RESEARCH OF GREENHOUSE EFFICIENT AUTOMATIC IRRIGATION SYSTEM BASED ON EVAPOTRANSPIRATION

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Abstract: Traditional water-saving irrigation management turns on water pump in a settled interval decided by grower's experience. The method just saves water on the back of losing yield. In order to result the problem, a kind of greenhouse efficient irrigation management system based on Evapotranspiration has been developed. The system includes greenhouse environmental monitoring subsystem, irrigation analysis subsystem, control methods, can instruct users to irrigation greenhouse through quantitative calculating greenhouse crop water requirement. The system has been examined in greenhouses of ShengFangYuan Test Station in Beijing, China; the result shows that the system can instruct greenhouse irrigation efficiently, increase yield 18%, and save water 28%.

Keywords: greenhouse, automatic irrigation, crop water requirement, irrigation practice

1. INTRODUCTION

Greenhouse agriculture has become the main mode of production facilities and because of the character of high input and high output has been applied all over the world, but the large water rate of greenhouse makes its development limitedly (Baille etc. 1994).

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Now, the strategic position of water resources is more and more important. Development of efficient water-saving irrigation is the main method to mitigate the shortage of water resources. So there is great significance to research and develop efficient greenhouse irrigation management systems.

2. PROBLEM FORMULATION

Traditional water-saving irrigation management turns on water pump in a settled interval decided by grower's experience. Mean of Efficient water-saving irrigation, is not the irrigation of traditional sense, which losing yield to save water, but the water-saving irrigation which improve the efficiency of water use. In order to result these problems, a Greenhouse Efficient Automatic Irrigation System Based on Evapotranspiration has been developed in this paper. It relies on modern science and technology to use water resources efficiently, in order to achieve high quality and crop yield with the littlest water source.

3. PROBLEM SOLUTION

Greenhouse Efficient Automatic Irrigation System Based on Evapotranspiration can collect greenhouse environmental parameters such as air temperature, air humidity and net radiation real time, and save the data in its mass data storage according to the interval set by user. The system then calculates the irrigation amount and time based on the data above by formula, and tell user in voice.

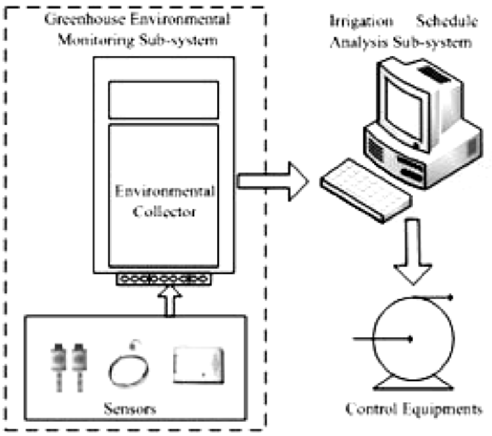

Figure 1. System structure

The system can communicate with PC in several kinds of way such as USB, Ethernet and RS232/485. There are three parts in the system, including greenhouse environmental monitoring sub-system, irrigation schedule analysis sub-system and all the irrigation control equipments in greenhouse. The real-time data collected in the greenhouse environmental monitoring sub-system, while the irrigation schedule analysis sub-system can calculate the irrigation amount and time based the data above.

3.1 Greenhouse Environmental Monitoring Sub-system

Main function of the Greenhouse Environmental Monitoring Sub-System is to collect and save data of greenhouse environmental parameters real time. In order to calculate the irrigation amount in different time based on the formula introduced in part of The Irrigation Schedule Analysis Sub-system, we must know the maximum and minimum daily temperature, net radiation of crop canopy and the relative humidity of air. So the Greenhouse Environmental Monitoring Sub-System consists of Sensors and Environmental Collector.

Air temperature and humidity sensors made by National Engineering Research Center for Information Technology in Agriculture are used in the Greenhouse Environmental Monitoring Sub-system. TDD-1 net radiation meter is used to measure crop canopy net radiation. Measuring accuracy of the air temperature sensor is ±0.2%, and measuring range is from -20°C to 70°C; Measuring accuracy of the air humidity sensor is ±2%, and measuring range is from 0 to 100%; Shortwave radiation measuring range of The TDD-1 net radiation meter is $0.27-3\mu m$, earth radiation measuring range of The TDD-1 net radiation meter is $3-50\mu m$.

In order to collect and save environmental parameters above, an Environmental Collector is developed. The core part of the Environmental Collector is single chip; control program is inserted in it. For the advantage of lower power consumption and mass storage, MSP430F149 is used in this system; system clock module is DS1302; voice module consists of AT89C4051 and PM50100 to tell the information and alarm; storage module consists of FM24CL64 and AT45DB08 to save mass data; 128*64 LCD display is used to show data; lithium charge managing chip TC4055; linearity power NCP500SN33 supply power to voice system; power chip TPS7333 supply power for whole system; the first serial interface of MSP430F149 communicates with voice system, the second serial interface of MSP430F149 and CP2101 are transform into USB interface, SPI interface is expanded into 3 serial interfaces by GM8141, connected with

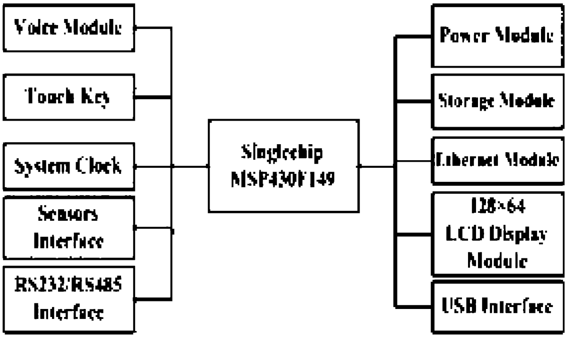

Figure 2. Structure of environmental collector

Ethernet module DNE-18, RS232 CMOS chip MAX3221 and RS485 CMOS chip SN65HVD3082, these consist of multiple serial communication module.

3.2 Irrigation Schedule Analysis Sub-system

The irrigation analysis is the core part of Greenhouse Efficient Automatic Irrigation System Based on Evapotranspiration. Through analysis the environmental data collected by monitoring sub-system, we can compute the less water volume to supply for crops' growth. Then carry on the instruction irrigation under the guidance of the crops water demand in the greenhouse.

The Computation of crops water demand based on the computational method of "Kc•ET0", where Kc is crop coefficient of certain crop, and ET0 is reference crop evapotranspiration. The product KC•ET0 is the crops evapotranspiration under the proper condition (in non-water-stress).

The crop coefficient Kc reflects the water demand difference between crop and the reference crop. One coefficients can be used to describe the infection of evaporation and transpiration, which also can be described by two coefficients separately, namely so-called single crop coefficient and double crop coefficient. When crops are small or planted quite sparsely, after rainfall or irrigation, soil evaporation plays the main role which can be accounted for a large proportion. Especially on a condition of soil surface frequently moist, the computed result of double crop coefficient method is closer to actual value. Therefore, the double crop coefficient method is used to calculate Kc in this paper.

FAO in 1998 published the "Computation Guide of Crops evapotranspiration volume and the Crops Water requirement (the FAO Irrigation And Draining water Handbook - 56)", in which Penman - M.Tess formula recommended to calculate ET_0 as the standard computational method. It has made extremely detailed stipulation to the formula exploitation conditions. And it has been approved an effective method (Allen,1998; Nandagiri etc. 2005; Temesgen etc. 2005; Utset etc. 2004).

FAO's recommendation Penman - M.Tess formula in fact is the composition of the radiation and the aerodynamics. And its combination equation form is as follows:

$$ET_0 = \frac{0.408\Delta(R_n - G) + \gamma \frac{900}{T+273} u_2 (e_s - e_a)}{\Delta + \gamma(1 + 0.34u_2)} \tag{1}$$

In the formula:

ET0: represents crop evapotranspiration, defined as: "transpiration and evaporation of the assumption crop similar to green grasses that in full water supply and exuberant growth condition, and they are 0.12m high; the fixed leaf resistance is 70 s/m, reflectivity is 0.23, broad surface, highly even";

Δ : represents the slope of saturation vapor pressure - temperature curves;

R_n : represents the acceptable net radiation of reference crop canopy surface;

G : represents soil heat flux;

γ : represents the thermometer constant;

T : represents the mean temperature;

U_2 : references the wind's velocity 0f 2m height;

e_s : represents the stream pressure of saturation vapor;

e_a : represents: the stream pressure of actual vapor.

The formula can be used to calculate the evapotranspiration of reference crop monthly, every 10 days, daily, even hour (Li Yulin etc. 2002). Because the formula calculates the amount of evapotranspiration to guide the greenhouse crop irrigation scheduling, it is calculated using daily (Hussein M. 2002).

An analysis of each parameter in the formula (1):

$$\Delta = \frac{4098 e_s}{(T + 237.3)^2} \tag{2}$$

$$e_s = \frac{e^0(T_{\max}) + e^0(T_{\min})}{2} \tag{3}$$

$$e^0(T) = 0.611 \exp\left(\frac{17.27T}{T + 237.3}\right) \tag{4}$$

$$e_a = \frac{e^0(T_{\min}) RH_{\max}/100 + e^0(T_{\max}) RH_{\min}/100}{2} \tag{5}$$

$$G = 0 \tag{6}$$

Note: In the daily calculation of reference crop evapotranspiration, it can be completely ignored (D. Itenfisu etc. 2003).

$$\gamma = 0.0016\frac{p}{\lambda} \tag{7}$$

$$p = 1010 - 0.115H + (0.00175H)^2 \tag{8}$$

Note: Beijing is located north latitude 39°48' east longitude 116°28', therefore elevation elevation H is 31.3m.

$$\lambda = 2.501 - 0.002361T \tag{9}$$

Note: T is the average temperature.

U_2: surveys by the wind speed sensor.

R_n: Uses the Measure of net radiation.

Put all parameters' values into the formula to calculate KC • ET_0, obtain the daily evapotranspiration of greenhouse crops.

In order to satisfy the crops high production demand, the water stored in the water accepting layer of crop's Root should be maintained at the appropriate scope in random time interval. It means that average soil moisture content of moist soil layer is usually not less than the minimum content allowed by crops and not more than the maximum content allowed by crops. The minimum moisture content and the maximum moisture content allowed by different crops, and the initial moisture content are known, The system according to calculations of the crop evapotranspiration rate calculate when the soil moisture content turn to the minimum moisture content allowed, and calculate the irrigation volume from the minimum moisture content allowed to the maximum moisture content allowed by crops. The system turns on irrigation equipment in the suitable date.

4. TESTING AND DISCUSSION

The system has been tested in six greenhouses with the same condition of ShengFangYuan in Beijing, China. Number the six greenhouses as 1, 2, 3, 4, 5, 6. The same amounts of cucumber seeding have been planted, greenhouse of NO.1, NO.2 and NO.3 irrigated with the traditional experience methods, greenhouse NO.4, NO.5 and NO.6 irrigated under the instruction of the Efficient Automatic Irrigation system. The result of testing shows that the system can instruct greenhouse irrigation efficiently, average increase yield 18%, and average save water 28%.

Table 1. Comparison of the crop yield and water consumption between greenhouses irrigated with the traditional experience methods and greenhouses irrigated under the instruction of the Efficient Automatic Irrigation system

	NO.	Crop Yield (Kg/ha)	Water Consumption (m^3/ha)
Traditional Irrigation method	1	75300	3090
	2	76500	3180
	3	80000	3300
Irrigate by the Efficient Automatic Irrigation System	4	90000	2000
	5	93700	2310
	6	91800	2540

5. CONCLUSIONS

With the further development of world's economy and society, the strategic position of water resources is more and more important Greenhouse is a kind of spending mass water plant, so development of efficient water-saving irrigation is significant. Traditional irrigation method saves water but losing yield, in order to result these problems, a Greenhouse Efficient Automatic Irrigation System Based on Evapotranspiration has been developed in this paper. The system improves the efficiency of water use to save water, relying on modern science and technology to achieve high quality and crop yield with the littlest water source.

The system has been examined in greenhouses of ShengFangYuan Test Station in Beijing, China; the result shows that the system can instruct greenhouse irrigation efficiently, increase yield 18%, and save water 28%.

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