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Research Article

The Research for the Greenhouse Water Evaporation Based on the Environmental Factors

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Abstract: To guide the greenhouse precision irrigation, influenced by the environmental factors, based on the definite plant, the greenhouse water evaporation characteristics are studied. The qualitative and the quantitative relationships between the environmental factors and the greenhouse water evaporation are probed into which will provide the theoretical basis for the water management of the facilities horticulture. Establishing the quantitative relations between the environmental factors and the water evaporation, between the environmental factors and the evaporation of soil water, between the environmental factors and the crop transpiration not only can reveal the environment factors to have the impact on the water evaporation changes, the soil water evaporation changes and physiological changes of the plant water, but also can use meteorological parameter to predict in the greenhouse crop transpiration for the water consumption. Then based on the predicted value timely the plant is supplied with the moderate water. Using genetic algorithm to optimize the models in different season in the different ranges value, the minimum of the evaporation of water is predicted, in order to achieve the purpose of right amount water needed for the plant, saving water, high yield and good quality.

Keywords: Genetic algorithm, the environmental factors, the greenhouse, the water evaporation

INTRODUCTION

The elements of agricultural climate resources are many, but mainly in three aspects: light, temperature and water. Under greenhouse conditions, due to the poor permeability of the membrane and the greenhouse often is in a state of relatively closed at times. The soil water and the plant water are not easily evaporated to form the high air humidity. It is very important for the greenhouse to research the whole water evaporation in the aspects. The cultivation technique and the conditions of light, heat and humidity are not the same, so the crops growth condition and the product also will be great differences. Transpiration rate measurement is very difficultly, the existing methods can only measure the total farmland evaporation and transpiration and the total amount cannot be decomposed into the evaporation and transpiration. There are many difficulties to overcome shortcomings to obtain the ideal results in the measurement (EI-Hassan, 1991).

In this study, based on the tomato a new method is reported to modify the water evaporation models. To investigate and analyze, some conditions are get. In the greenhouse, in the evaporation process the water evaporation is mainly parts. According to the water different parts, the sum of the water evaporation is calculated in this study. Tomato is taken as the object and the relational models between the environmental factors and the water evaporation are established in the greenhouse. The greenhouse water evaporations include the water evaporation, the soil water evaporation and the crop transpiration. The sum of these three parts is calculated and is the greenhouse whole evaporations. The aim of this study is to improve the greenhouse precision irrigation. Establishing the quantitative relations between the environmental factors and the water evaporation, between the environmental factors and the evaporation of the soil water, between the environmental factors and the plant transpiration not only can reveal the environmental factors to have the impact on the water evaporation changes, the soil water evaporation changes and physiological changes of the plant water, but also can use meteorological parameter to predict in the greenhouse crop transpiration for the water consumption. The method can improve the accuracy of the quantitative relationships between the environmental factors and the greenhouse water evaporation. To study the effect of process conditions, then based on the predicted value timely the plant is supplied with the moderate water. Using genetic algorithm to optimize the models in different season in the different ranges value, the minimum of the water

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evaporation is predicted. Furthermore, the effect of the research will provide the theoretical basis for the water management of the facilities horticulture (Du *et al*., 2001; Pan and Cai, 2002; Liu *et al*., 2003; Cai *et al*., 2005; Imrark *et al*., 1998).

MATERIALS AND METHODS

The following steps include the influence factors of water evaporation in the greenhouse and the experiment design. The experiment designs include the test basic condition, the greenhouse microclimate environment factors, the greenhouse water, the soil water and the crop transpiration measurements.

Methods:

The influence factors of water evaporation in the greenhouse:

- **The influence factors of soil water evaporation:** The water in the soil is the basic condition of the crop life. The greenhouse soil water changes are affected by meteorological factors and soil properties, crop growth and the relationships are complicated. In the modern greenhouse, soil water component is mainly affected by the greenhouse environment factors. The soil heat is mainly from the sun radiation and every moment the sun radiation conditions change. The absorption and the loss of the solar radiations are different in the soil. Therefore, the soil water components have changes in the day and night. The number of the soil water not only is affected by the greenhouse environment factors, but also have influences on the environment factors in greenhouse, especially the temperature and humidity of the greenhouse.

The soil evaporation is affected by the meteorological conditions outside, such as solar radiation, temperature, ground temperature, humidity, wind speed, precipitation infiltration way and at the same time have the influences on the soil internal factors, such as the soil water content, diving buried depth, soil texture and structure, soil color and surface properties, the transport capacity of the soil capillary (Penman, 1948).

When the soil water content is higher than usual, the number of the soil evaporation is greater than the number of the water evaporation on the earth's surface. If the water consumed of the soil evaporation be recharged fully, the rate of evaporation is stable and the soil evaporation only is affected by meteorological factors and has nothing to do with the water content. The regression analysis among the soil water evaporation, temperature, relative humidity and the solar radiation is made and the results showed that the three environmental factors is related to the soil water evaporation value. In the practical application of the greenhouse environment control, if the relationship between the soil water evaporation and the environment variable is robust, with these relationships the computer control system of the water irrigation will be optimize. The greenhouse water evaporations include separates the water evaporation、the soil water evaporation and the crop transpiration.

- **The influence factors of the crop transpiration:** As is known to all, in the situation of the crop growth, the evaporation of the water in the soil on the one hand is through the soil surface, on the other hand the transpiration of the water is through the hole and crop leaf, the whole is called transpiration. The plant transpiration is a complex physiological process, not only is made the influence by the plant itself morphology and physiological condition, but also is affected by various external condition restriction. For the greenhouse environment optimization control the quantitative relationship of between the plant transpiration and the environmental factors is the necessary physiological and ecological information.

The experiment designs: Through the theory and analysis, it can be seen that the process of the evaporation and the transpiration in the greenhouse is very complicated and many parameters are measured difficultly. In this study, an idea that according to the different process of the evaporation in the greenhouse water, the greenhouse water evaporation is including the water evaporation, the soil water evaporation, the crop transpiration, is put forward. In the greenhouse, the overall water evaporation is thought as total water consumption. Based on the above analysis, this study is designed into the water evaporation, the soil water evaporation and the crop transpiration experiments. The following is introduction about the measurement.

- **The test basic condition:** The test is made in summer in the greenhouse in China academy of agricultural sciences research of the solar greenhouse vegetables flowers. The test site is in Beijing. The area is located in the northern latitude 39°26 and longitude 116°19. The solar radiation is high, the sunshine time is long and the annual temperature change is big. The distance from east to west is 80m for the greenhouse and the distance from the north to the south is 7m. The greenhouse is covered with plastic film and the light transmittance is about 58%. The test is made by the organic soil.
- **The greenhouse microclimate environment factors measurement:** In the greenhouse with the data acquisition system, every ten minutes and

every five minutes automatically environmental factors are recorded respectively.

- **The greenhouse water measurement:** The greenhouse internal water is evaporated because of the influence of the greenhouse environment factors, not only through the soil and the plant, but also itself. So with the evaporating dish the greenhouse evaporation is measured every day and the quantitative relationship is established between the water evaporation and the environment factors.
- **The soil water measurement:** In the greenhouse the relationship between the soil water evaporation and plant transpiration is inseparable. In order to measure their relationship, in this experiment when in the absence of the plants measuring the soil water evaporation is measured with the weighing method. The lower limit for the number of the soil water is set to 35% and the upper limit is 50%. If soil water value is below the lower limit, the soil will be irrigated and the upper limit value will not be exceeded in the irrigation water. The water in the soil is the source of soil water evaporation.
- **The measurement of crop transpiration:** The tomatoes as the research object and the plastic cultivation tank as experiment tool, the experiment was made in the institute of vegetables and flowers Chinese academy of agricultural sciences. The length of the plastic cultivation tank is 77.6 cm and the wide is 29.2 cm and the height is 24.6 cm. The test was in winter from November to December. The values of the soil water evaporation and the tomato transpiration are recorded with weighing method to measure every day. The value of the soil evaporation basic is zero with plastic film covered the soil surface to control the tomato transpiration. The variation value of the cultivation tank weight is recorded every day. The weigh variation value of the soil tank is recorded every day. The sum of the weigh variation value of the soil tank is the variation of the water consumption for the tomato transpiration and the variation of the absorption water for the tomato growth. The absorption of the water tomato plant is calculated by the method of the sampling and the drying every day. Every time the root sampling is taken out and each part weight is measured for the tomato with the electronic weigher. The correction is made before the each weighing and the roots, the stems, the leaves and the plant total fresh weight are test. Every part is put in the oven. When the temperature is at 115°C, the green is removed. Then under the condition of 75°C, all the parts are dried to the constant weight from 2 to 3 days. The drying weights are measured. In the whole growth period of the tomato and the old leaves are continuously beat away and measured. The transpiration data are collected in the seedling stages and the flowering period of the tomato.

ANALYSIS METHODS

According to the experimental measurement data, the water evaporation is mainly affected by the indoor temperature, the indoor humidity and the indoor light. The correlation between the water evaporation and environmental factors is analyzed (Table 1).

According to the experimental measurement data, the soil water evaporation is mainly affected by the soil temperature, the indoor temperature, the indoor humidity and the indoor lighting. The correlation between the water evaporation and environmental factors is analyzed (Table 2).

According to the experimental measurement data, the tomato transpiration mainly is affected by the indoor temperature, the indoor humidity and the indoor light. The correlation between the tomato transpiration and the environmental factors is analyzed (Table 3).

Table 1 to 3 show that the water evaporation is mainly affected by the indoor average humidity. The soil water evaporation is affected by the indoor average temperature. The tomato transpiration is mainly affected by the indoor average light. The soil average temperature influences the soil water evaporation. The effect of the soil average temperature

Table 1: The relevance between the water evaporation and environmental factors

The environmental factors	The relevance with water evaporation
The indoor average temperatura (ºC)	0.6811
The indoor average humidity (%)	-0.91979
The indoor average light (Radiation intensity (J/m^2/h)	0.790728

Table 2: The relevance between soil water evaporation and environmental factors

The environmental factors	The relevance with the soil water evaporation
The soil water temperature (°C)	0.591084
The indoor average temperature (°C)	0.676205
The indoor average humidity (%)	-0.47762
The indoor average humidity (J/m^2/h)	0.595798

Table 3: The relevance between tomato transpiration and environmental factors

The environmental factors	The relevance with water evaporation
The indoor average temperatura (ºC)	0.692156
The indoor average humidity (%)	-0.58087
The indoor average light (Radiation intensity (J/m^2/h)	0.843006

is more than the indoor average humidity in the soil water evaporation.

RESULTS AND DISCUSSION

Through the indoor environmental data (including the indoor average temperature, the indoor average humidity and the indoor average light) regression analysis, the following quantity relational expressions are get.

The relational expression between the water evaporation and the average values of the indoor environmental factors:

$$y = 8.3692 + 0.0378x1 - 0.0839x2 + 0.004x3 \quad (1)$$

$x1$ = The indoor average temperatura (°C)
$x2$ = The indoor average humidity (%)
$x3$ = The indoor average light (Radiation intensity J/m^2/hour)
y = The water evaporation (g)

The relational expression between the water evaporation and the indoor average temperature:

$$y = -3.489 + 0.2676x1 \quad R^2 = 0.4639 \quad (2)$$

$x1$ = The indoor average temperature (°C)
y = The water evaporation (g)

The relational expression between the water evaporation and the indoor average humidity:

$$y = 11.3606 - 0.1047x2 \quad R^2 = 0.846 \quad (3)$$

$x2$ = The indoor average humidity (%)
y = The water evaporation (g)

The relational expression between the water evaporation and the indoor average light

$$y = 0.1259 + 0.022x3 \quad R^2 = 0.6253 \quad (4)$$

$x3$ = The indoor average light (Radiation intensity J/m^2/h)
y = The water evaporation (g)

The relational expression between the soil water evaporation and the environmental factors the average values of the indoor environmental factors

$$y = -0.3882 + 0.0083x1 + 0.0072x2 + 0.0028x3 + 0.0014x4 \quad (5)$$

$x1$ = The soil average temperatura (°C)
$x2$ = The indoor average temperatura (°C)
$x3$ = The indoor average humidity (%)
$x4$ = The indoor average light (Radiation intensity J/m^2/h)
y = The soil water evaporation (g)

The relational expression between the soil water evaporation and the soil average temperature:

$$y = 0.0241x1 - 0.1031 \quad R^2 = 0.3494 \quad (6)$$

$x1$ = The soil average temperature (°C)
y = The soil water evaporation (g)

The relational expression between the soil water evaporation and the indoor average temperature:

$$y = 0.0146x2 - 0.0691 \quad R^2 = 0.2281 \quad (7)$$

$x2$ = The indoor average humidity (%)
y = The soil water evaporation (g)

The relational expression between the soil water evaporation and the indoor average humidity

$$y = -0.0151x3 + 1.5783 \quad R^2 = 0.2281 \quad (8)$$

$x3$ = The indoor average humidity (%)
y = The soil water evaporation (g)

The relational expression between the soil water evaporation and the indoor average light (Radiation intensity J/m^2/h)

$$y = 0.0024x4 - 0.0096 \quad R^2 = 0.355 \quad (9)$$

$x4$ = The indoor average light (Radiation intensity J/m^2/h)
y = The soil water evaporation (g)

Under the condition of the soil water adequate supply, the tomato transpiration is mainly affected by the environmental factors.The transpiration is affected by the environmental factors differently. The humidity air is also an important factor to influent the tomato transpiration. In addition, the soil surface temperature has a certain influence on the tomato transpiration, but the effect is not very obvious. The tomato transpiration is a positive correlation with the indoor average temperature and the indoor average light. The tomato transpiration is a negative correlation with the average indoor humidity.The largest effect on the tomato transpiration is the indoor average light, the second is the indoor temperature, the third is the average indoor humidity.Through the indoor environment meteorological data (including the indoor average temperature、the average humidity、 the average light) regression analysis was made. The relational expression between the single plant tomato transpiration and the average values of the indoor environmental factors:

$$y = -0.0407 + 0.0008\,x1 + 0.0003\,x2 + 0.0003\,x3 \quad (10)$$

$x1$ = The indoor average temperatura (°C)
$x2$ = The indoor average humidity (%)
$x3$ = The indoor average light (Radiation intensity J/m^2/h)
y = The single plant tomato transpiration (kg)

The relational expression for the single plant tomato transpiration and indoor average temperature:

$$y = 0.0018x1 - 0.0059 \quad R^2 = 0.4791 \quad (11)$$

$x1$ = The indoor average temperature (°C)
y = The single plant tomato transpiration (kg)

The relational expression for the single plant tomato transpiration and indoor average humidity:

$$y = -0.0022\,x2 + 0.2303 \quad R^2 = 0.3374 \quad (12)$$

$x2$ = The indoor average humidity (%)
y = The single plant tomato transpiration (kg)

The relational expression for the single plant tomato transpiration and indoor average light:

$$y = 0.0004\,x3 - 0.0031 \quad R^2 = 0.7107 \quad (13)$$

$x3$ = The indoor average light(Radiation intensity J/m^2/h)
y = The single plant tomato transpiration (kg)

The application of the genetic algorithm in the evaporation model: Genetic algorithm is global optimization algorithm and developed a kind of new search adaptive in recent years. Its' convergence is better than the traditional nonlinear programming method and the adaptability is strong and it can achieve the global optimal. So it has very broad application prospects (Ge *et al*., 2008).

In the water and the soil evaporation model, there is no genetic influence, only in the greenhouse environment factor. The influence of water and the evaporation of the soil is affected at moment by the environmental factors changes in the greenhouse. The water and the soil evaporation are always change, if the minimum value of the evaporation can be predicted in the model, it is not only favorable for the growth of the plants, but also to save water.

The evaporation of water in front of the model is taken as an example, the model are optimized by the genetic algorithm. Thus the minimum value will be determined in the following model how much are the temperature, the humidity and the light with the genetic algorithm:

$$y = 8.3692 + 0.0378x1 - 0.0839x2 + 0.004x3 \quad (14)$$

$x1$ = The indoor average temperatura (°C)
$x2$ = The indoor average humidity (%)
$x3$ = The indoor average light (Radiation intensity J/m^2/hour)
y = The water evaporation (g)

In the greenhouse, in winter, the temperature, the humidity and the light change at times and the values are different. When the temperature, the humidity and the light are in a certain range, by genetic algorithm the water evaporation minimum can be calculated and the minimum can be predicted in advance. When the temperature T is [5, 10], the humidity H is [98,100] and the light L is [10, 40], the minimum of the water evaporation will be calculated. By MATLAB programming, the water evaporation minimum is calculated 0.5189g.

CONCLUSION

In the sunlight greenhouse, the water evaporation related research is carried out. The crop evaporation and the transpiration change rules are revealed. The determination and the estimation of the requirement water are explored under the drip irrigation condition. The crop growth and the development regularity are studied under the condition of the greenhouse. These will play a positive role to raise the level of the greenhouse management and the production in China.

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