Telemonitoring System of Greenhouses using Weather Station to calculate ANN Temperature in Crop Plant

Iván M. Gómez Azpilcueta[1], Gerardo Yamil Díaz Aguirre[1], Adriana Rojas Molina[1], Manuel Toledano Anaya[1] and Alejandro Castañeda Miranda [2]
[1] Facultad de Informática, Universidad Autónoma de Querétaro, Av. de las Ciencias Sin Número Campus Juriquilla, Juriquilla, Querétaro, Qro. 76230. México.
adriana.rojasmolina@gmail.com
[2] Ing. en Tecnología del Frío, ESAp, Universidad Autónoma del Estado de Hidalgo, Calle Ejido de Chimalpa Tlalayote S/N, Col. Chimalpa, Apan, Hgo. 43920, México
alejandro_castaneda@uaeh.edu.mx

Fecha de recepción: 6 de noviembre 2015

Fecha de aceptación: 16 de diciembre 2015

Abstract. In recent years, the use of greenhouses for agricultural production has grown rapidly and continuously in Mexico. One of the most important factors that has a deep impact in plant cultivation in order to increase production efficiency has been monitoring continuously evapotranspiration proposed in [1], which due to the topography of the country and regions designated for construction of greenhouses, should be performed remotely. To make this monitor an embedded system with a virtual machine is deployed [2]. The embedded system proposed allows remote connectivity through a telemetry and telemonitoring system via the web. To maintain optimum performance of the greenhouse should be controlled variables as temperature, humidity, solar radiation and others to achieve adapt properly controlled in the greenhouse environment, externally monitored external climatic conditions in the greenhouse with the use of an embedded weather station. In this paper the study and implementation of a specialized embedded system for greenhouses, which uses neural diffusion algorithms to obtain independently the Evapotranspiration occurs.

Keywords: Telemonitoring, Greenhouses, evapotranspiration, Weather Station, Artificial Neural Networks, Modelling temperature, Pattern Recognition.

1 Introduction

A technological trend in Mexico's agricultural production of crops in greenhouses, which is used in the continuous production of products under a closed environment are difficult to generate [2]. An important aspect is controlling a good environment for plant development; it is to calculate fundamental parameter evapotranspiration, which is the product of the sum of two phenomena occurring in soil-cultivation ratio, crop transpiration and evaporation from the soil, it is the fundamental loss of water, from which the water requirement of crops [5] is calculated. A schematic evapotranspiration process shown in Figure 1, where the plant transpiration, which is water loss as vapor through stomata, cuticle and the periderm. This process heat from the air is used for passing liquid water on vegetation in water vapor, so that the low temperature in the vicinity of the leaves. Of the total amount of water that is absorbed soil, carried on the stem and transpired to the atmosphere, only a very small fraction of 1% is incorporated into biomass. Almost all the water lost by the blade makes through stomatal pores, which are more abundant on the underside of the leaf. The transpiration rate is influenced by such factors as the plant species and size, soil moisture, the amount of sunlight considering its duration and intensity, air temperature or wind speed, where climatic factors are temperature, solar radiation, rainfall, humidity, wind speed. For it is monitored by a weather station, as shown in Fig. 2 supports to monitor the smooth running of the plant for implementing data, mathematical model where the variables involved in question is used and is calculated and calibrated the monitoring system by multiparameter control system settings, therefore, an embedded system is implemented using climatic variables of the environment and other parameters to regulate the conditions inside the greenhouse.

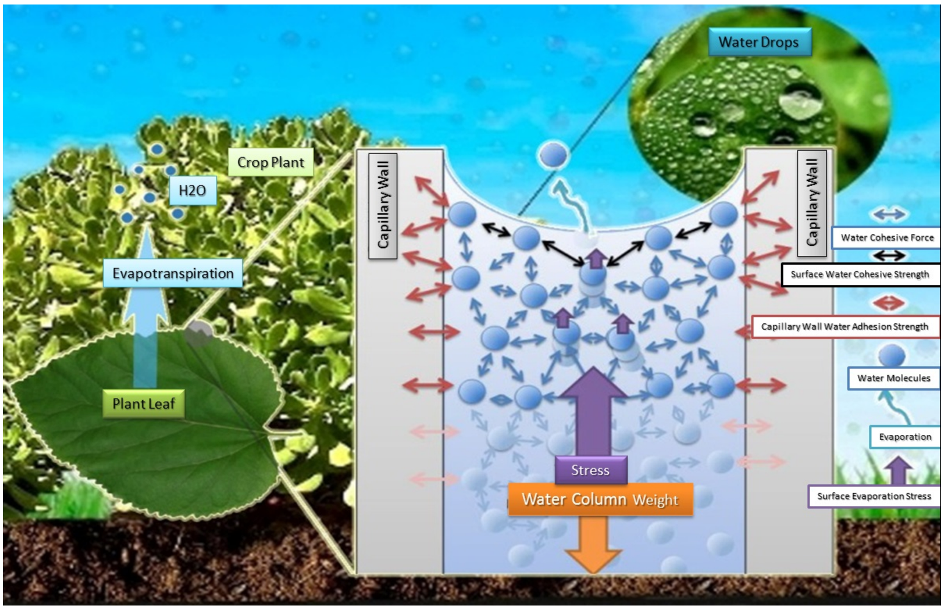

Figure 1. Schematic of the process of evapotranspiration.

As with agribusiness control systems embedded systems it worked with solar dryer's agro-industrial products, controlling the moisture of the product [3]. In the same context, the developed mathematical models to estimate the amount of water that is absorbed by agricultural soil drainage [4]. Based on the experience in these two previous works related to the topic, this paper develops. Which focuses on the development of an embedded incorporated into crops to greenhouses to determine its evapotranspiration system. Cultivation of crops is mainly climate dependent in normal conditions. All vegetables have their own seasons in which they can be grown. But with the greenhouse technology, farmers can grow almost any ornamentals and vegetables in any season. This technology has made possible to have all vegetables throughout the year. Green house technology provides a controlled and favorable environment for the crops to grow in all seasons. The technology saves crops from cold in winter, from heat in summer and from rain in monsoon. Implicitly, the main features of a greenhouse for correct functionality are in principle the right to collect most orientate the solar heat, store the heat, insulate all other areas, to minimize heat loss leaking, natural maximize ventilation. For proper control of it, their disturbances are supported by external monitoring the greenhouse with the support of weather station variables [2]. All greenhouse cultivation systems, regardless of geographic location, comprise fundamental climate control components and depending on their design and complexity, they provide more or less climate control, and condition to a varying degree plant growth and productivity. Air temperature as well as solar radiation and air relative humidity is one of the most important variables of the greenhouse climate that can be controlled. It conditions not only crop development and production but also energy requirements, which can account for up to 40 percent of the total production costs. The majority of plants grown in greenhouses are warm-season species, adapted to average temperatures in the range 17–27 °C, with approximate lower and upper limits of 10 and 35 °C. If the average minimum outside temperature is less than 10 °C, the greenhouse is likely to require heating, particularly at night. When the average maximum outside temperature is less than 27 °C, ventilation will prevent excessive internal temperatures during the day; however, if the average maximum temperature is less than 27 or 28 °C, artificial cooling may be necessary. The maximum greenhouse temperature should not exceed 30 at 35 °C for prolonged periods [6].

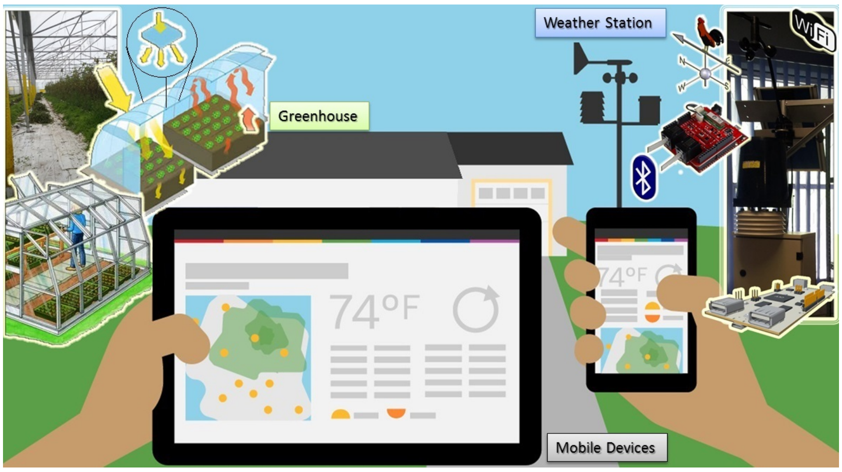

Figure 2. Devices for monitoring weather station.

As it is shown in Fig. 2, the use of devices shown to monitor weather station and variables involved in greenhouse crop evapotranspiration, which is done by various communication protocols telematic. Note that a critical factor in controlling humidity inside the greenhouse is water, in terms of both quantity and quality, is crucial to the success of horticulture greenhouse production. Often As water supplies are limited, it is necessary to use low quality water for irrigation purposes. Where growers increasingly face problems associated with low quality water, what is the most important physical and chemical water quality parameters. The presence of high soluble salts in irrigation water is one of the most limiting factors in greenhouse crop production [1]. Once provided water quality as a fundamental variable of the channels must be the main parameter monitoring and control of evapotranspiration of a greenhouse is temperature, In order to obtain the continuous monitoring of evapotranspiration, in this work it is done through an embedded system that connects to a web page, and to calculate the temperature of evapotranspiration in greenhouse environment a neural network is used, to estimate the temperature of an Artificial Neural Network (ANN) which is integrated to the variables of the weather station with embedded software on a platform with Linux mounted on a PCDuino device, which in turn contains an operation menu that is accessed through a screen, is used touch. Both tools technology are described in the following sections.

2 Embedded Telematics System

Based on this, the proposed mathematical models to predict the temperature the interior of evapotranspiration greenhouses in this study is based on the analysis of the following input variables: outside air temperature To, outside air relative humidity Rho, wind speed Ws, global solar radiation flux Sr, inside air relative humidity Rhi; being the inside air temperature the output variable Ti, a schematic of the embedded variables to incorporate input and output system shown in Fig. 3.

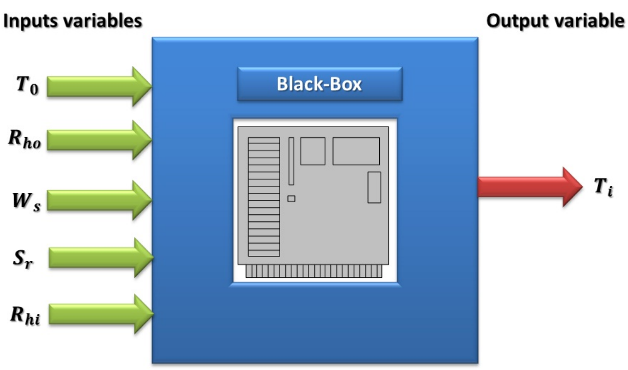

Figure 3. Blocks diagram of the pattern of black box used to predict the temperature of evapotranspiration in Greenhouses.

The schematic of FIG. 3 is implemented using SparkFun Weather Shield (DEV-12081), which collects data using XBee-Wifi (WRL-12570) information wireless technology from a remote and external weather monitoring station greenhouse. The weather station that grants you access to barometric pressure, relative humidity, luminosity and temperature. There are also connections to sensors such as wind speed, direction, rain gauge (RJ11 connectors for rain and wind sensors) and GPS for the location (GP635T GPS module). The prototype utilizes the electronic circuits for the following variables: HTU21D humidity, MPL3115A2 barometric pressure, and ALS-PT19 light sensors. Finally, Weather Shield can operate from 3.3V up to 16V and contains voltage regulators and signal translators for all devices. The hardware implementation of the embedded system according to Fig. 2 is as follows, the data obtained by the weather station are remotely sent by a wireless protocol and captured by exchanger protocols exchanger protocols is constituted by a hardware integrated for PCDuino (DEV-12856), a hard disk SATA II (database), a touch screen (SEN-13101), a Bluetooth (WRL-12580) and a GSM / GPRS (CEL-09 607) device cellular data query. The weather station and feed protocols exchanger using renewable energy (Solar Kit 75 Wh), using solar cells (MP7.2-150), charge controllers (CT-SOLAR1X5A-12 / A2), batteries 12 V / 100 Ah (PS121000) and DC / DC converters 50W (HF50W-SD12-5) with 12 Vdc (in) 5V / 10A (out) to load and use of system devices. The software implementation of embedded system according to FIG. 2 is as follows, the data generated by the weather station are concatenated and sent by a wireless remote serial protocol to 2.4 GHz. with a baud rate of 115,200. These captured by the exchanger protocols, data is manipulated exchanger protocols by PCDuino that has a Linux operating system, the data frame is defragmented for Lexical Analyzer Syntactic implemented in Monodevelop (development environment for C # to Linux), the acquired data is stored on a hard disk using a database (SQL Lite) and requested through a GSM / GPRS WAP device in a way that generates a local IP by a virtual machine for subsequent connection to a website, this system telemonitoring allows viewing of data (https://www.embeddedcastaneda.com/weather/weather.html).

3 Methodology used

Artificial neural networks methodology is used in this work and tries to emulate biological neural network and interconnecting neurons are obtained. For this simplified mathematical model of the biological neuron is assumed. This model is described mathematically by Eq. 1 and represents a generalization proposed by McCulloch and Pitts in 1943.

$$y = f\left[\left(\sum_{i=1}^{N} \omega_i \bullet x(n-i)\right) - b\right] \quad (1)$$

From Eq. 1 it has to be outside the neuron receives a threshold by N inputs to which associates a set of vector of synaptic weights (ω_i, where i = 1 ... N). Consider x is the input vector and b is a constant called offset or bias, f is the activation function. In this study, the activation function used is a sigmoid that has the following form of Eq. 2.

$$f(x) = \frac{1}{1+e^x} \quad (2)$$

From Eq. 2 is the product of the weights applied by the respective inputs over the threshold (or offset adjustment) to an activation function f (x), the Y output is obtained. The sigmoidal response corresponding to an Artificial Neural Network (ANN) is the output is determined by the input vector p. Its characteristic representation is according to Eq. 3.

$$a_i = \sum_{j=1}^{R} w_{ij} P_j \quad (3)$$

According to Eq. 3, it can be noted as the connection (synapse) between the inlet and outlet pj ai is the weight wij. Thus Hebb's postulate implies that if a positive value pj ai produces a positive value, the value of wij should be increased. The result of a new training pattern in matrix form is defined by Eq. 4.

$$W_{ij}^{new} = W_{ij}^{\text{previous}} + \alpha(a_{iq})(p_{jq}) \quad (4)$$

The training of an ANN is undertaken by a procedure called backpropagation (BP) based learning algorithm which is a supervised algorithm. This method requires a set of training patterns, and their corresponding desired outputs, and autonomously adjusts the connection weights among neurons. Correction of the weights is made according to imposed learning rules and thereby, obtains unique knowledge from the data [9].

3.1 Artificial Neural Network (ANN)

In this section the supervised version of the ANN is briefly described. The parameters adjustment of a model used to represent a system is called System Identification. System Identification methods are often classified into two major categories: grey and black box models. Compared with direct modelling, which is governed by the system's physical laws, these models are well suited for building a mathematical model where the system's mechanism is not well understood or where its properties change in an unpredictable manner [6]. The grey box method is a formulation of the model in which the parameters are traceable to actual physical principles. The black box method relates mathematically measured inputs to measured outputs in which the model parameters are transformed without any traditional physical significance. The black box models do not require previous knowledge of the system, which can be an advantage if the information on the system's dynamics is limited; however, it involves the problem of selecting an adequate structure for the model. Another advantage of this type of models is the possibility of obtaining a broad model with a relatively small set of measurements. The model can be improved as new data are entered. Compared with a grey box model, the black box approach requires less time and effort to be developed. Generally, in a black box model, non-statistical methods or statistical methods are used to formulate the relationship between inputs and outputs. The model of neural network is determined by three factors: 1) the topological structure of the network; 2) the neuron characteristics; and 3) the raining algorithm. The ANN implemented in this study is a Multi-Layer Perceptron (MLP) that includes an input layer of 5 nodes, an hidden layer with variable number of hidden nodes and an output layer that has only one node. The input variables into the ANN are: outside air temperature To, outside air relative humidity Rho, wind speed Ws, global solar radiation flux Sr, inside air relative humidity Rhi; being the inside air temperature the output variable Ti, the schematic Artificial Neural Network (ANN) implemented as shown in Fig. 4.

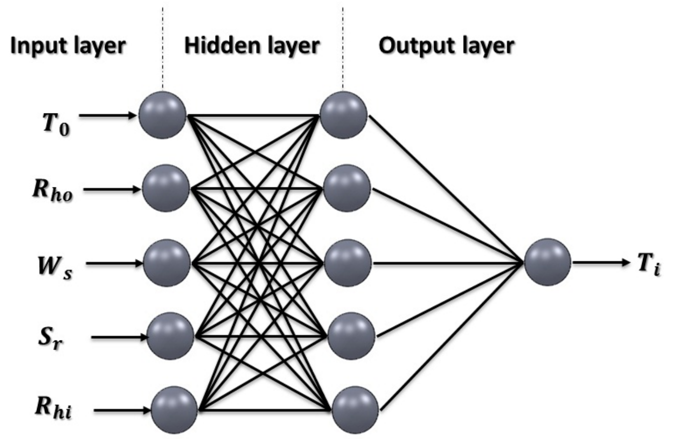

Figure 4. Feed forward artificial neural network.

3.2 Selecting Measurement Parameters

In order to obtain the coefficients for both the ARX and ANN mathematical models several measures were done to predict the inside air temperature in Greenhouse. This research is based on the analysis of the input variables, which are: To, Rho, Ws, Sr, Rhi, being the inside air temperature the output variable Ti (Figs. 3 and 4). The measures of the foregoing variables were done by sampling every 10 minutes during a period of 365 days. Those were divided into four groups, which represents the four seasons of the year, though only two seasons were used as data for this project: summer and winter seasons.

3.3 Training

The architecture of ANN models is loosely based on the biological neural system. ANN allows the estimation of possibly non-linear models without the need of specifying a precise functional form. ANN's can be viewed as parallel and distributed processing systems that consist of a huge number of simple and massively connected processors called neurons [10]. Each individual neuron consists of a set of synaptic inputs, through which the input signals are received. Then, the incoming activations are multiplied by the synaptic weights and summed up. The outgoing activation is determined by applying a threshold function to the summation. The threshold function can be a linear, or a nonlinear function that decides the output of the neuron. The structure of the neuron is shown in Fig. 5.

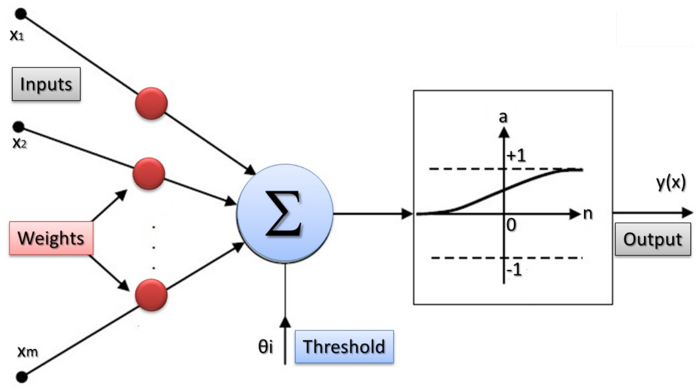

Figure 5. Model of an artificial neural.

4 Experimental Results

The results of the embedded system implemented of the weather station are shown in Fig. 6., the variables plotted are: external temperature, external humidity, wind speed, solar radiation, internal temperature and internal humidity. It is noteworthy that these variables are used to establish the limits of operation ANN temperature evapotranspiration used for greenhouses (see Fig. 4).

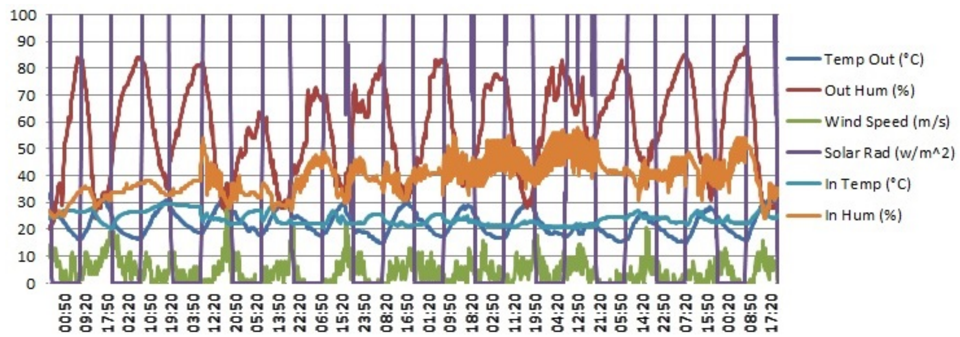

Figure 6. Results of the weather station.

From Fig. 6, the implementation of the ANN variables obtained on temperature, implies that several ANN models were performed and tested according to their capacity of inside temperature prediction. The data was divided into four groups related to the seasons of the year, involving just two seasons: summer and winter for this research. The 144 samples are considered as equivalent to one day. The estimation of the temperature and the error of the models from that summer season were analyzed. Fig. 7, show the accuracy of the ANN model respect to the internal temperature. The results of the estimate data are compared to the measured data; it was observed that the ANN model has a minimal error compared to measure. The result of the model implemented for the prediction of the inside temperature of the Greenhouse of the summer season, it was observed that the ANN model has a minimal error compared to measure, the result of the best models implemented for the prediction of the inside temperature of the Greenhouse; namely, the ANN models reach better results of the internal temperature prediction referring to measured.

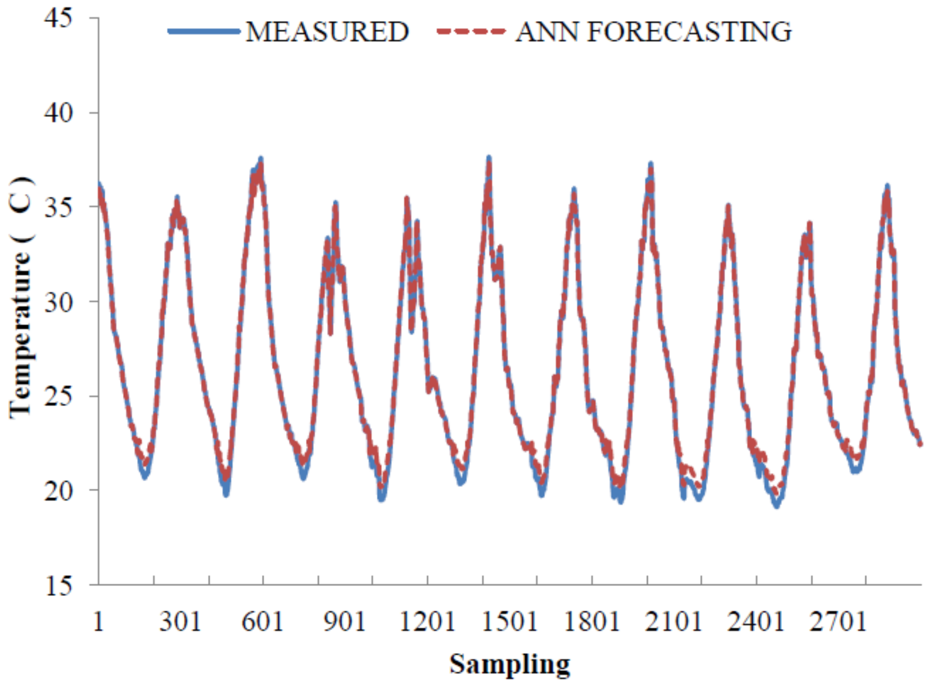

Figure 7. Original data versus results of artificial neural network for the summer season of sampling; ––– measured; - - - forecasting.

5 Conclusions and Directions for Future Research

In this paper we proposed to what extent linear autoregressive model with external artificial neural network models (ANN) were used to predict the dynamic behavior of the temperature air in the interior of a Greenhouse. The temperature predictor uses a Multi-Layer Perceptron (MLP) artificial neural network, which is trained by Levenberg-Marquardt backpropagation (BP) algorithm, and the data validity was done by means of analysis of variance (ANOVA) method also compared with the ANN model. For this, measurements of outside air temperature, outside air relative humidity, wind speed, global solar radiation flux, inside air relative humidity were used as the input variables to the system, and different structures of ANN model were tested. The external climate variables provided by the weather station were divided into two main sections corresponding to summer and winter seasons, in order to develop and evaluate the ANN model and data sample. By means of programming, the acting indexes were calculated for each one of the structures, selecting those models with better prediction of the real conditions of interior temperature. The evapotranspiration statistical method was used to analyze the variation of the two seasons comparing the neuronal network and the ANN model results versus real data. The best results of indoor temperature prediction were obtained by the structures of ANN models; with a 95% of confidence level, so the best models are given by the ANN with a coefficient of determination of 0.9549 and 0.9590, corresponding to the summer and winter season respectively.

Acknowledgments. We would like to thank Rene Preza-Cortés for their technical support and the Mixed Fund CONACYT- Queretaro State Government (QRO-2012-C01-191356) for their economic support for the development of this research.

References

1 [1] A. Rojas, A. Noriega, G. Herrera, R. Chaparro, Sistema de Riego para Invernaderos Hidropónicos Basado en la Evapotranspiración del Cultivo, Naturaleza y Desarrollo, 1(1), pp. 23-29, 2003.

2 [2] R. Castañeda, E. Ventura, R. Peniche, G. Herrera: Analysis and Simulation of a Greenhouse Physical Model Under Weather Conditions of the Central Region of México, Agrociencia, 41, pp. 317-335. 2007.

3 [3] A. Castañeda, J.G. Ríos, J. Meza, J.A. Ortega, G. Herrera, A continuous production roselle (Hibiscus sabdariffa L.) dryer using solar energy: *JFAE*, 12(1), pp.96-104, 2014.
4 [4] C. Chavez, C. Fuentes, F. Brambila, A. Castañeda, Numerical Solution of the Advection-Dispersion Equation: Application to the Agricultural Drainage, *JAST*, 16(6), pp. 1357-1388, 2014.
5 [5] Rodríguez F., M. Berengel, J.L. Guzmán J., A. Ramírez, Modeling and Control of Greenhouse Crop Growth: Springer Inc., 2015.
6 [6] M. Qaryouti, Good Agricultural Practices for greenhouse vegetable crops, Food and Agriculture Organization of the United Nations Inc., 2013.
7 [7] L. Ljung, System identification, Theory for the User, Prentice-Hall Inc., 1999.
8 [8] S.L. Patil, H.J. Tantau, V.M. Salokhe, Modelling of tropical greenhouse temperature by auto regressive and neural network models, Biosystems Engineering, 99, pp. 423-431, 2008.
9 [9] H. Uchida, G. Pieters, M. Deltour, Modelling greenhouse temperature by means of auto regressive models, Biosystems Engineering, 84, pp. 147-157, 2003.
10 [10] G. Zhang, E. Patuwo, Y. Hu, Forecasting with artificial neural networks: The state of the art, International Journal of Forecasting, 14, pp. 35-62, 1998.