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# FUZZY LOGIC BASED GREENHOUSE CLIMATE CONTROL FOR TOMATO PRODUCTION

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## ABSTRACT

A fuzzy logic based Greenhouse climate control is presented in this research. Primarily seven most important greenhouse climate parameters affect tomato production are considered soil type, plant water use capability, plant root depth, temperature, humidity, irrigation quantity required for crop grow and light day. Manual tomato crop data input, actuator and sensor nodes has been managed by fuzzy logic controller which mimics the brain of the planter to provide reliable, power conserving and autonomous control system of a greenhouse. Contrarily, the conventional control methods are not efficient in terms of energy, labor interference, productivity and flexibility. In this research, the adoption of artificial intelligent (AI) approach to controlling tasks within greenhouse is presented. Fuzzy inference system has been designed and fused within the coordinator node of real time sensors; simulation of nodes and actuators has been presented. The proposed fuzzy controller of tomato crops proves high efficiently, cost effective method, beside flexibility of tuning the whole system for other agricultural tasks.

**Keywords:** green house, tomato, climate control, fuzzy logic.

## 1. INTRODUCTION

Tomatoes are one of the basic food crops of vegetables when most people in the world. Tomatoes growing well in warm fertile land exchange good advertising in areas exposed to direct sunlight for at least 6 hours a day. Tomato crop of choice for agriculture gardening is standard because it can grow in almost all types of land rows, plus it gives a great crop of relatively small area. Most varieties produce from 4.5 to 7 kg of fruit per leaf. Although they contain a high percentage of water has high nutritional value. as a source of energy, where many vegetables and other food crops got high benefits due to its contents of salts and vitamins and organic acids. Substantial the importance of this crop yields per unit area is still small compared to what it should have been due mainly to lack of correct methods in the cultivation of this yield. Many researchers use advanced technology in controlling environmental factors affecting mainly on the growth and the quality and quantity of agricultural crops, including tomato crop. The greenhouse is used, the weather conditions for the development of agricultural crops where work to control temperature and humidity and other environmental factors are excellently to reflect its impact on Agricultural crops [1-3].

Intelligent control system that combine sensors and actuator nodes currently are considered as one of the most significant technology in the greenhouse climate control [4-5]. Intelligent control system based on Fuzzy logic controller has great advantages in terms of cost, flexibility, autonomy and robustness as it compared to classical control system [6]. Greenhouses are used to enhance the environment condition for crops; hence, the climate control of a greenhouse (GH) requires deploying of multi types of sensors and actuators [7]. Using automatic control will highly assist of reducing energy conservation, scalability, enhance productivity process and reduce human intervention [8-11].

Greenhouse climate control based on fuzzy control system shows highly efficient improvement of crop production. Also it helps in lowering the cost of laborers through using a remote base station for monitoring and controlling the processes of the greenhouse [12-13]. Emerging artificial intelligent (AI) techniques like neural network and fuzzy logic within greenhouse (GH) control applications provides favorable conditions for crops growing and health [14].

This paper presents an Artificial Intelligent (AI) approach based on agriculture information of tomato crops to control precisely the GH climate of temperature, humidity, irrigation, ventilation and lighting autonomously. The main focus is to show the efficiency of adopting of Fuzzy Inference system (FIS) to build intelligent coordinator that keeps the GH parameters at the desired set values. This research shows several issues which has been addressed such as GH control system design based on Fuzzy inference system for tomato crop, deceasing power consumption within actuating nodes connected to a heater, humidifier and fan devices based on FIS control.

## 2. DESIGN GREENHOUSE CLIMATE CONTROL OF TOMATO CROP

First of all to design GH climate control based on fuzzy inference; Life cycle of a tomato plant should be study and analysis, Environmental requirements affecting the crop, and design Fuzzy inferences.

### A. Life cycle of a tomato plant

Evolving tomato plant through stages to produce fruits of safe for consumption or marketing and these stages are as follows

a) Germinating stage can split into multiple separate stages of germination process is standard but in fact overlapping phases with each rows, these stages are stage water absorption and digestion of nutrients and germination stage. At this stage the seed absorbs water, which increases the moisture content of the seed rows, then turn such complex food carbohydrates, fats and proteins stored in the endosperm Simple materials and transmitted to the embryo axis growth points. Providing developmental stages take their shape gesture and begin the emergence of leaves and reproduction.

b) Vegetative growth stage with increased nutrients and environmental factors help from heat and humidity & lighting continues vegetative growth of tomatoes and continue with this stage of plant water consumption on the rise.
c) Flower stage the plant water consumption peak during this stage.
d) stage of fruiting: So the process of fertilization must have strobe lighting and humidity around 50-70% plus optimal temperature is 25-29 ºC currently emerging fruits begin to be the optimal temperature for holding fruits are 18-20 ºC worse either optimal temperature that ripen in the fruit is 28 Cº and no Rosary off well in temperature less than 10 Cº and maturity period of the fruit around 50-70 days after vaccination and at one stage Fruiting irrigation amounts begin to decline. [1-3]

**B) Environmental requirements affecting the crop**

a) proper soil crop
often tomato can be grows in various types of land but it thrive in the land of light free of salts and alkaline then decrease the crop after increasing the rate of salinity, as well as soil salinity increases lead to increased incidence of benimatoda Complexity of the roots as well as lead to increased incidence of fungal. There foreknowledge of what type of soil used in GH, in addition to calculate the applicability of soil water retention before the second irrigation.
b) Effect of optical length: length of photoperiod effect on tomato plants blossom to neutral is standard but a great effect on vegetation as plant growth decreases significantly decreased if Plants were exposed for less than eight hours daily light advertising as plant growth decreases as well when exposed to daily lighting periods of (17) an hour or more.
c) Temperature degree: tomato is summer vegetable crops and temperature of 25-30 degrees Celsius is the appropriate degree of tomato seed germination for 6 days while for germination to 14 day at 15 degrees Celsius and the temperature of the vegetative growth and maturation of fruits varies between 25-30 degrees Celsius day while the temperature of the flowers and the Decade range from 15-25 °C day, and temperatures less than 15 °C to configure a wide dark green leaves and stems are thick while at low temperature of 10 degrees Celsius no growth depends upon the fruits of tomato and Low temperature less than 12 degrees Celsius due to the death of pollen which leads to incomplete pollination and fertilization of the flowers. Night temperature also plays an important role on growth and flowering and fertilization does not occur, and therefore not nodes of flowers are present when night temperatures below 13 ° c.
d) The moisture almost vegetable crops depend on the type of moisture, so this parameter has been considered.
e) Flourish grow tomatoes when a humidity of 60-65% and high humidity caused damage such as fungal diseases and poor absorption of nutrients, particularly calcium as a result of lack of transpiration than Leads to the appearance of syphilis end rot fruits plus a few nodes but good ventilation can reduce the spread of these diseases.
f) Aeration: The ventilation process is known from most important processes in agriculture greenhouses, and as we know that tomato flower shemale doesn't need insects for pollination when hypoventilation rise Relative humidity inside greenhouses and increase viscosity of pollen in the anther and difficult to move to Venus, which reduces the rate of vaccination and contract thus reducing the crop so that ventilation process within the tunnels are very important because they reduce the humidity inside greenhouses As well as the result of air enter the tunnel working on shaking the flowers they help to complete the process of pollination.
g) Irrigation: Tomato irrigation depends on several factors including: soil texture and proportion of salts and plant age and date farming and prevailing weather conditions and regular irrigation is one of the most important success factors for crop irrigation increases lead Fungal diseases waving roots and delay maturity of fruits and lead to increase irrigation to cracking the fruit while the lack of irrigation that lead to poor vegetative growth and flowering and fruiting and lack of water leads to small size Fruits and fruit rot infection severe party pink, leading to the fall of flowers and fruits [1-3].

Therefore, for a rich harvest of yields, the tomatoes must provide the right environment to grow this plant. It is obvious that the tomato plant requires the aforementioned growth stages to different environmental factors that control unit is designed to set out on fuzzy logic control on climatic conditions inside the greenhouse. Where the information is entered into the console starts with soil type and vulnerability to water retention when the next irrigation used and time (day/night) plant growth stage and deep roots and plant water retention and ambient temperature, humidity and relative humidity.

## 3. FUZZY LOGIC APPROACH

For a rich harvest of tomatoes must provide the right environment to grow this plant. It is obvious that the tomato plant requires the aforementioned growth stages to different environmental factors therefore a control unit for climatic conditions control within GH based on fuzzy

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logic controller is designed. The methodology designed controller of tomatoes crop is shown in Figure-1. [15-16]

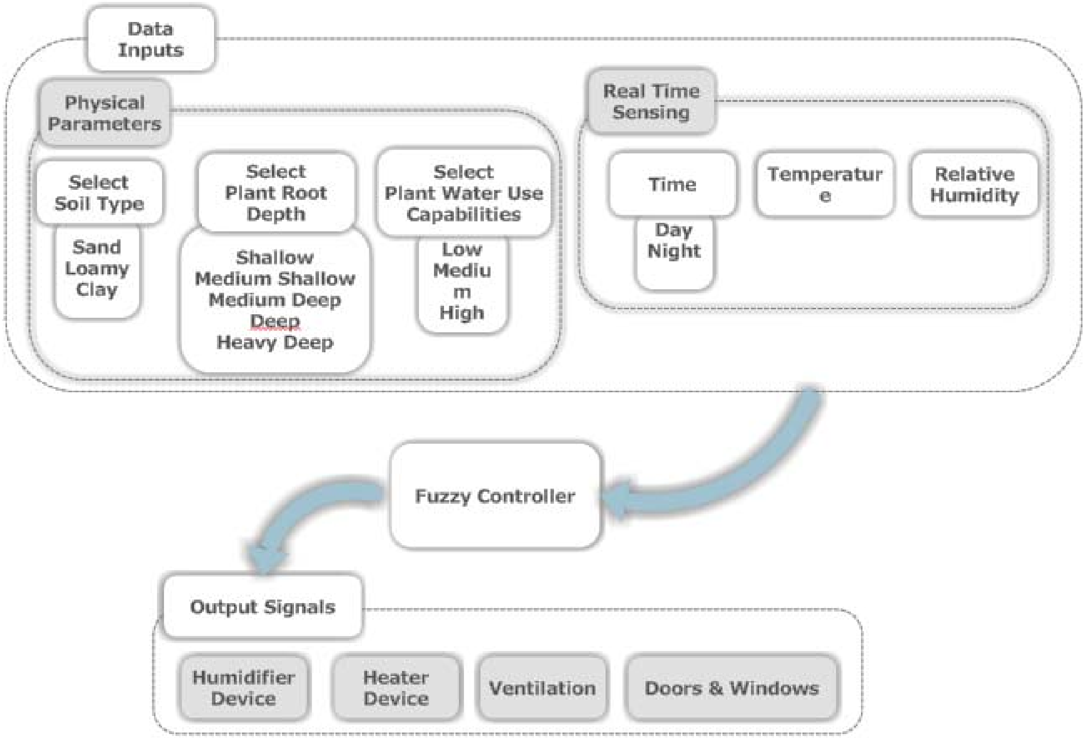


**Figure-1.** Methodology of proposed fuzzy control.

To ensure proper design and operation of greenhouse of tomatoes crop control system, several parameters should be considered Where these parameters is entered into the controller starts with soil type and vulnerability to retain water into irrigation date, time (day/night), plant growth stage, deep roots, portability Plant water retention, ambient humidity and temperature relative humidity. To design the Fuzzy Logic Controller (FLC) four steps must be follow:

**a) Identification and declaration of inputs and output**

In the first step, we have identified inputs, outputs and linguistic variables. The process of declaring the values of input and output called universe of discourse and are shown in the following tables [3, 6].

Table-1 provides values on the rooting depth of various plants. The plant rooting depth is importance to estimate the age of plant then the required quantity of water. Table-1 shows that tomato crop rooting depth is 45.7 cm (1.5ft).

**Table-1.** Effective rooting depth of mature crops and fuzzy membership function.

| Crop name | Rooting depth | Linguistic variable | Fuzzy member range |
|---|---|---|---|
| Tomato, Cabbages, Cauliflowers, Clover (Ladino) | 45.7cm | Shallow | [0 0 30.5 46] |
| Beans, Carrots, Beets | 61cm | Medium Shallow | [30.5 46 61 76] |
| Kiwifruit, Brussels, Peppers | 91.5cm | Medium Deep | [61 76 91.5 107] |
| rapes, Loganberries, Sugar Beets | 122cm | Deep | [91.5 107 122 137] |
| Mangoes Tree and other Tree Fruits | >122cm | Heavy Deep | [122 137 151 152] |

Table-2 provides values on the Available Water Storage Capacities (AWSC) of various soils. The AWSC is the amount of water that can be stored in the soil against the force of gravity. As the soil texture becomes finer, more water can be stored. Plants are capable of extracting only a portion of the water from the soil before being stressed.

**Table-2.** AWSC: Guide to available water storage capacities of soils (AWSC: Inch. of water per foot of soil [Inch(W)/Foot(S)].

| Soil texture | AWSC [Inch(W)/Foot(S)] | Linguistic variable | Range |
|---|---|---|---|
| Sand | 1 | Sand | [0 0 1 1.5] |
| Fine Sandy Loam, | 2 | Loamy | [1 1.5 2 2.5] |
| Clay, Organic Soils | 3 | Clay | [2 2.5 3 3.5] |

Table-3 indicates the maximum percentage of moisture that should be removed before irrigation is required for a crop.

**Table-3.** Availability coefficient to determine plant water use capabilities.

| Crop name | Plant water use capabilities (%) | Linguistic variable | Range |
|---|---|---|---|
| Peas, Potatoes | 15 | Low | [0 0 10 15] |
| Tree Fruits, Tomatoes | 30 | Medium | [10 15 20 25] |
| Other crops | 35 | High | [20 25 40 40] |

Table-4 indicates Soil Moisture Content sampled from Soil moisture sensor. Water content or moisture content is the quantity of water contained in a soil called soil moisture. The soil moisture measurement device, or sensor, shall represent soil moisture status in units of soil water tension or matric potential, registering in cent bars (cb) or kilopascals (kPa) when read with a compatible reading device.

**Table-4.** Soil moisture content in centibars reading obtained from the soil moisture sensor.

| Sensor moisture | Reading soil moisture level (CentiBars) | Linguistic variable | Range |
|---|---|---|---|
| Field Sensor Moisture Sensor Reading | 10 | Saturated | [0 0 6 12] |
| | 20 | Adequately Wet | [6 12 18 24] |
| | 30 | Normal | [18 24 30 36] |
| | 40 | Dry | [30 36 60 60] |

Table-5 indicates the Environment Temperature in degree Celsius obtained from temperature sensor.

**Table-5.** Environment temperature in degree centigrade obtained from temperature sensor.

| Sensor temperature sensor | Reading soil moisture level (Cent bars) | Linguistic variable | Range |
|---|---|---|---|
| Environment Temperature in Degree Centigrade obtained from Temperature Sensor | 10 | Very Cold | [0 0 10 15] |
| | 20 | Cold | [10 15 20 25] |
| | 30 | Normal | [20 25 30 35] |
| | 40 | Hot | [30 35 40 45] |
| | 45 | Very Hot | [40 45 50 50] |

Table-6 indicates the Relative Humidity. Relative humidity is the percentage of maximum water content at a given temperature. Most growers work with relative humidity expressed in %. A good indication of air

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humidity would be the absoluter humidity in g/m3 but horticulturist usually works with Relative Humidity (RH) in percents. RH 100% means extremely humid condition and for instant 50% indicated very dry air conditions.

**Table-6.** Environment Relative Humidity (RH) in percentage obtained from sensor.

| Relative humidity sensor reading | Soil moisture level (Centi bars) | Linguistic variable | Range |
|---|---|---|---|
| Environment Relative Humidity in Percentage | 10 | Low | [0 0 10 20] |
| | 20 | Medium | [10 20 30 40] |
| | 30 | High | [30 40 50 60] |
| | 40 | Extremely High | [50 60 60 60] |

**b) Identification of membership functions**

In this step, the linguistic variables are identified and membership values for each linguistic variable are calculated.

**c) Fuzzy inference and decision making**

The fuzzy inference system consists of fuzzy rules that are devised by an expert knowledge base through system input-output learning. In the fuzzy rules, triangular and trapezoidal-shaped membership functions are used for the variables to simplify the computations. The most commonly used fuzzy inference technique is Mamdani method. Fuzzy rule basedrives the inference system to produce fuzzy outputs, which are defuzzified to get system outputs. In this case, we have considered 7 input variables and each consists of fuzzy linguistic variables.

**d) Defuzzification**

The transformation from a fuzzy set to a crisp number is called defuzzification. For any given crisp input value, there may be fuzzy membership in several input variables, and each will cause several fuzzy output cells to fire or to be activated. This brings the process of defuzzification of output to crisp value. In practice, defuzzification is done using centroid method. Table-7 shows the actuators ranges used.

**Table-7.** Output crisp of heater, humidifier, ventilation, and irrigation devices.

| Output actuator | Linguistic variable | Range |
|---|---|---|
| **Heater** | Off | [0 0 25 45] |
| | Med | [25 45 55 80] |
| | Fast | [55 80 100 100] |
| **Humidifier** | Off | [0 0 20 30] |
| | Med | [20 50 80] |
| | Fast | [70 80 100 100] |
| **Ventilation** | Off | [0 0 30 45] |
| | Med | [40 50 60] |
| | Fast | [55 70 100 100] |
| **Irrigation** | Off | [0 0 20 45] |
| | Med | [20 35 65 80] |
| | Full | [65 80 100 100] |

## 4. RESULT AND DISCUSSIONS

The improvement of tomato crop technique has been carried out using MATLAB simulation tool. The developed software for the proposed work was tested under different input condition and provided good results in terms of accuracy. The results obtained by the proposed system and estimated numerical methods are tabulated for the purpose of comparative studies.

Maximum Soil Water Deficit (MSWD) is the maximum moisture that can be removed from the soil before irrigation is again required. The soil type and crop rooting depths must be determined to calculate MSWD.

The numerical method and fuzzy calculation of amount of water to be applied (Inch of Water per Foot) are almost equal. In addition, parallel monitoring for GH environments parameters such as temperature and humidity. Using Fuzzy controller shows that this method requires less amount of water for the same yield when compared to the currently method followed by the farmer and control the GH climate to suitable tomato crop required. Thus the sample result shown in the table 8 & 9 given below ensures the effectiveness and accuracy of proposed system.

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**Table-8.** Day-sample of simulation input data and output results for tomato crop fuzzy logic control.

| **Input data** | | | |
|---|---|---|---|
| **Plant properties & environment sensing** | **Soil Type / Tomato crop** | | |
| | **Sand** | **Loamy** | **Clay** |
| Rooting Depth (cm) | 45 | 45 | 45 |
| Water Storage Capacity of Soil [Inch (W)/ Foot (S)] | 0.976 | 1.68 | 2.36 |
| Plant Water Use Capability (%) | 30 | 30 | 30 |
| Max. Soil Water Deficit [Inch(W)/Foot(S)] | 0.35 | 0.625 | 0.764 |
| Temperature Sensor | 13 | 13 | 13 |
| Relative humidity Sensor | 23 | 23 | 23 |
| Output control signals | | | |
| Irrigation [Inch (W)/Foot(S)] | 0.689 | 0.72 | 1.26 |
| Heater | ON till 29.47C$^{o}$ | ON till 30.13C$^{o}$ | ON till 30.28C$^{o}$ |
| Humidifier | ON till 63.45% | ON till 61.62% | ON till 59.76% |
| Ventilation | OFF | OFF | OFF |

**Table-9.** Night-sample of simulation input data and output results for tomato crop fuzzy logic control.

| **Input data** | | | |
|---|---|---|---|
| **Plant properties & environment sensing** | **Soil type / Tomato crop** | | |
| | **Sand** | **Loamy** | **Clay** |
| Rooting Depth (cm) | 45 | 45 | 45 |
| Water Storage Capacity of Soil [Inch(W)/Foot(S)] | 0.976 | 1.68 | 2.36 |
| Plant Water Use Capability (%) | 30 | 30 | 30 |
| Max. Soil Water Deficit [Inch (W)/ Foot (S)] | 0.35 | 0.625 | 0.764 |
| Temperature Sensor | 7 | 7 | 7 |
| Relative humidity Sensor | 19.4 | 19.4 | 19.4 |
| **Output control signals** | | | |
| Irrigation [Inch (W)/ Foot (S)] | 0.36 | 0.51 | 0.976 |
| Heater | ON till 15.21 C$^{o}$ | ON till 14.96C$^{o}$ | ON till 15.2C$^{o}$ |
| Humidifier | ON till 60.1% | ON till 59.25% | ON till 60.76% |
| Ventilation | OFF | OFF | OFF |

## 5. CONCLUSIONS

Tomato Crop GH climate control is the most important concern in the domain of agriculture. By monitoring soil moisture, temperature and relative humidity and by taking into consideration the other parameters like plant root depth, soil texture and water storage capacity of soil, plant water use capabilities one can make good harvest of tomato and also in achieving high yield. The work presented here brings out the potential advantages of applying FLC technique for GH climate control which included Irrigation System. The simulation result provides an exact idea for temperature, humidity, and water output for the prescribed agricultural field.

The advantages of applying FLC are increasing Irrigation Efficiency, increasing the type of crop and harvest, in addition saving the electrical power. The result of the work shows it's highly recommended to build new generation of intelligent GH climate controller.

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