The application of soil temperature measurement by LM35 temperature sensors

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***Abstract*— Consider revising medium temperature used LM35 temperature sensor, what is an economic and feasible method. This study mainly researches the applicability of LM35 temperature sensor in soil temperature testing field. Selected the sensor, and based on the theoretical equation between the sensor output voltage and Celsius temperature; introduced correction coefficient, carried through the calibration experiment of the sensor; further more, it is applied to the potted rice's soil temperature detection. The calibration results show that, each sensor correction coefficient is different from others, but these numerical are close to 1, the linear relationship was very significant between tested medium temperature and sensor output voltage. In the key trial period of rice potted, used LM35DZ type temperature sensor to measure the soil temperature. The analysis result show that, the changing trends are basically equal both soil temperature and air temperature, and the characteristics of soil temperatures are lag. The variance analysis shows that, the difference was not significant paper film covered and without covered on soil temperature.**

Keywords-LM35DZ temperature sensor; calibration; soil temperature; detection

I. INTRODUCTION

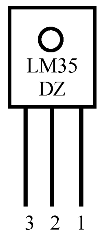
The caloric conversion of soil leads to soil heat and mass flow, which affects soil temperature. The soil temperature is one of the important environmental factors. with the changing of climate, topography, vegetation, soil type, planting form, and other factors, the soil temperature is closely related with some processes, such as crop planting time, tillering growth, and wintering safety etc .The change of soil temperature directly impact on soil nutrient absorption and soil moisture keep and sport, The soil temperature plays a certain role on many of the physical processes of soil. The soil water and heat migration is an important research problem. Therefore, the observation of soil temperature real time and understanding of soil temperature variation have vital significance to agricultural production and scientific research [2, 4, 7].

The traditional measuring method is to insert the sensor into soil before read the records. The measurement of soil temperature has some characters, such as larger area, much observation points, and the time observation lasting is longer etc, which results in detecting data inaccurate in that survey crew visual fatigue and other factors [5]. At present, commonly used soil temperature measuring instruments mainly involves non-contact thermo-detector by infrared spectrum, the temperature sensor using the PN junction transistor, and the temperature sensor using thermostats. The measuring precision is higher than using the infrared, but the cost is higher, too. It needs calibration the system parameters that measurements using the transistor PN junction and thermostats [4].This study mainly research the applications of LM35 integrated circuit temperature sensors in soil temperature measurement. The sensor has some advantages such as lower cost, high reliability, measurement and carry easy, as well as can be embedded within the designated soil achieve long-term observations.

II. THE WORKING THEORY OF LM35 TEMPERATURE SENSOR

LM35 is integrated circuit temperature sensor made by National Semiconductor. It has higher precision and wider range of linear working. The output voltage LM35 linear proportional Celsius temperature, at ordinary temperatures, it can provide ±1/4℃ common precision of room temperature without need additional calibration or fine-tune [8]. The test used LM35DZ-92 type temperature sensor with plastic packaging. The pin functions as shown in figure 1, basic working parameters are:

- Working voltage: dc 4 ~ 30V;
- Working current: less than 133 μA;
- Output voltage: + 6V ~-1.0V;
- Output impedance: 1mA load 0.1Ω;
- Measuring precision: 0.5 ℃ (in + 25℃);
- Leak current: less than 60 μA;
- Scale factor: linear + 10.0 mV / ℃;
- Nonlinear value: ±1/4 ℃;
- Calibration means: use directly Celsius temperature calibration;
- Measuring temperature range: 0 ~ 100 ℃.



1 power +Vs; 2 output V_{out}; 3 grounding GND

Figure 1. LM35DZ temperature sensor's pin function.

This experiment mainly research about testing crop root layer soil temperature used LM35DZ temperature sensor.

The biggest changing range of soil temperature is 0 ~ 40 ℃. According to the test requirements, the detection circuit was designed,which be shown in figure 2. Three core wires, LVVP type ,were used measurment ,and it's length is 600mm. one side of the wire connects the sensor pins, the other side connects power source and output terminal. The sensor adopts 9V batteries, the sensor's output voltage(V_{out}) was detected using the type VC97 multimeter. The theory computation formula of soil temperature (T) is:

$$T = V_{out}/K_t \, . \tag{1}$$

Account for: T—Soil temperature, ℃, V_{out}—Soil temperature multimeter's output voltage, mV, K_t—Linear scale factor, adopt 10.0 mV /℃.

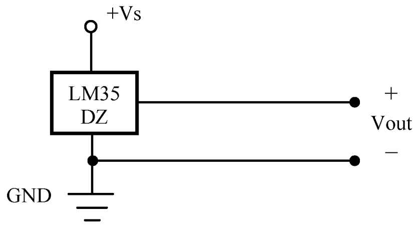


Figure 2. The principle of detection circuit about LM35DZ temperature sensor.

III. LM35 TEMPERATURE SENSOR'S CALIBRATION EXPERIMENT

A. Test materials and methods

In order to validating the detection performance of LM35DZ temperature sensor,and achieving test the soil temperature to multipoint repeatly, the experiments of detection performance about sensor calibration must carry out. Preparating ice water mixture, filtering on its heating, calibrating LM35DZ test results used glass mercury thermometer; Choosing twelve LM35DZ temperature sensors for calibration experiment, using standard glass mercury thermometer (WBG-0-2,made in hongxing instrument and meters factory ,in Wuqiang County, HeBei Province), the range of temperature measurement is 0~50℃, measurement accuracy is 0.1℃. Adopt SPSS13.0 software to analysis the test data.

B. The analysis of experiment result

Based on the theoretical equation (formula1) between the sensor output voltage and medium temperature, introduced correction coefficient(K),revised the values of the sensor's assessment. Used the least squares to carry through linear regression analysis on the test data, and got the equation relationship between all temperature sensors and the correction coefficient of temperature-voltage.As shown in table 1. Visibly, it exists good linear relationship between medium temperature and sensor output voltage, Each sensor's correction coefficient is different from the others, but these numerical are close to 1. In order to getting accurate measurement results of temperature, it must calibrate to LM35DZ temperature sensor. The variance of linear regression analysis shows that,it is very significant linear relationship between medium temperature and output voltage.

TABLE I. THE REGRESSION ANALYSIS OF LM35DZ TEMPERATURE SENSOR'S TEMPERATURE CHARACTERISTICS

Sensor serial number	Correction coefficient(K)	Regression equation	Correlation coefficient(R^2)
1	1.005	$T = 1.005V_{out}/K_t$	0.9999
2	1.020	$T = 1.020V_{out}/K_t$	0.9996
3	1.009	$T = 1.009V_{out}/K_t$	0.9997
4	1.009	$T = 1.009V_{out}/K_t$	0.9999
5	0.985	$T = 0.985V_{out}/K_t$	0.9999
6	0.994	$T = 0.994V_{out}/K_t$	0.9994
7	1.031	$T = 1.031V_{out}/K_t$	0.9997
8	0.999	$T = 0.999V_{out}/K_t$	0.9999
9	1.011	$T = 1.011V_{out}/K_t$	0.9996
10	0.999	$T = 0.999V_{out}/K_t$	1.0000
11	1.012	$T = 1.012V_{out}/K_t$	0.9996
12	0.995	$T = 0.995V_{out}/K_t$	0.9999

IV. THE TEST OF SOIL TEMPERATURE BASED ON LM35 TEMPERATURE SENSOR

A. Test plan

Applying LM35DZ temperature sensor to paper film covers rice potted experiments, detecting the soil temperature of rice. The test is worked in laboratory for agricultural machinery, Shenyang Agricultural University in 2010. Geographical position for 41°11'-43°2' N latitude, 122°25'-123°48' E longitude. Toughened plastic soil bin was used, and its length is 600mm, the width is 415mm, the height is 430mm. Tested soil is the brown loam, natural moisture content is 6.35%, the total weight of soil and soil bin are 100kg. Test papers were made in YFY Biotech Co. Ltd, Jiangsu, China, and its specification is 100000mm×1260mm, the thickness is 0.1 mm. this paper will decompose naturally after forty days.

The test carrying out under the same conditions, such as rice type, seedlings, transplanting, density, and field management measurements etc. Two treatments are designed in the test: F is planting rice under paper mulching, W is planting rice without overburden, and each treatment is done three times. Each test embedded within two LM35DZ in basin of temperature sensors, embedding depth for 10cm. Select several key time of rice growth points, detecting daily soil temperature of various treatments from 8:00 to 17:00, testing time interval for one hour.

B. The analysis of experiment result

Selected three key points-in-time in the period of rice's growth stages, involving with regreening, tillering, and booting. To analysis of the diurnal variation characteristics of soil temperature, as shown in figure 3-5. In rice's regreening stage and tillering stage, soil temperature are trends that rising in first and declining then, boundary point in 15:00 around, the changing trends are basically equal both soil temperature and air temperature, and the characteristics of soil temperatures are lag. In rice's booting stage, the rice grows thrives, the surface of soil coverage increased, which lead to soil temperature rises slowly. At the time from15:00 to17:00, the soil temperature changes tend to be gentle.

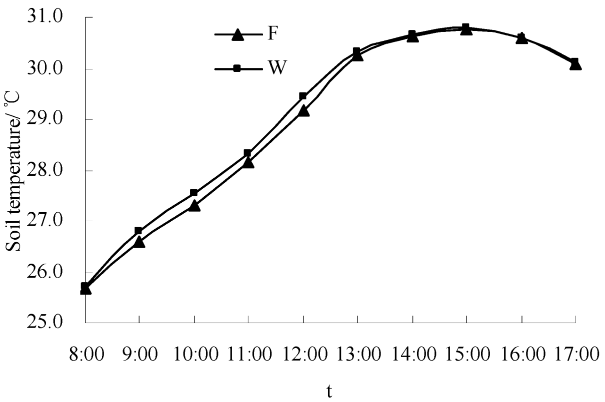


Figure 3. The curve of diurnal change in soil temperature of regreening stage.

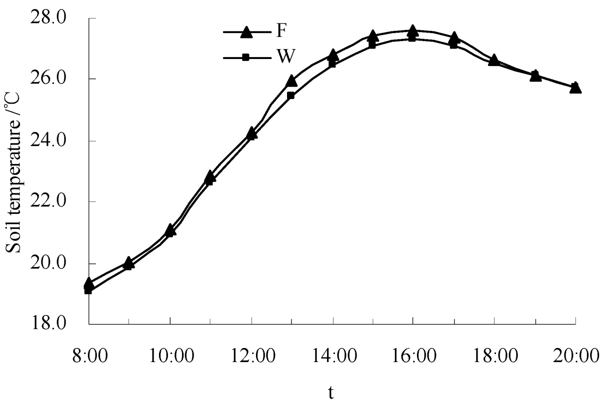


Figure 4. The curve of diurnal change in soil temperature of tillering stage.

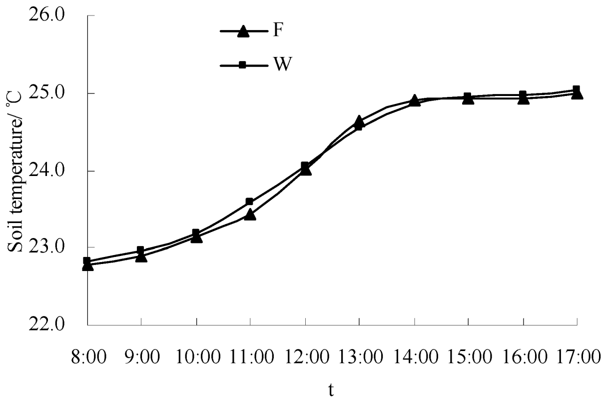


Figure 5. The curve of diurnal change in soil temperature of booting stage.

Paper covering has changed the boundary layer structure of the soil, thus influences the changing trend of soil temperature. In the regreening stage (June 10, sunny weather), at the period from 8:00to13:00, the soil temperature of paper covering is lower than without covering; the soil temperatures of the two processing are basic equal after 13:00. The probably reason is that paper covering has slowed the heating speed of the soil. In the tillering stage (June 23, sunny weather), at the period from 8:00to15:00, the soil temperature of paper covering is higher than without covering; the soil temperatures of the two processing are basic equal after 15:00. The reason is to likely that paper covering has improved the physical properties of the soil. In booting stage (August 18, sunny weather), paper film has completely decomposed, the soil temperatures of the two processing are basic equal. The Variance Analysis show that, it is not significant difference that of the two processing soil temperature.

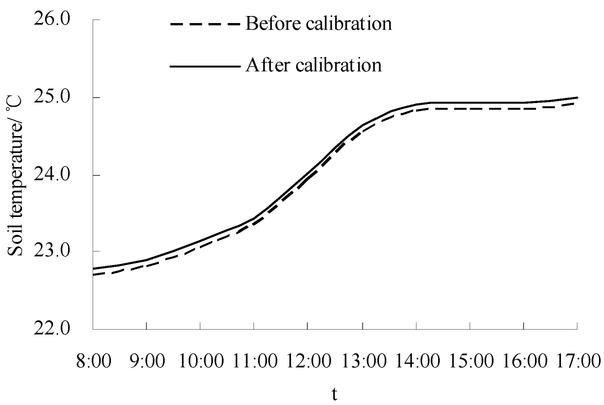


Figure 6. The contrast of the test results to paper covering before and after calibration of the sensor.

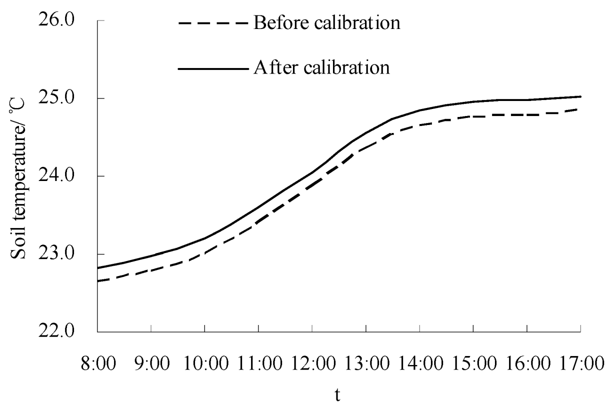


Figure 7. The contrast of the test results to without covering before and after calibration of the sensor.

In order to analyzing the effect of calibration experiment about the temperature sensor, according to the test data on August 18, contrast the test results two circumstances before calibration the sensor and after calibration , as shown in figure 6 and 7. The results show that, the values of after sensor calibration are higher than before calibration. The Variance Analysis shows that, it is not significant that values of before sensor calibration and after calibration. It is thus clear that, the application results of LM35DZ temperature sensor are equal to that of calibration experiment.

V. CONCLUSIONS

The calibration experiments of LM35DZ type temperature sensor detection performance were carried on in this study. Based on these experiments, applied these sensors to the soil temperature detection. Through compared the paper covered the rice and without covering potted experiments, the application effects of LM35DZ type temperature sensor were studied. Preliminary conclusions have been drawn as the following:

(1) In order to correcting the errors of pins welding production and other processes, the calibration experiments of LM35DZ temperature sensor detection performance were carried on. The results show that, each sensor correction coefficient is different from others, but these numerical are close to 1.Visibly, the linear relationship was very significant between tested medium temperature and sensor output voltage.

(2) Applying LM35 temperature sensor to paper film covers rice potted experiments, detecting the soil temperature of rice. The tests results show that, the changing trends of each treatment are basically equal both soil temperature and air temperature, and the characteristics of soil temperatures are lag.

(3) Both Calibration experiment and the soil temperature detecting test indicate that, the values of after sensor calibration are higher than before calibration. But, it is not significant that values of before sensor calibration and after calibration. Obviously, in some cases what requirement is not particularly strict, it can be directly applied the temperature characteristic equations before calibration, to calculate the medium temperature.

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