Telemetering system and its application for fruit cultivation in greenhouses

Zhang Daohui, Wang Jiawei*, Zong Xiaojuan, Wei Hairong,
Zhu Dongzi, Liu Qingzhong*

(*Key Laboratory of Fruit Tree Biotechnology Breeding, Shandong Institute of Pomology, Taian, Shandong 271000, China*)

Abstract: Circuit of the temperature measurement equipment was improved in order to develop temperature telemetering system for cultivating fruit facilities. The traditional temperature measuring equipments used in monitoring temperature changes in greenhouse include mercury column, merbromine column, kerosene column glass rod thermometer and mechanical inductive thermometer. Compared with the traditional method of temperature measurement the new system reduces the labor requirement and promotes precision monitoring and control of the temperature. In addition, the temperature in the greenhouse was very accurate especially at night or in rainy and snowy weather. This new temperature telemetering system will promote the development of the fruit protection cultivation.

Keywords: sweet cherry, temperature wire telemetering, universal instrument, temperature measurement and control system

DOI: 10.3965/j.ijabe.20130602.002

Citation: Zhang D H, Wang J W, Zong X J, Wei H R, Zhu D Z, Liu Q Z. Telemetering system and its application for fruit cultivation in the greenhouse. Int J Agric & Biol Eng, 2013; 6(2): 13－18.

1 Introduction

Temperature is an important environmental factor for cultivation in the fruit protection areas. The precision of the temperature detection and control in the cultivation environment plays significant roles in yield and quality[1]. The average annual income of farmers who produce fruits in the protection facility increases by 5-10 times compared with that in the open-air farmland[2]. Extraordinary economic benefits make obvious increase of cultivation area in the protection area for the past few years. Various facility cultivation greenhouses emerged all around the country successively. Due to limited technical level, economic basis and cultivation experience there are many problems, especially in temperature detection technique and methods for cultivation in the greenhouse. The traditional temperature detection equipments such as mercury column, merbromine column, kerosene column glass rod thermometer and mechanical inductive thermometer, usually respond slowly with single functions and cause high frequency to record temperature value in the greenhouse. It is difficult to detect temperature promptly and accurately especially at night or in rainy and snowy weather. Therefore, multi-functional, easy-to-use modern electronic measurement and control instruments began to be developed and put into practice. The modern electronic measurement and control instruments can detect air and

Received date: 2011-12-18 **Accepted date:** 2013-04-08

Biographies: Zhang Daohui, Researcher, research interests are storage, refreshment and environmental control; Tel: 13505388816; Email: daohuizhang@sina.com. **Zong Xiaojuan**, Associate Researcher, research interests are fruit germplasm resources and breeding; Email: xjzong812@163.com. **Wei Hairong**, Associate Researcher, research interests are fruit germplasm resources and breeding; Email: hrwei2004@163.com. **Zhu Dongzi**, Associate Researcher, research interests are fruit germplasm resources and breeding; Email: zhudongzi@gmail.com.

***Corresponding author: Liu Qingzhong**, Researcher, Taishan Scholar, research interests are fruit germplasm resources and breeding; Tel: 0538-8266663; Email: qzliu001@126.com. **Wang Jiawei**, Assistant Researcher, research interests are fruit germplasm resources and facility cultivation; Tel: 0538-8266605; Email: wangjw-sdip@qq.com.

ground temperature in the greenhouse at any time. However, this new instrument belongs to common instrument with strong expertise in the selection and using[3]. The user must know well the operational and technical indexes before using it. Adjustments are allowed to be made if the default values are not applicable for the cultivation characteristics in the fruit protection area[4,5]. For this reason, this study was conducted on these electronic measurement and control instruments in the sweet cherry cultivation facilities for three consecutive years. Therefore, appropriate apparatus was selected which can meet requirements for the sweet cherry cultivation and the circuit of some instruments was improved with pertinence. The improved instruments have been used in single-span, double-span, three-span and five-span greenhouses, respectively. With this improved temperature measurement system, the temperature in the greenhouse was regulated and controlled more accurately, which significantly improved production efficiency, greatly reduced the amount of labor, increased sweet cherry yield, and improved the quality of the fruit.

2 Materials and methods

2.1 Selection of main functions and technical indexes

The electronic measurement and control instrument used in the fruit protection cultivation is mainly used for detecting air temperature and ground temperature in the greenhouse. It is used in measuring and/or controlling indexes such as humidity, pressure, flow rate, rotation speed and water level. Different types of the instrument represent different applications and functions, and the same instruments are produced by different manufacturers according to the same standard for type and index[6,7]. Thus, the temperature measurement and control instrument used in sweet cheery facility cultivation can be reasonably used via analyzing concrete type and index. There are many product types from the manufacturers of the same instrument, so solid expertise is needed in the choosing process. Table 1 shows main performance and technical indexes of 10 instruments that the user must know. These are selected according to the working principle and operation criteria of various electronic measurement and control instruments and can also be used in measurement and control of temperature. Main indexes such as resolution ratio and range of measurement and control of XMTD-2002 instrument can meet requirements of cultivation in the fruit protection area. It is also shown by the market research that the prices are at the lower-middle level, thus, the instrument can be regarded as a suitable one. The range of working temperature of 10 instruments in Table 1 is between 0℃ and 50℃, but the fruit production takes long time which reaches to the mid-winter season and the instrument often works outside the greenhouse, where the temperature is far lower than 0℃[8]. This will cause substantial error in the device resulting in the measurement discrepancies. Therefore, circuit and individual index of the instrument need improvement so as to fully meet cultivation requirements.

Table 1 Type and main performance of 10 common electronic temperature measurement and control instruments

Name of electronic temperature measurement and control instrument	United domestic type	Type and name of temperature transducer	Main use	Resolution response /℃	Working temperature /℃	Measurement and control range /℃	Explanation
Digital temperature indicator	XMZ-101	Thermocouple	Temperature measurement	0.1, 0.5	0~50	0~400	Full scale display
Digital temperature display controlling instrument	XMTD-2002	CU50 (G) copper thermal resistance	Temperature measurement and regulation	0.1	0~50	-50~150	Full scale display and clamped single-limit regulation
Digital temperature display controlling instrument	XMTE-8002	Pt100 (BA1) platinum thermal resistance	Temperature measurement and regulation	0.01, 0.1, 1	0~50	-199.9~199.9	Full scale display and clamped single-limit regulation
Digital temperature display controlling instrument	XMT-113	Input voltage signal (mV)	Temperature measurement and regulation	0.1, 1	0~50	0~500	Full scale display overrun alarm

Name of electronic temperature measurement and control instrument	United domestic type	Type and name of temperature transducer	Main use	Resolution response /℃	Working temperature /℃	Measurement and control range /℃	Explanation
Digital temperature display controlling instrument	XMT-12F5	Input current signal (mA)	Temperature measurement and regulation	0.1,1	0~50	0~500	Full scale display overrun alarm
Intelligent digital-display controlling instrument	XMTB-8302	Pt100 (BA2) platinum thermal resistance	Temperature measurement and regulation	0.01, 0.1, 1	0~50	-199.9~199.9	Full scale display and time scale regulation
Intelligent digital-display controlling instrument	XMTA-2603	Input voltage signal (mV)	Temperature measurement and regulation	0.01, 0.1, 1	0~50	0~500	Full scale display, single-phase silicon-controlled dephasing trigger control
Intelligent digital-display controlling instrument	XMT-174	Input thermal resistance signal	Temperature measurement and regulation	0.01, 0.1, 1	0~50	-199.9~199.9	Full scale display, single-phase silicon-controlled zero-passage trigger control
Intelligent digital-display controlling instrument	XMT185	Input current signal (mA)	Temperature measurement and regulation	0.01, 0.1, 1	0~50	-199.9~199.9	Full scale display, three-phase silicon-controlled zero-passage trigger control
Intelligent digital-display controlling instrument	XMTA-2905	Input current signal (mA)	Temperature measurement and regulation	0.01, 0.1, 1	0~50	-199.9~199.9	Full scale display and clamped double-limit regulation

2.2 Improvement of the instrument circuit and parameters

Via mapping and analyzing the electronic temperature measurement and control system, it is found out that although instruments are diverse in appearance, their internal structures and theories applied in unit circuit are basically identical[9]. Figure 1 shows the functional block diagram of temperature measurement and displays circuit of XMTD-2002 instrument. It represents the same temperature measurement and control instrument of other type temperature measurement devices. There are five unit circuits in the circuit: power transformation, signal transformation, multilevel signal filtering, signal amplification and LED display. The temperature drift errors[10] of all unit circuits can be detected one by one via zero-signal input method[11] to determine the source of the temperature drift error which is generated by signal transformation circuit. And this circuit is mainly made of Wheatstone bridge circuit[12] and thermal resistance temperature transducer. Figure 2 shows the original schematic circuit diagram of signal transformation. W_1 is 1 kΩ presetting potentiometer with simple glass axis and the temperature coefficient is ±0.025%/℃. R_1, R_2, R_3 are 10 kΩ, 10 kΩ, 100 Ω fixed resistance with metal oxidation film respectively and the temperature coefficient is ±0.035%/℃. Rt is Pt100 platinum thermistor. Improvements were made by changing the electronic component with low temperature coefficient and reference voltage source was changed according to Wheatstone bridge temperature compensation and diphasic compression theory of temperature drift in the instrument[13] and combined with repeated reversion and experiment at the spot. Figure 3 shows the improved schematic circuit diagram of signal transformation. G is integrated band-gap reference voltage source MC1403[14]. The integrated circuit inputs 5 V direct voltage and outputs 2.5 V reference voltage with function to prevent temperature drift; in this case, the working power of the signal transformation circuit is changed from 5 V to 2.5 V. W_1 is HP-16 1 kΩ precise wire-wound potentiometer, the temperature coefficient is ±0.002%/℃.

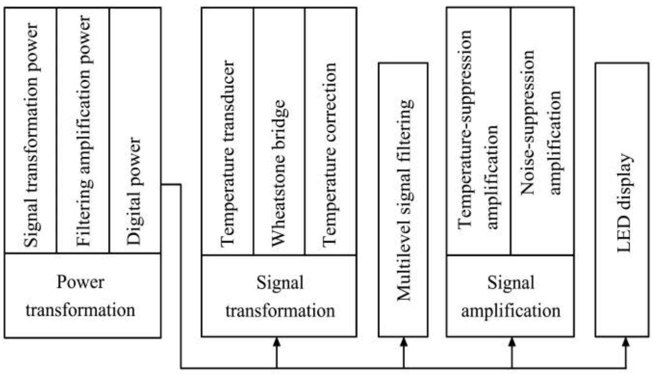

Figure 1 Functional block diagram of temperature measuring instrument

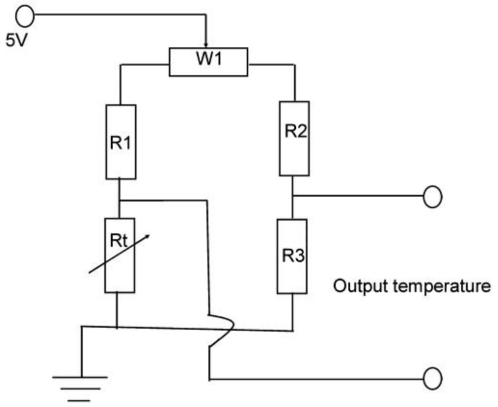

Figure 2 Original schematic circuit diagram of signal transformation

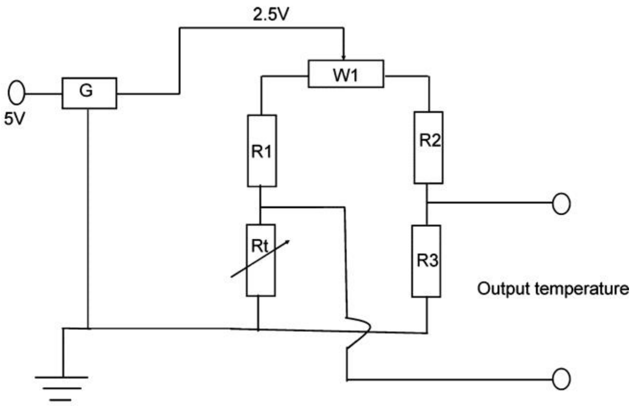

Figure 3 Improved schematic circuit diagram of signal transformation

3 Results

3.1 Improvement effect

The temperature drift curves of improved and unimproved XMTD-2002 instrument were detected via freely-designed detection method[15] (Figure 4). The measured temperature value is stable at 0℃ (ice water mixture). When the working temperature is lower than 3℃ or higher than 45℃, the measurement error was larger when compared with the improved equipment When the same method was applied on various different types of instruments the results were the same i.e., the indexes and data were different in Table 1. This is because the instrument was covered with the plastic shell with bad heat dispersion. This result in the increase of temperature inside the shell than the outside of the shell and there was a shift-up of index of practical working temperature. Applicable range of the improved XMTD-2002 instrument to the working temperature is obviously widened, the lower limit is increased over 22℃ and the working temperature index is improved from 0-50℃ to negative 22-50℃, which meets the requirements of the fruit cultivation where the temperature needs to be monitored and controlled for the long production period.

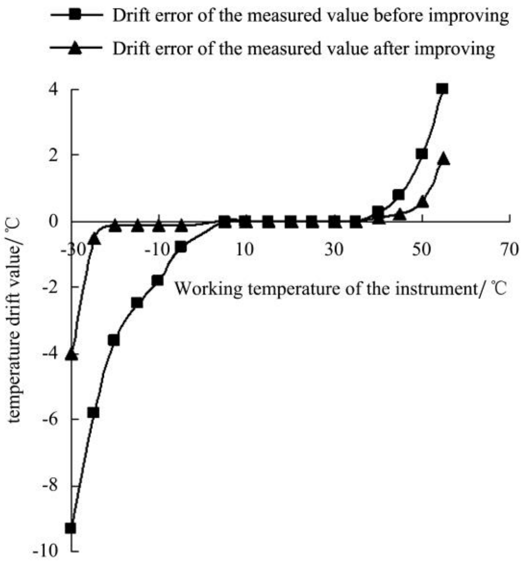

Figure 4 Temperature drift curve before and after improving the instrument

3.2 Application of improved instrument in the five-span greenhouse for cultivation

The improved instrument can be used in single-span, double-span, three-span and five-span greenhouse respectively. It showed that it is more economical and convenient to use firewood, coal or gas to raise temperature in the greenhouse than using electric heating thermostat. Electric heating thermostat means more infrastructure and investment. Therefore, the measurement and control system for the cultivation of fruit is mainly used to monitor air temperature or ground temperature in the greenhouse as shown in Figure 5. The system is fixed on the wall of the isolation room outside the greenhouse and five waterproof temperature transducers are fixed. The wire telemetering of temperature in the greenhouse is realized by connecting a three-core signal cable to the measurement and control system in the isolation room. Figure 5 shows five temperature values, representing air temperature and ground temperature in five greenhouses. Figure 6 shows appearance of north side of the five-span greenhouse for sweet cherry cultivating, the operator can monitor the temperature change in the greenhouse at any time and can increase, decrease or maintain the same temperature, which significantly reduces the labor requirement ad increased the efficiency of the system. The system has been operated to conduct wire telemetering for cultivation temperature of sweet cherry facility in the greenhouse for successive three years. Results were observed in both yield and quality of sweet cherry which has been increased tremendously when compared with the same greenhouse whose temperature is monitored by traditional method. The economic return was also increased as the average selling price of the product has risen to 7.5 times that of the same variety cultivated in the open.

Figure 5 Working state of the temperature measurement and control system for sweet cherry facility cultivating

Figure 6 Five-span greenhouse for sweet cherry cultivating

4 Conclusions and discussion

After the electronic measurement and control instrument improvement, the temperature telemetering system for fruit facilities cultivation has strong adaptability and high precision. Its major functions and technical indexes can fully meet the requirements of fruit cultivation. Therefore, it can be promoted and supplied as a professional measurement and control system.

Heating and warming of the fruit production area by firewood, coal and gas etc., cannot be automated considering the cost and safety. It is more suitable in the current national conditions to regulate temperature in the greenhouse via the monitoring value of the instrument by manual work. In contrast, heating and warming by electric energy can be fully-automated.

The temperature measurement device replaced the traditional mercury column and mechanical inductive thermometer. This reduces labor intensity and promotes a better scientific management of the system. This new technique pushes forward the development of precise monitoring and controlling system for the fruit production in the greenhouse.

Acknowledgements

This work was supported by Grants from the International S&T Cooperation Project of China (Project No. 2012DFR30700), Special Fund for Agro-scientific Research in the Public Interest of China (Project No. 200903019), The Ministry of Agriculture 948 Project of China (Project No. 2011-Z40), Shandong agricultural improved variety project [No. (2010)6] and Taian scientific and technological development planning item (20075014).

[References]

[1] Wustenberghs H, Verbeyen J, Keulemans J. Preliminary experiences with super intensive protected growing of sweetcherries. Acta Horticulturae, 1993; 349: 59-61.

[2] Sun R H, Wang T, Qin Z H, Yang F, Guo Y J. Occurrence trends and preventive treatment against plant diseases and insect pests of large cherries in Shandong protection area. Deciduous Fruiter, 2010; 1: 24-25. (in Chinese with English abstract)

[3] Huang X L, Wang Y, Sun Q X. Thermodetector and error compensation in temperature controlling system. Academic Journal of Harbin Institute of Technology, 1996; 28(4): 48-51. (in Chinese with English abstract)

[4] Zhang D H, Liu Q Z, Zong X J, Shen G N, Wang J W, Li B. Research on error and improvement for temperature measurement of farm-oriented temperature controlling

instrument. Shandong Agriculture Science, 2011; 2: 95-98. (in Chinese with English abstract)

[5] Shen Y Y, Guo J X, Gao D S. Temperature and fruiter facility gardening. Academic Journal of Shandong Agricultural University, 2000; 31(2): 217-220. (in Chinese with English abstract)

[6] Guo H G, Song J H, Zhang Y, Song X S. Research on humiture change law in heliogreenhouse with different structures. Shangdong Agriculture Science, 2009; 8: 43-45, 48. (in Chinese with English abstract)

[7] Zhang L M, Pan H F, Wu Q Y. The verification system for common instrument and meter based on LabVIEW and PXI design. China Test, 2010; 36(2): 70-73. (in Chinese with English abstract)

[8] Zhang N, Sun Z B, Zeng G. Change of extreme air temperature in 1955-2005. Academic Journal of Nanjing Institute of Meteorology, 2008; 31(1): 123-128. (in Chinese with English abstract)

[9] Zhang D H, Zhao H J, Zhou G F, Zong X J, Shen G N, Liu Q Z. Control method of temperature drift for temperature controlling instrument of agricultural products storage facilities. Academic Journal of Agricultural Machinery, 2010; 41(6): 108-112. (in Chinese with English abstract)

[10] Huang D M, Xu X K. Nonlinearity bearing calibration of platinum resistor transducer based on functional transformation theory. Academic Journal of Sensor Technology, 2006; 19(6): 2547-2549. (in Chinese with English abstract)

[11] Zhang D H, Jia F J, Yang J X, Zhang J L. Temperature drift and detection method for common storage and refreshment temperature controlling instrument. Deciduous Fruiter, 2004; 36(1): 36-38. (in Chinese with English abstract)

[12] Zhang D H, Lu M S, Wang T M, Wang S Z, Zhang J, Jia F J. Standard signal output device of the electronic measurement and control instrument. China patent, ZL00247521.9[P], 2001-05-16. (in Chinese)

[13] Zhang D H, Zhou G F. Diphasic suppression device for temperature drift of the electronic measure and control instrument. China patent, ZL200820021440.5[P], 2009-1-28. (in Chinese)

[14] Chen L, Li M, Zhang R X, Lai Z S, Yu J G. A kind of band-gap reference circuit with output buffered low-temperature coefficient. Electron Device, 2008; 31(3): 108-112. (in Chinese with English abstract)

[15] Zhang D H, Liu Q Z, Wei H R, Zhou G F, Shen G N. Reason analysis and control of temperature fluctuation in the fruit cooling bank. Agricultural Engineering Academic Journal, 2009; 25(6): 180-185. (in Chinese with English abstract)