data processing, $\mathbf{X}_{1,1}$,$\mathbf{X}_{1,2}$,$\mathbf{X}_{1,3}$ and $\mathbf{X}_{4,1}$ is the measurement value of four angular rate sensors in the east direction, $\mathbf{X}_{2,1}$,$\mathbf{X}_{2,2}$,$\mathbf{X}_{2,3}$ and $\mathbf{X}_{4,2}$ is the measurement value of four angular rate sensors in the north direction, $\mathbf{X}_{3,1}$,$\mathbf{X}_{3,2}$,$\mathbf{X}_{3,3}$ and $\mathbf{X}_{4,3}$ is the measurement value of four angular rate sensors in the sky direction. In the process of data preprocessing, a large amount of redundant data appears, which is equivalent to 4 independent sensors being tested together in the east, north and sky direction, providing conditions for multi-sensor data fusion. However, such data processing will reduce the response speed of the system to some extent. For applications with higher response speed requirements, interpolation can be used to meet the requirements.

2.2. Overview of Crop Growing Environment

(1) Definition of crop growing environment

One of the key points in the development of precision agriculture in China is the well-deserved growing environment of crops, which is a key part of modern agriculture. According to the experimental experience of greenhouse planting industry in China, it is necessary to improve the precision of data collection in order to really improve the management and control of crop growth environment and growth parameters. Growth environment data include light, soil, temperature and humidity, water content, carbon dioxide concentration, etc. It will play a key role in forming a modern agricultural industry system with Chinese characteristics if we can regulate the growth environment of the crops. At present, the main collection of growth environment data is in the charge of professional manual, transformation and upgrading is imperative, represented by science and technology, to make crop growth environment information more efficient, faster and more accurate [11-13].

(2) Classification of crop growing environment

1) Light

Light is an essential source of energy for crops, mainly from the sun and partly from a variety of artificial sources. Illumination is one of the bases of crop growth and development. Illumination plays an important role in the synthesis of organic compounds and the high yield of crops. According to experiments, more than 90% of the dry matter in crops is produced by photosynthesis. The formation and operation of the various organs of crops are inseparable from the role of light, which is its direct role, such as light can help seed germination, green leaves to stretch, differentiation of roots and leaves, etc. In addition, photosynthesis affects the functioning of the crop and thus the quality of the crop products. To sum up, the importance of light to crop production ultimately lies in the change of crop population structure and crop yield quality.

2) Soil

Soil microbial biomass is an important feature to measure soil fertility. As part of the organic matter in the soil, soil microbial can provide nutrients to the soil, which is equivalent to the function of warehouse. Soil microbes can also be used to explore soil energy flow and material circulation. Microbial biomass, as a marker of soil fertility, affects the transformation of organic matter into soil, reflects the availability of soil nutrients and soil biological activity, and is the most sensitive indicator of soil quality and environmental change. With the deterioration of the global environment, soil microbial biomass as an environmental indicator has attracted more and more attention. It is generally believed that plants with larger roots provide more organic matter and higher soil microbial biomass than plants with smaller roots. Soil microbial biomass varies at different growth stages even for the same crop. The results showed that the soil microbial biomass carbon content was higher in the trifoliate period of wheat, and gradually decreased with the decrease of the external temperature. After the wheat turned green, the soil microbial biomass carbon content increased and reached the highest value before and after the flowering.

3) Water

Crops, like other plants, need a large amount of water in the course of our life activities. This water is mainly absorbed from the soil by the root system. Different crops often have different water requirements and different water storage capacities of the same crop at different growth and development stages. The amount of water in soil is one of the important factors that affect crop yield [14-17].

4) CO2

Carbon dioxide is a common compound in the air and a substrate for crop photosynthesis. The increase of atmospheric concentration will affect the physiological response of crops, thus affecting the mass and biomass distribution of the aboveground and underground parts of crops, as well as the activities of root system and soil organisms in the soil.

5) Temperature and humidity

Crops in the appropriate temperature and humidity conditions, to normal development, different crops have different requirements for temperature and humidity, and the same crops in different growth and development period of the appropriate temperature and humidity is also different.

2.3. Overview of Crop Growth Parameters

(1) Definition of crop growth parameters

Crop growth parameters are the assessment of environmental conditions (including soil environment, crop yield of farmland microclimate and other meteorological disasters affecting crop growth), crop diseases and pests, supply and nutrition status, yield forecast, and various management measures for medicinal crops, which ensure the normal growth of crops in a timely and targeted manner. The identified agrometeorological conditions affect the growth and development of crops as well as the yield and quality of crops. The basis of observation learning is the climate and meteorological forecast data of crop growth and the assessment of crop field management and guidance to provide services for high yield, high quality, high efficiency and accuracy of agriculture.

(2) Classification of crop growth parameters

1) The development

Based on the agricultural weather forecast of the arrival date of a certain period of crop growth, determining the growth rate between one growing season and the next is the key to predict the growing season. The growth rate of crops depends on their biological characteristics, light intensity, temperature and humidity and other meteorological conditions, soil conditions and farming methods. When soil conditions, cultivation techniques and control levels are relatively uniform, the growth rate mainly depends on the biological characteristics and meteorological conditions of crops. Responses to conditions such as light and temperature vary greatly depending on the type of crop, variety and stage of development. Within the zero biological limit and the appropriate maximum temperature range, the growth rate accelerated as the temperature increased. In addition to the influence of temperature, the duration and intensity of sunlight also affect the growth rate of crops to some extent.

2) Density

Planting density and method in place, reasonable use of environmental conditions, improve the yield and quality of crops. Planting density should be based on the characteristics of different varieties, soil water, fertilizer local conditions. One of the radishes in a category called zhejiang long, seedlings 40 cm, spacing 40-50 cm. The method of watering sowing is to sow covered soil before watering and cover the soil before watering. The latter has underwater feet and leaves that germinate easily. After summer sowing, in addition to soil cover, should also be covered to keep wet, ensure rapid and regular budding, to prevent heavy rain into the soil [18-20].

3) Leaf surface index

Leaf area index (LAI) affects photosynthetic radiation interception of crops, water absorption, latent and sensible heat fluxes, and CO2 exchange between surface ecosystems and the atmosphere. In some crop growth models, LAI is also an important input parameter and conditional variable. LAI is the determinant of photon-vegetation interaction canopy radiation transmission model, and has been used as a key link between canopy reflection and crop growth model in remote sensing data assimilation. The measurement of LAI index time variation law during the whole growth period of crops is helpful to the correction of crop yield and biomass prediction models.

The leaf area index calculation model includes canopy porosity P0 and a constant of the top-looking canopy infrared image, where the constant a is the parameter to be corrected. The leaf area index calculation model is:

$$\mathrm{LAI} = -a * \ln(P_0) \tag{7}$$

Among them

LAI -- is leaf area index

P0 -- refers to the canopy porosity of the infrared image of the top view canopy

A- as constant

4) Plant height

Plant height is one of the important indexes of crop growth parameters, and plant height is positively correlated with lodging index. Improvement of plant type is a necessary means for crop breeders and an important way to coordinate the contradiction between yield and quality.

5) Looks like the

Crop growth refers to the condition and trend of crop growth. In the period of crop growth, by obtaining the information of crop phenotype related to crop yield in time for the growth study, the trend of crop yield in the region can be predicted, so as to provide prior knowledge and reliable basis for crop yield estimation. Therefore, the study of crop growth has important theoretical value and practical significance for maintaining national economy and people's livelihood, ensuring food security and macro-control of food market.

3. The Experiments

3.1. Experimental Settings

(1) Experimental background

The environment for growing crops is the main component of new agriculture and one of the priorities of agricultural development in China. At present, the collection of crop growth environment and crop growth parameters is mainly based on experienced manual management. The wireless communication monitoring system breaks through the traditional geographical, climatic and natural conditions for the development of culture and the planting of tomorrow's crops. The existing monitoring system for crop growth environment is not accurate, wastes resources and runs in a complicated way. Environmental changes required for crop growth must be adjusted in a timely manner in order to contribute to disaster resistance and mitigation in agriculture and scientific culture. This system can reduce the artificial manipulation and measurement error in the actual production process, reduce the agricultural production cost, and maximize the collection, convergence and real-time transmission of environmental information for crop growth has a great role [21-23].

(2) Experiment setting process

In order to verify the performance of the designed system in all aspects, 15 tomato plants were selected as the test object in the greenhouse at 29℃. The 15 tomato plants were evenly distributed in the test area of 750mm×750mm. Meanwhile, a blank control group was set up. Physiological parameters, such as density, leaf index, plant height and diameter of tomato fruit, were collected for each tomato plant at the same time and sent to the display interface of the upper computer. The collection interval was 2h, and the total monitoring time was 24h.

Wheat, barley, oats and rye were simultaneously cultured for data collection test of wireless communication monitoring system.

3.2. Experimental Steps

(1) Monitoring the accuracy of wireless communication monitoring

Professional manual measurement data and data collected by wireless communication monitoring system are used for comparison and error calculation.

(2) Monitoring the stability of wireless communication monitoring

According to the growth environment data monitored and the comparison of the manual measurement data, the data errors in different time periods were observed.

(3) Convenience of using wireless communication monitoring

Using the data of the control group, the cost output of the two types of monitoring data was monitored according to the comparison between labor cost consumed and wireless communication monitoring cost.

(4) Use different crops to collect their data

In the crops of tomato, wheat, barley, oats and rye, the wireless communication monitoring system was used to monitor the growth environment and various parameters of growth parameters, and to observe whether the wireless communication monitoring system could be widely used in various crops [24-26].

3.3. Matters Needing Attention in the Experiment

(1) The principle of contrast

In setting up the experiment, usually create two group, one is to use the wireless monitoring data of the experimental group, one is to use professional artificial measured data of the control group, and then through the intervention or control wireless monitoring in order to eliminate or reduce data error, after can see wireless communication more clear, more comparative monitoring environment for the growth of crops and crop growth parameter precision. Among them, the use of a lot of control methods, by positive control, standard control, self-control, but the most commonly used is blank control method.

(2) Randomness principle

The randomness principle of wireless communication monitoring experiment means that samples are randomly and arbitrarily selected within the scope of monitoring crop growth environment and crop growth parameters experiment. Only in this way can we ensure the significance of wireless communication monitoring experiment, reduce the unnecessary result error brought by wireless communication monitoring experiment system, and balance the conditions brought by various applications.

(3) The principle of parallel repetition

It shows the variation range of one application of wireless communication monitoring, such as monitoring the temperature of tomato at 14:00, and observing the difference between professional manual and wireless communication monitoring. For the sake of scientific rigor, this experiment must be repeated many times. In order to reduce the data error caused by unnecessary factors as much as possible, samples must be randomly selected. Of course, this cannot guarantee the complete elimination of all the influences caused by unnecessary factors. The parallel repetition principle is the answer to this puzzle.

(4) Principle of single factor variable

That is, control variables, highlighting one application data of wireless communication monitoring experiment, while other variables remain unchanged. To observe the effect of the data on the experimental results of wireless communication monitoring, that is to say, the control of other variables unchanged must be consistent. It is because we are prone to forget some basic principles when doing experiments, which can lead to errors when solving or designing experiments. Therefore, in the block chain experiment, we must attach importance to the necessity and criticality of the basic principle of the experiment.

4. The Discussion

4.1. Effectiveness of Wireless Communication Monitoring

(1) Data show that in the crop growth environment and the data of crop growth parameters, professional artificial measured data and wireless communications monitoring data error is not too big, but still there are certain error, cannot be one hundred percent accurate, the light intensity and co2 content, temperature, plant density, leaf area index, plant height, fruit diameter data error is small, the error of the soil moisture content is a little obvious, this is because the soil moisture content of the creation of the sensor performance is not the type of sensor is accurate. The data collection table is shown in table 1 and figure 3.

Table 1. Tomato growth environment and parameters at 2 pm

Crop growth parameters	Professional manual data	Wireless communication monitoring data
Light intensity (lx)	60thousand	59.8thousand
Soil moisture content (%)	50	43
CO_2(ul/l)	240	238.34
Temperature(C°)	29	29
Plant density (mm)	50	51
LAI(cm^2)	1.8	1.76
Plant height (cm)	21.5	21
Fruit diameter (cm)	4.3	4.8

(2) The data showed that in the experimental site of the thermostatic greenhouse, the basic temperature was maintained at 29±2 ℃. Among them, it can be kept around 29 ℃ from 11 o 'clock to 15 o 'clock in the daytime, which is caused by outdoor solar energy. The monitoring data of wireless communication after 13:00 are consistent with the data measured manually by professionals. There is a certain difference between the two data measured between 7:00 and 11:00. The error is within the range of experimental error. The data collection table is shown in table 2 and figure 4.

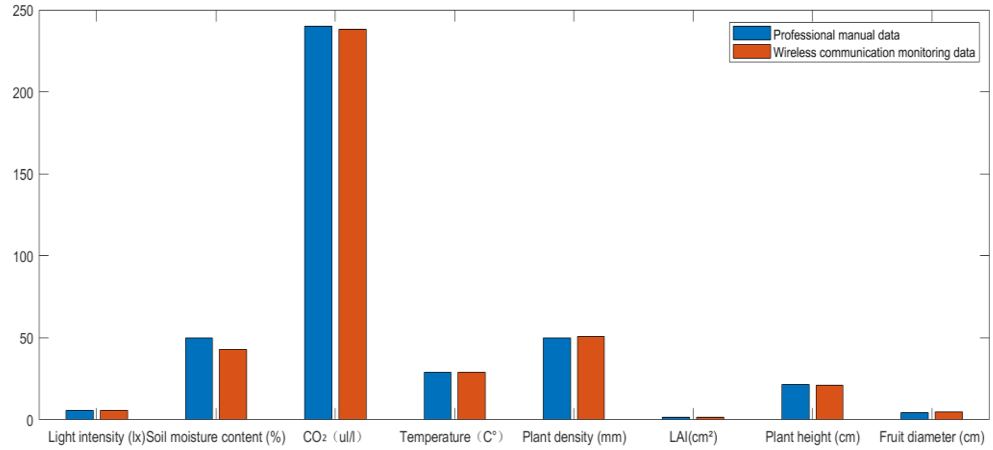

Figure 3. Tomato growth environment and parameters at 2 pm

Table 2. All-day tomato temperature monitoring

	Professional manual data	Wireless communication monitoring data
7:00	27.8	27.1
9:00	28.4	27.9
11:00	29.0	28.9
13:00	29.5	29.5
15:00	29.3	29.3
17:00	29.0	29.0
19:00	28.5	28.5
21:00	27.6	27.6
23:00	27.4	27.4

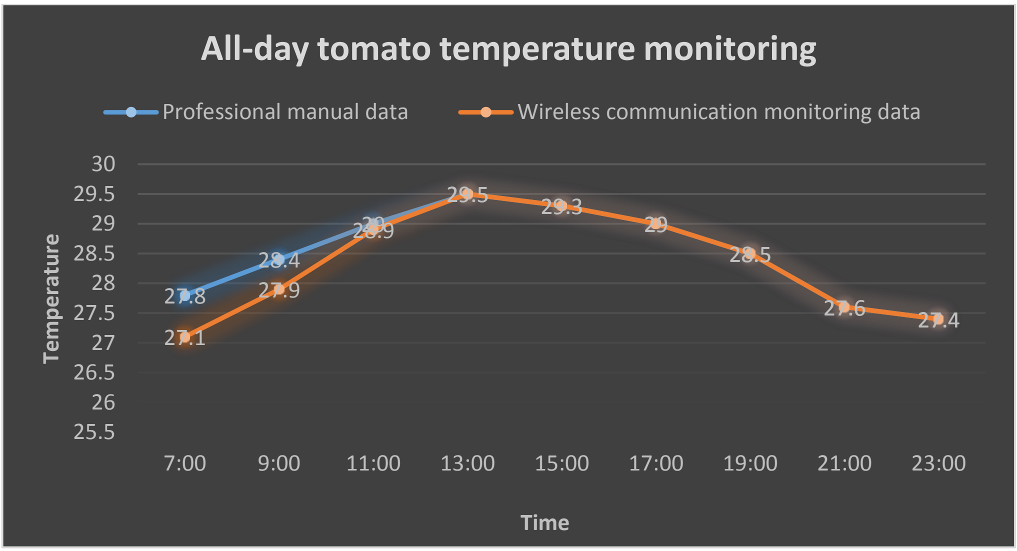

Figure 4. All-day tomato temperature monitoring

4.2. Convenience of Using Wireless Communication Monitoring

(1) Monitoring data show that the use of wireless communication can work 24 hours of normal operation, and use professional artificial test data, and requires manual shift operation, the operation is laborious and consumption of certain human costs, are able to ensure the accuracy of wireless monitoring system, select wireless monitoring is belong to the low cost and high efficient and convenient. It can not only collect the data of growing environment and growth parameters of corresponding crops, but also recycle a set of equipment to ensure accurate and effective data, so as to put precision agriculture into practice and make preparations for the improvement of people's quality of life. The data collection table is shown in table 3 and figure 5.

Table 3. Labor cost of growth parameter data collection

	Before		Now		
	Manually measured data	Manual quantity (person)	Wireless monitoring data	Manual quantity (person)	Labor volume (%)
Light intensity (lx)	60thousand	15	59.8thousand	5	-66.67
Soil moisture content (%)	50	14	43	4	-71.43
CO_2(ul/l)	240	16	238.34	6	-62.50
Temperature(C°)	29	15	29	5	-66.67
Plant density (mm)	50	15	51	5	-66.67
LAI(cm²)	1.8	13	1.76	3	-76.92
Plant height (cm)	21.5	16	21	6	-62.50
Fruit diameter (cm)	4.3	14	4.8	4	-71.43

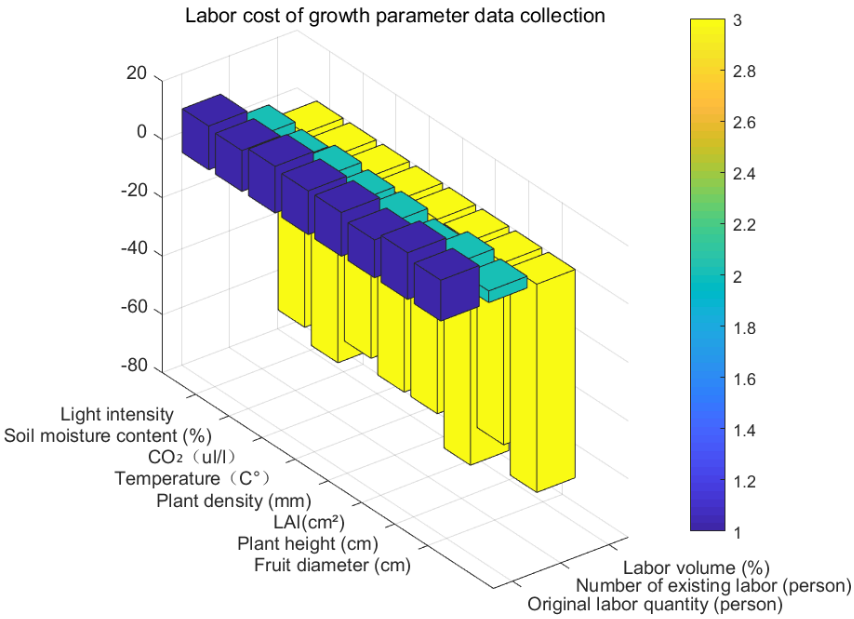

Figure 5. Labor cost of growth parameter data collection

(2) Data show that the wireless monitoring used in tomato, crops such as wheat, barley, oats, rye, in its various growth environment and crop growth parameter data and the data obtained from

monitoring of human error is not big, fall within the scope of permissible error, show that wireless monitoring of crop growth environment and crop growth parameters precision reaches can help people never leave home to get the indicators of crop, then make the corresponding measures, increase the crop yield. The data collection table is shown in table 4 and figure 6.

Table 4. Monitoring of growth environment parameters of different crops at 14

	Tomato		Wheat		Barley		Oats		Rye	
	Artificial	Wireless communication	Artificial	Wireless communication	Artificial	Wireless communication	Artificial	Wireless communication	Artificial	Wireless communication
Light intensity (lx)	60thousand	59.8thousand	44.5thousand	42.3thousand	50thousand	49.5thousand	50thousand	50.1thousand	50thousand	50.4thousand
Soil moisture content (%)	50	43	70	73	65	68	77	75	57	57
CO_2(ul/l)	240.00	238.34	300.00	292.30	400.00	400.04	350.00	352.11	300.00	301.44
Temperature(C°)	29	29	30	30	29	29	29	29	29	29
Plant density (mm)	50	51	25	25	33	32	30	31	26	26
LAI(cm²)	1.8	1.76	5.2	5.0	1.34	1.39	1.73	1.75	1.57	1.52
Plant height (cm)	21.5	21.0	63.1	63.0	89.3	89.5	76.3	76.0	88.0	88.1

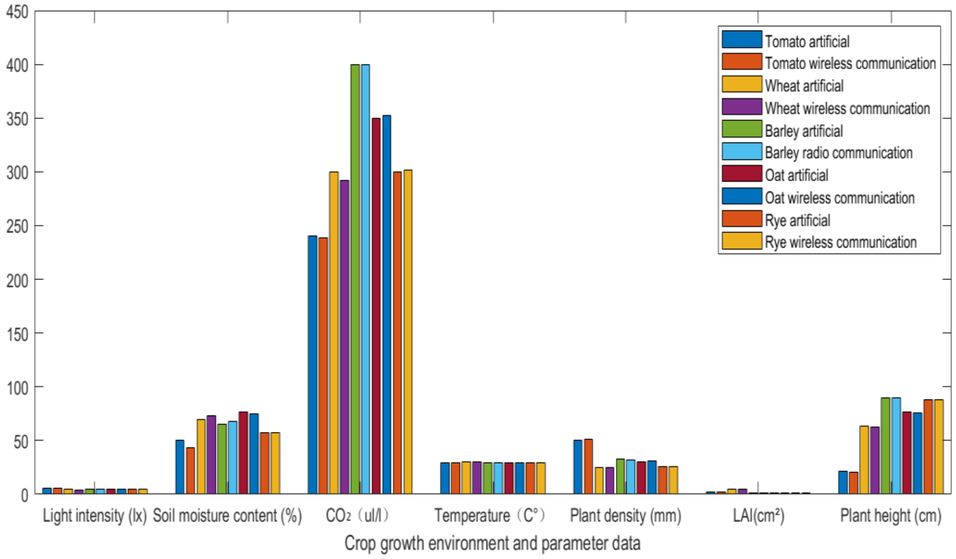

Figure 6. Monitoring of growth environment parameters of different crops at 14

5. Conclusion

(1) As the top priority of the new generation of information technology, wireless communication monitoring system is used in many fields such as collection, transmission, processing and management of transactions, so as to give people a new way to obtain and digest information. In this study, based on the large amount of data collection information of crop growth environment and crop growth parameters, and combined with the unique advantages of wireless communication monitoring technology, a system was designed to monitor crop growth environment and crop

growth parameters by wireless communication.

(2) The design of this study is to provide a set of convenient, practical and low-cost plans for the monitoring of farmland crop information, so as to design a wireless communication system for monitoring crop growth environment and crop growth parameters. It can not only reduce the complexity of system operation, but also ensure that the system has a good application prospect and development under the condition of reliable stability and perfect function.

(3) This paper aims to study the system of monitoring crop growth environment and crop growth parameters through wireless communication, so as to realize the transformation of precision agriculture with low cost and high accuracy, which is a key innovation at present. In this experiment, sensors were placed in tomato, wheat, oats, rye and other crops to measure relevant growth environment and growth parameters, and the experimental data were observed through wireless communication monitoring system. The experimental data show that the simultaneous use of wireless communication monitoring system at 14:00 is consistent with the professional manual environmental data. When the same experimental environment data is measured all day long, the wireless communication monitoring data is in good agreement with the professional manual data. At the same time, under the high precision of wireless communication monitoring, the cost of professional labor is higher and human resources are wasted. The experimental data show that the wireless communication monitoring system can not only reduce the farmers' labor force by 66%, but also reduce the production cost by 45%, greatly reduce the output of human and material resources, and improve the efficient high-tech level of precision agriculture in China.

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Data Availability

Data sharing is not applicable to this article as no new data were created or analysed in this study.

Conflict of Interest

The author states that this article has no conflict of interest.

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