Simulation of Evaporation and Transpiration of Eggplant Under Mulch Drip Irrigation in Greenhouse

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Abstract. Based on the principle of soil water balance, the change of soil water content during the whole growth period of eggplant with the variety "Angela" as the material is simulated through the test of greenhouse environmental factors. The crop coefficient is determined by the optimization method. The evapotranspiration of eggplant is simulated under the condition of drip irrigation under mulch film. The results showed that the simulated values of soil water content in the growth period of eggplant are in good agreement with the measured values, and the relative error is less than 10%. The variation rule of the crop coefficient and eggplant leaf area index are consistent. The crop coefficient in the early increases gradually, in the vigorous growth period of crop coefficient reaches the maximum value of 0.518, then began to decreases from 0.518 reduced to 0.505 and then increased gradually. The fluctuation is mainly affected by pruning management. The change of water requirement of eggplant in greenhouse is smaller in the early stage of growth between 0.2 ~ 2.4mm/d. And the change in the late of the growth period is larger between 0.1 ~ 3.1mm/d. The accumulated value of evaporation and transpiration increases gradually, and the highest value is 290mm/d.

Keywords: drip irrigation under mulch film, eggplant, evaporation and transpiration, simulation

1 Introduction

The soil water content of root layer has great influence on the growth, yield and quality of eggplant. To explore the eggplant growth period of water requirement rules and the optimum irrigation scheme which determine the scientific and quantitative irrigation index and guide the agricultural production, alleviate the water shortage in agriculture, reduce waste of water in agriculture, improve agricultural water use efficiency etc. problem has important significance[1-4]. Evaporation and transpiration in vegetable research is generally under traditional irrigation condition, and mainly aims at different types of vegetables water requirement characteristic and different growth stages water requirement characteristic and different natural conditions of vegetables water requirement rules to conduct qualitative analysis. However, due to the different irrigation drainage and field management measures, the micro climate environment of crop growth has also changed a lot. The research results obtained under the traditional production conditions are obviously not suitable for the crop water requirement under the condition of drip irrigation in greenhouse. Calculation model for the domestic fruit and vegetable crops evapotranspiration is mainly to establish water requirement regression empirical model using meteorological factors and yield. The empirical model can be used for the calculation of crop water requirement in a certain period of time, but for different regions, it is necessary to accurately estimate crop water requirement in combination with local climatic conditions, and to correct the parameters of the formula [5-9].

2 Experiments and Methods

2.1 Experimental Samples

The experiment is carried out at the experimental base of the West Campus of Tianjin Agricultural University. The soil of the experimental area is loam, and the basic properties of the soil are shown in table 1. During the experiment, the planting of Eggplant in the greenhouse is Angela, and the planting date is September 13, 2014. We have planted 55 ridge crops in the greenhouse, 1100 strains. Irrigation mode is the drip irrigation under mulch film. Emitter flow rate is 2.0L/h. The length of one time irrigation was 280min.

Table 1. Soil basic feature

Depth of soil /cm	pH	Salt content /g/kg	Organic matter content /%	Available phosphorus /mg/Kg	alkaline nitrogen/mg/Kg
20	7.22	2.43	2.01	121.9	103.1
40	7.34	1.98	1.35	93.7	79.4
60	7.57	1.45	1.65	57.4	41.5
80	7.21	1.32	1.32	43.2	31.4
100	7.76	1.21	1.08	40.6	30.7

2.2 Experimental Methods

Using the Internet of things system tests the soil moisture content which aims at the characteristics change. The Internet of things system terminal set up in the middle of the greenhouse, from the ground 2m. The video capture terminal is erected at the top of the greenhouse to ensure that the whole greenhouse can be monitored. In the data acquisition terminal system, air temperature and humidity sensors, solar radiation sensor are integrated in the Internet of things system terminal. Soil temperature and soil moisture sensors are embedded in the layered soil (20 cm under the ground). In order to ensure that the internet of things system can achieve the desired goal and reliable operation, the first log terminal and data acquisition module respectively corresponding debugging, to ensure that each part can be normal and reliable operation. Only in ensuring the reliability of each part of the system under the premise of the system continues to carry out the relevant testing of the entire system until the desired target. Rectangle of blade can be seen as a rule, every time we measure crop longitudinal maximum length of the blade as the blade length calculation, horizontal maximum length as the blade width calculation, so the calculated area is equal to the length of blade, multiply, wide's production. The actual size of leaf samples gather from small to large series, and then back to the laboratory with laser scanning leaf area meter blade to abstain the actual area, finally find out the actual area and calculation area of the relationship. The corresponding calculation formula: y=0.6449x+9.2414. The square of correlation coefficient is 0.8721. y is the eggplant leaf measured area,cm^2; x is eggplant leaf area calculation, cm^2.

2.3 Simulation Calculation of Evaporation and Transpiration

We use the soil water correction coefficient to analyze the effect of insufficient water supply on crop water requirement. The calculation formula is as follows:

$$ET = K_s K_c ET_0 \tag{1}$$

In the formula（1）, ET represents fact crop water requirement, mm/d. K_s represents correction coefficient which effects soil water deficiency in root zone on crop water requirement. K_c represents crop coefficient, which is related to the crop species, growth period and population leaf area index, and is a reflection of the biological characteristics of crops. ET_0 represents reference crop evapotranspiration, mm/d.

2.3.1 Calculation of Crop Coefficient

Many literatures show that the leaf area index of crop population and the crop coefficient are linear in a certain period of time:

$$K_c = aLAI + b \tag{2}$$

In the formula (2), K_C represents crop coefficient of eggplant. LAI represents the leaf area index. a and b represent coefficient of demand.

By using the least squares method to simulate and calculation of soil moisture content and the actual test of soil moisture minimum squared error objective function, we use the optimization inversion method to determine the value of a and b. The objective function is as follows:

$$SS = \min \sum_{j=1}^{N} (\theta_j - \hat{\theta}_j)^2 \tag{3}$$

In the formula (3), SS represents the objective function. θ_j and $\hat{\theta}_j$ represent measured and simulated values of soil water content. N is Test quantity.

In this experiment, the water content of soil $\hat{\theta}_j$ is simulated by using 0-100cm soil water balance equation.

The results of each parameter in the iterative calculation are shown in Table 2.

Table 2 Validation and calibration of eggplant crop coefficient parameters

Parameter	Initial value	Optimal value
a	0.2	0.100
b	0.3	0.717
SS	107.46	16.31
Sample quantity		20
Standard deviation		0.96

2.3.2 Calculation of soil water correction coefficnient

The Jansen calculation model is as follows:

$$K_s = \begin{cases} 1 & \theta \geq \theta_j \\ \dfrac{\ln(AW+1)}{\ln(101)} & \theta_j > \theta \geq \theta_{wp} \\ 0 & \theta < \theta_{wp} \end{cases} \tag{4}$$

$$AW = \frac{\theta - \theta_{wp}}{\theta_{cr} - \theta_{wp}} \tag{5}$$

In the formula, Ks represents soil water correction coefficient. AW represents real effective soil moisture percentage. θ is the moisture content of soil root layer. θ_{cr} is the moisture content of soil is affected by the water deficit. Reference to the existing research literature, θ_{cr}=0.90θ_c. θ_c represents field water holding capacity. θ_{wp} represents crop wilting water content, by experiment θ_{wp}=0.2θ_c, θ_c=0.28 cm^3/cm^3.

3 Results Analysis

3.1 Changes of Leaf Area Index of Eggplant with Time

The variation of leaf area index with time is drawn by using the conversion coefficient and the test results. Eggplant leaf area index from 0.63 initial increases gradually, after reaching the peak value appeared in the first increase and then decrease, and then increase the volatility process, the main reason is the eggplant pruning management measures. We get the maximum value of the leaf area index of eggplant in the whole growth period is 1.07, and the minimum is 0.53.

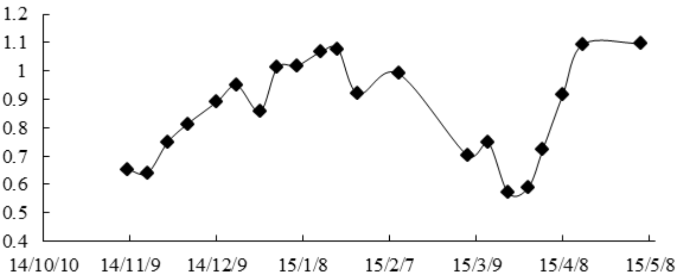

Fig.1 Dynamic curve of eggplant leaf area index

3.2 Irrigation Amount of Eggplant

The irrigation time and irrigation amount of eggplant were given in Fig 2. The irrigation quota is changed from 32 to 50mm. The number of irrigation times is 12 times. The irrigation quota is 510mm.

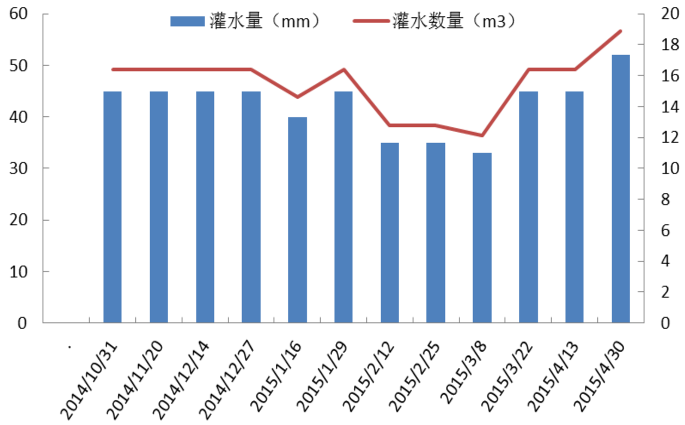

Fig.2 Corresponding Irrigation Amount

3.3 Comparison between Simulated and Measured values

From figure 3, we can see that the simulated values of soil moisture content in eggplant growing season coincide with the measured values, and the relative error between them is relatively small.

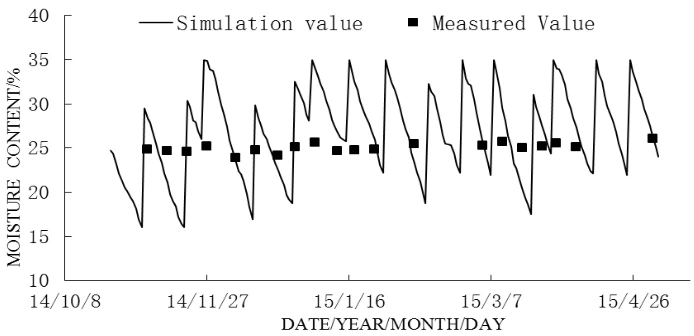

Fig.3 Simulation and Measured Values of Soil Moisture Content of Eggplant

3.4 Variation Law of Crop Coefficient

The variation rule of the crop coefficient and eggplant leaf area index are consistent. The crop coefficient in the early increases gradually, in the vigorous growth period of crop coefficient reaches the maximum value of 0.518, then began to decreases from 0.518 reduced to 0.505 and then increased gradually. The fluctuation is mainly affected by pruning management.

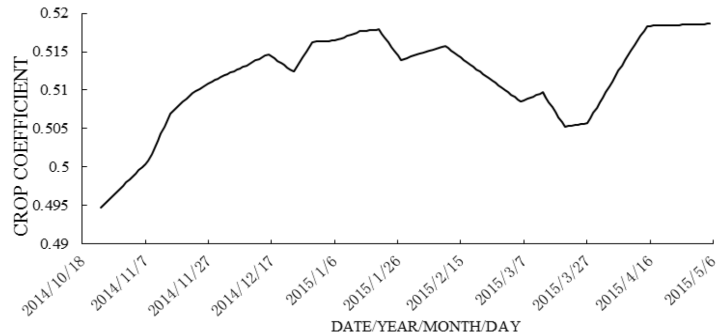

Fig.4 The Variation of Eggplant Crop Coefficient with Time

3.5 Changes of Evapotranspiration

From Figure 5, we can see that the change of water requirement of eggplant in greenhouse is smaller in the early stage of growth between 0.2 ~ 2.4mm/d. And the change in the late of the growth period is larger between 0.1 ~ 3.1mm/d. The accumulated value of evaporation and transpiration increases gradually, and the highest value is 290mm/d.

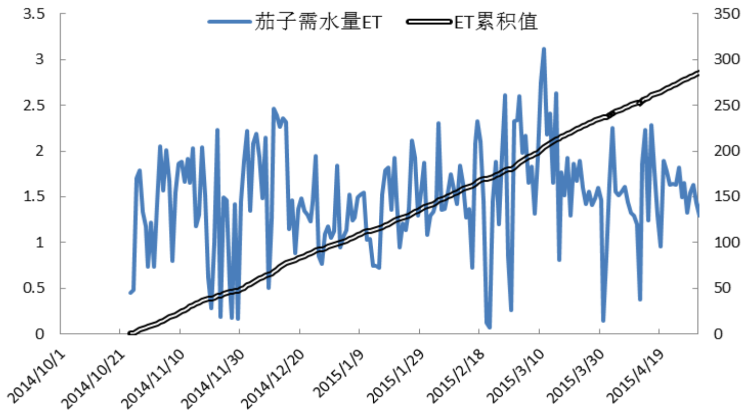

Fig.5 The Variation of Eggplant Crop Coefficient

4 Conclusions

According to the method of parameter inversion, the variation law of the variation law of the crop leaf area index is consistent with the suitable crop coefficient which is determined by the local climate and crop conditions. The crop coefficient affected by pruning management, performance is first increased and then decreased trend to increased volatility.

The variation of evapotranspiration of Eggplant is that the evapotranspiration is smaller in the prophase of growth between 0.2 ~ 2.4mm/d. And the change in late of the growth period is larger between 0.1 ~ 3.1mm/d.

Crop evapotranspiration calculation model is the main content. And the calculation of crop evapotranspiration is mainly depended on reference crop evapotranspiration and crop coefficient. The soil moisture correction coefficient is introduced, and the most reliable way to obtain the crop evapotranspiration is obtained by the measured method.

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