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INCREASING THE PLANT PRODUCTIVITY USING THE AUTOMATIC CONTROLLED IRRIGATION SYSTEM: A COMPARATIVE EXPERIMENTAL STUDY

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Abstract: With the development of technology, today, the use of technology in the field of agriculture has become widespread. In order to meet the increasing demand for agricultural products, automation techniques should be used in agricultural areas in order to make the production of agricultural products simpler and more efficient. In this study, an automation system is designed by making use of technology against problems such as irrigation problem and water shortage, which have become an important problem in agricultural areas. The data coming from the humidity sensor placed in the soil is processed to the controller. According to these processed data, when the soil is dry and the plant needs water, the water-pumping set automatically activates and meets the water needs of the plant. Optimum use of irrigation water to be used in agriculture is prevented unnecessary agricultural irrigation, reducing excessive water waste and providing a very high level of energy savings. At the same time, the negativities caused by excessive irrigation have been prevented. It is observed that the automatic controlled irrigation system used in this study saves a lot of water compared to the conventional irrigation system and increases the productivity of the plants to a great extent.

Keywords: Drip irrigation, Automatic control, Productivity, Water savings

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1. Introduction

The developments in industry and technology, the increase in people's living standards and the living population have led to the emergence of water problems in the world and in our country since the last half of the twentieth century. Disruption of the ecosystem balance, continuous climatic changes and misuse of lands, as well as events such as floods and landslides, and climate changes can be seen as the main causes of water crisis. It is foreseen that this crisis and the demand for water are gradually increasing. As a result of the researches, it is shown that the increasing water demand on the Earth and the decreasing clean water supply curves will intersect in 2029. According to this result, it is concluded that there will be a serious water problem and a water crisis and even a situation leading to drought will occur throughout the world (Alparslan et al., 2008).

Most of the water around the world is used for irrigation of agricultural lands. Technological developments and irrigation in agriculture have a significant impact on Turkey's economic volume gain, the increase in the yield rate in agricultural areas and the gradual decrease in migration to cities. Irrigation method in agricultural lands is called as a concept covering systems such as the quality of the water network to be irrigated and the ways in which the water will reach the user (Erzurumlu, 2017; Wondatir and Belay, 2020). In order for the irrigation projects to be prepared realistically, the daily, monthly or periodic water costs of the plants that are planned to be produced should be measured. For the measurements of the water need in the area to be irrigated, the amount of water consumed by the plant must be determined (Özgüler, 1997; Kartal et al., 2019).

In Çakır and Calis (2007), a remote-controlled irrigation system was designed using PIC 16F877 integration for an automatic control system plant irrigation project. The system is irrigating automatically or manually over the PSTN telephone line. A system design that works with soil wetting and humidity sensor detection was used in this study. If the soil is moist, the system does not work, if the soil is dry, the system activates and performs the irrigation process. Since this system works automatically, it saves time and manpower. In Fidan and Karasekreter (2011), an SMS-controlled irrigation automation control unit (SKB) was developed. In the related study, the user can control via SMS and at the same time, it automatically adjusts the irrigation time and sends an information message to the user in case of rain. In the literature, there are many studies on agricultural irrigation organization and water management problems (Acatay, 1996; Sayın, 1993).

In Milla and Kish (2006), infrared sensor and microcontroller are used for erosion prevention and a healthier irrigation system. With this designed system, information such as how long and how often the irrigated area needs to be irrigated is transferred to the computer and recorded in the memory. Al-Ali et al. (2001) designed an automatic irrigation system with solar rays and PLC. There is no control system for remote intervention in this system, the system consists only of a control unit. Kırnak (2006) developed a system that automatically performs drip irrigation that measures soil moisture via computer. With this system, with the right amount of irrigation at the right time, a great saving was achieved in water by eliminating the unnecessary irrigation process. Salivahanan et al. (2001) designed an intelligent irrigation system using fuzzy logic algorithm. There is no remote control unit in this system. In Jin et al. (2007), a system was designed to receive data from greenhouses by utilizing GSM/SMS technology. With this designed system, the success of measuring soil rate, soil temperature and greenhouse temperature has been achieved.

In Kırda et al (2007), the yield of mandarin is investigated under traditional restrained and newly introduced semi-wet irrigation applications and it is concluded that the deficit irrigation, both through partial root drying and conventional deficit irrigation must consider and balance savings of water and depreciation of marketable fruit quality. In Yıldırım et al. (2018), a smart automated drip irrigation system running with solar-powered energy is designed for a greenhouse system and it is concluded that it is possible to save water and fertilizer and increase the amount of energy by increasing the number of solar panels. In Zürey et al. (2020), an automatic nozzle control system is developed for the orchard sprayers to avoid the pesticide residues to the soil and it is observed that this system detects objects within 5 m distance with high stability. In Kesler et al. (2022), the normal and the fuzzy controlled irrigations ara compared with each other by using inputs e temperature, humidity, and soil moisture and an efficiency of 53.77% is obtained in irrigation water in seedling cultivation.

In this study, the water savings and the productivity of eggplant, tomato and pepper plants irrigated with conventional irrigation and micro-controller aided automatic controlled irrigation system are experimentally compared with each other.

2. Materials and Methods

An 8-bit, 8 MHz Atmega328 using Arduino Uno micro-controller is chosen for this study. ESP8266 Wi-Fi module is used to provide the remote control of irrigation process. In order to control the water requirement of plants, it can be provided by measuring the humidity of the soil. The used plant humidity sensor has 2 legs that measure humidity and these legs should be buried in the ground by the root of the plant without damaging the plant. When the plant humidity sensor legs are placed in the soil where the plant is located, a resistance occurs and this resistance creates a voltage difference between the two legs of the humidity sensor. It means that the higher the humidity of the plant, the higher the conductivity of the sensor. In Figure 1, the block diagram of soil humidity controlled plant irrigation system is given. First, humidity sensors are placed in the soil where the plant is planted. The operation of the water-pumping set is controlled by processing the information received from these sensors by the micro-controller. Yet, the water-pumping set also supplies the water to the drip irrigation system.

In this study, the plants planted in the first row are irrigated from the first water tank with the conventional method. The plants planted in the second row are irrigated with the system given in Figure 1 from the second water tank.

The plant water requirement is determined by the plant humidity sensor in the system and the system automatically gives the plant the water needed by the plant. Also, a Wi-Fi module is used for controlling and monitoring the irrigation system in order to check the irrigation system operation and manually control.

2.1. Plant Drip Irrigation System

Irrigation is the most important input in both increasing and improving the yield in plant production. The introduction of water, which is necessary for plant growth but cannot be met naturally, to the soil without creating environmental problems is called “irrigation”. Irrigation method refers to the way of the irrigation water is delivered to the plant root zone. Since the characteristics of agricultural areas (soil structure, topography and climate) are different, the way water is applied to the plant root zone is also different. Generally, plants are irrigated by one of the methods of surface, sprinkler and infiltration irrigation (Taş and Kırnak, 2015).

In order to obtain the highest yield and quality product from the unit area, it is necessary to know the amount of irrigation water and the irrigation time to be applied, along with other regional measures. Due to the limited water resources, drip irrigation is gaining importance all over the world. At the same time, this allows cultivation without stress on the plant. Ankara, which is the application area of this study, has a continental climate, limited water resources, the annual precipitation is not sufficient and drip irrigation is needed. Drip irrigation also provides energy savings in cases where water is forced. Drip irrigation prevents water and nutrient losses without creating surface runoff and infiltration. It allows irrigation with water with high salt content. At the same time, fertilization and spraying can be done with irrigation. Quality and standard products can be obtained. It allows irrigation in all kinds of areas and early harvest. Importantly, it prevents erosion and soil loss. Irrigation can be done at low pressures. In drip irrigation, the labor cost is very low compared to conventional irrigation methods (URL). With the automatic control drip irrigation system designed in this study, it is aimed to save labor, time and water and to increase the product yield.

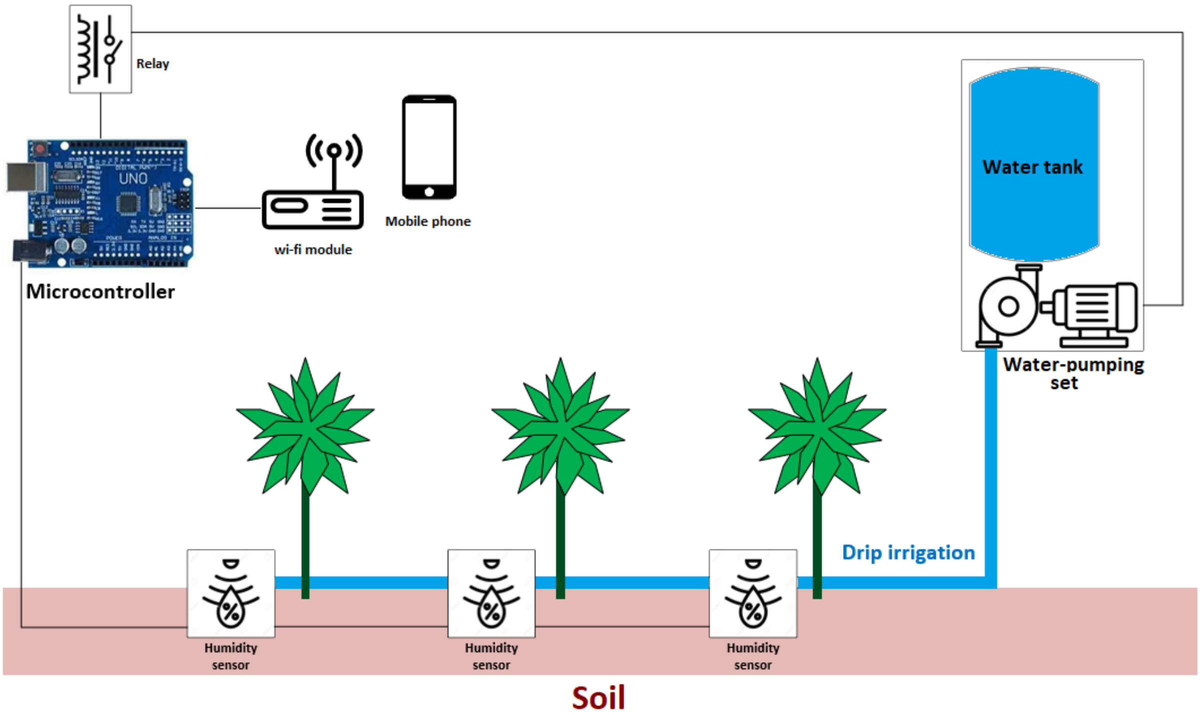

Figure 1. Soil humidity controlled plant irrigation system designed in the study.

3. Results and Discussion

In this study, an experimental comparison of crop yield and water savings is presented over plants irrigated with conventional methods and with automatic controlled drip irrigation. In the study, two 300-liter water tanks are used one for automatic controlled irrigation and for conventional irrigation. The amount of water consumed from the water tanks used is compared in quarterly periods as from May to June (first period), from June to July (second period) and from July to August (third period) and the monthly water savings are compared by the measurements. In Figure 2, the amounts of water consumed by conventional means (red color) and automatic controlled irrigation (green color) are given in the first, the second and the third months and in total. Figure 2 shows that for three months and total irrigation, the water consumed by automatic controlled irrigation is less than by conventional irrigation. The water savings are 13%, 19% and 22% in the first, second and third months, respectively. Therefore, the total water savings is 19% with automatic controlled drip irrigation.

In this study, three different plants, namely pepper, tomato and eggplant, are irrigated with two different methods as conventional and automatic controlled irrigation. Kızılcahamam district of Ankara is chosen as the application area of the study. The product yield and water savings in these two ways are also compared with each other. In Figure 3, the photos of these three plants irrigated in two different ways is given for the end of the 3rd month. In Figure 3, it is observed that the plants irrigated with the automatic controlled yield more products than the plants irrigated with the conventional way.

All cells at the boundaries of the membrane system of plant tissues play an important role in maintaining the normal course of the physiological process. Many proteins and enzymes are located in the membranes. For this reason, changes in membranes cause losses and normal physiological changes. Electrolyte leakage is defined as loss of cytoplasm in cells due to membrane damage (Fan et al., 2003). Membrane permeability can change due to environmental stress. Electrolyte leakage is used to describe the change in membrane permeability (Whitlow et al., 1992). In this study, ADWA AD3000 desk type EC meter is used to determine electrolyte leakage values. In Figure 4, electrolyte leakage values of three different plants irrigated with conventional and automatic controlled irrigation are given for three months. In Figure 4, Conv and Auto represent the conventional and automatic controlled irrigations, respectively. Pep (green colors), Egg (purple colors) and Tom (red colors) represent the pepper, eggplant and tomato, respectively. It is observed that the electrolyte leakage of plants irrigated by automatic controlled is less than the leakage of electrolyte from plants irrigated by In Figures 5a, 5b and 5c, the comparison of harvested products is given in terms of number. In Figures 5d, 5e and 5f, the comparison of harvested products is given in terms of weight. In Figure 5, I and II represent the first and second harvest period, respectively. The first harvest period is from June to July and the second harvest period is from July to August. In Figure 5, orange and blue colors indicate conventional and automatic controlled irrigation, respectively. When the Figures 5a, 5b and 5c are compared within themselves, it is observed that the number of the crops irrigated with automatic controlled is more than those irrigated with conventional means for all three plants and two harvest periods. Similarly, when the Figures 5d, 5e and 5f are compared within themselves, it is observed that the weight of the crops irrigated with automatic controlled is greater than the weight of those irrigated with conventional means for three plants and two harvest periods. The yields with automatic controlled irrigation for pepper, tomato and eggplant are 53%, 69% and 13% for the first harvest period, respectively. The yields for the second harvest period are 42%, 30% and 15% for pepper, tomato and eggplant, respectively. The highest yield for the first harvest period is obtained in tomato and the highest yield for the second harvest period is obtained in pepper. While the yield of pepper and tomato decreases in the second harvest period, the yield of eggplant increases in the second harvest period.

As discussed in Section Introduction, in the literature, there are many studies that provide water saving and product efficiency with different methods. While in Kale et al. (2017), the maximum yield for wheat is 31%, in this study, the maximum yield is 69% for tomato. In Zhang et al. (2018), winter wheat production efficiency increases with water saving management in the North China Plain. In this study, it is concluded that the automatic controlled irrigation method has a positive effect on the development and productivity of the plants compared to the conventional irrigation method.conventional means for all three plants.

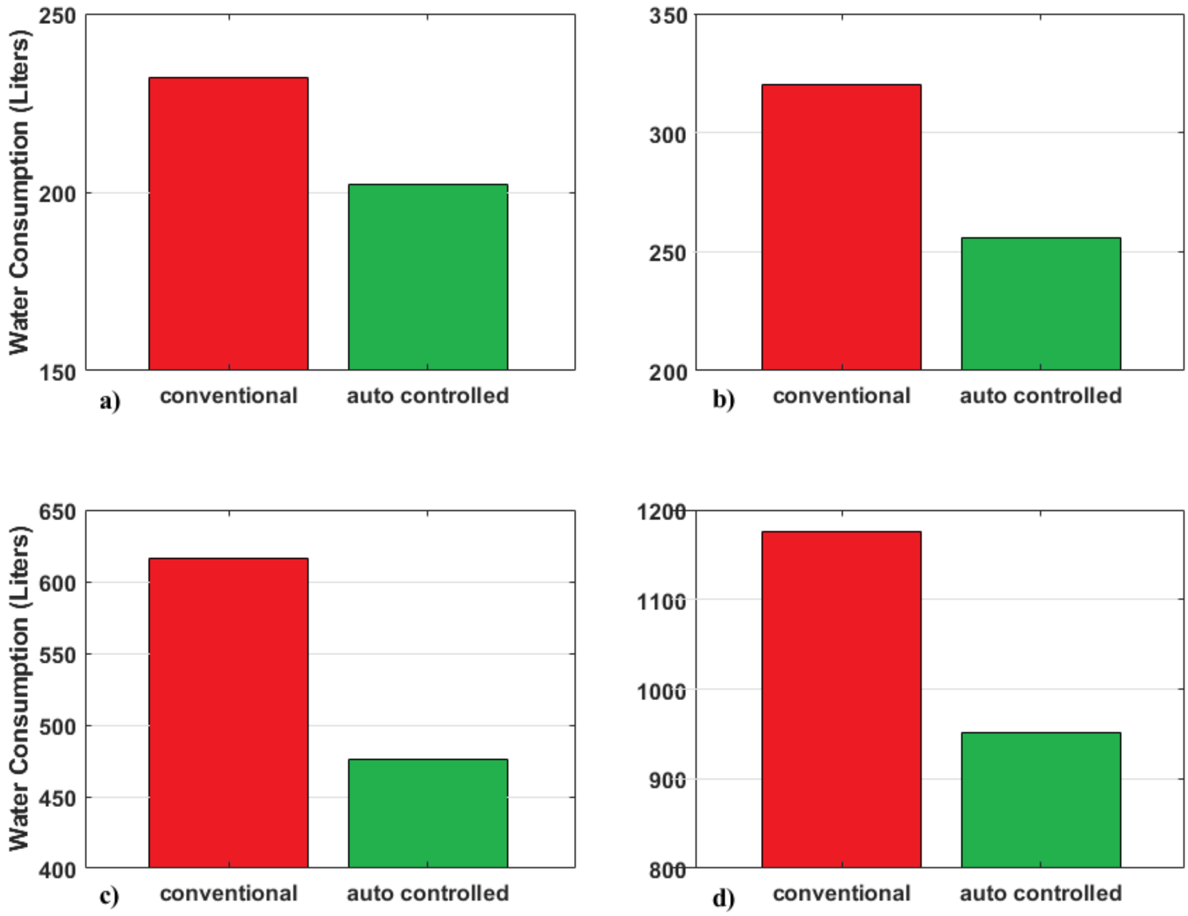

Figure 2. Consumption of water for: a) the first month, b) the second month, c) the third month and d) in total.

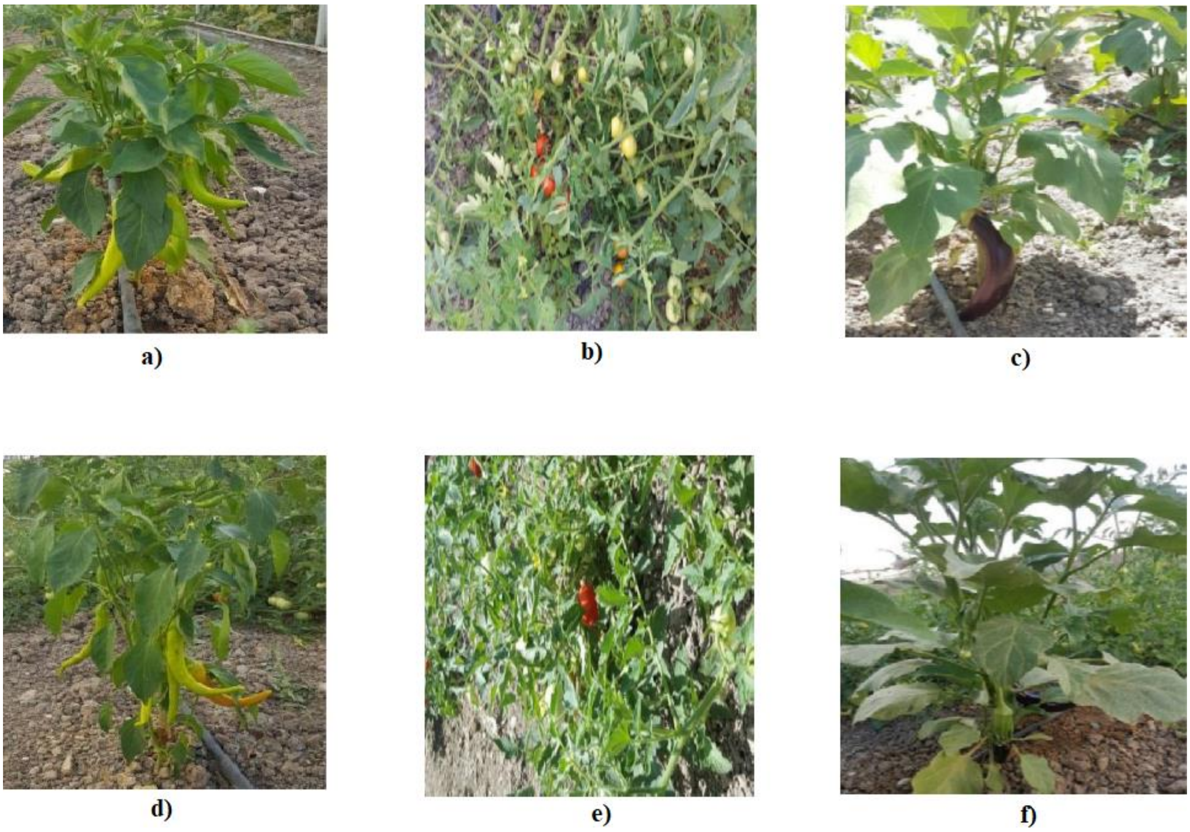

Figure 3. The photos of pepper, tomato and eggplant planted within the scope of the study. For automatic controlled irrigated a), b), c) and conventional irrigated d), e), f).

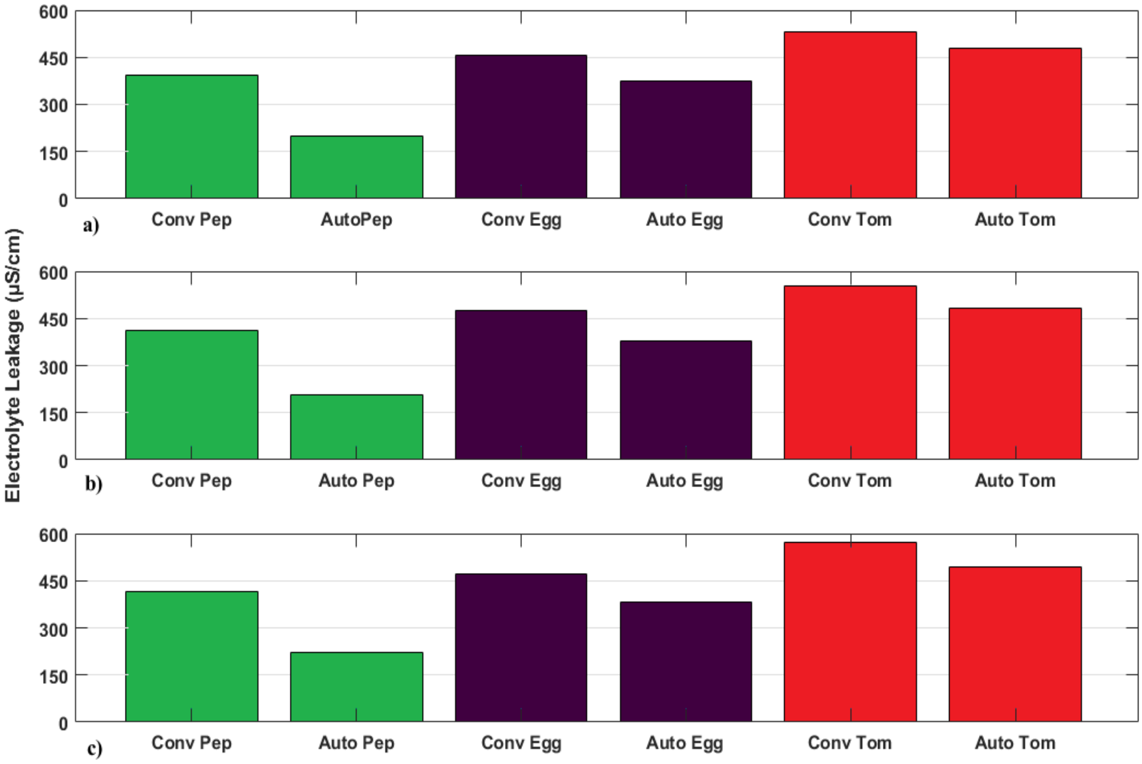

Figure 4. The monthly values of the electrolyte leakage of the three plants irrigate with the conventional means (Conv) and automatic controlled (Auto) for: a) first period, b) second period and c) third period.

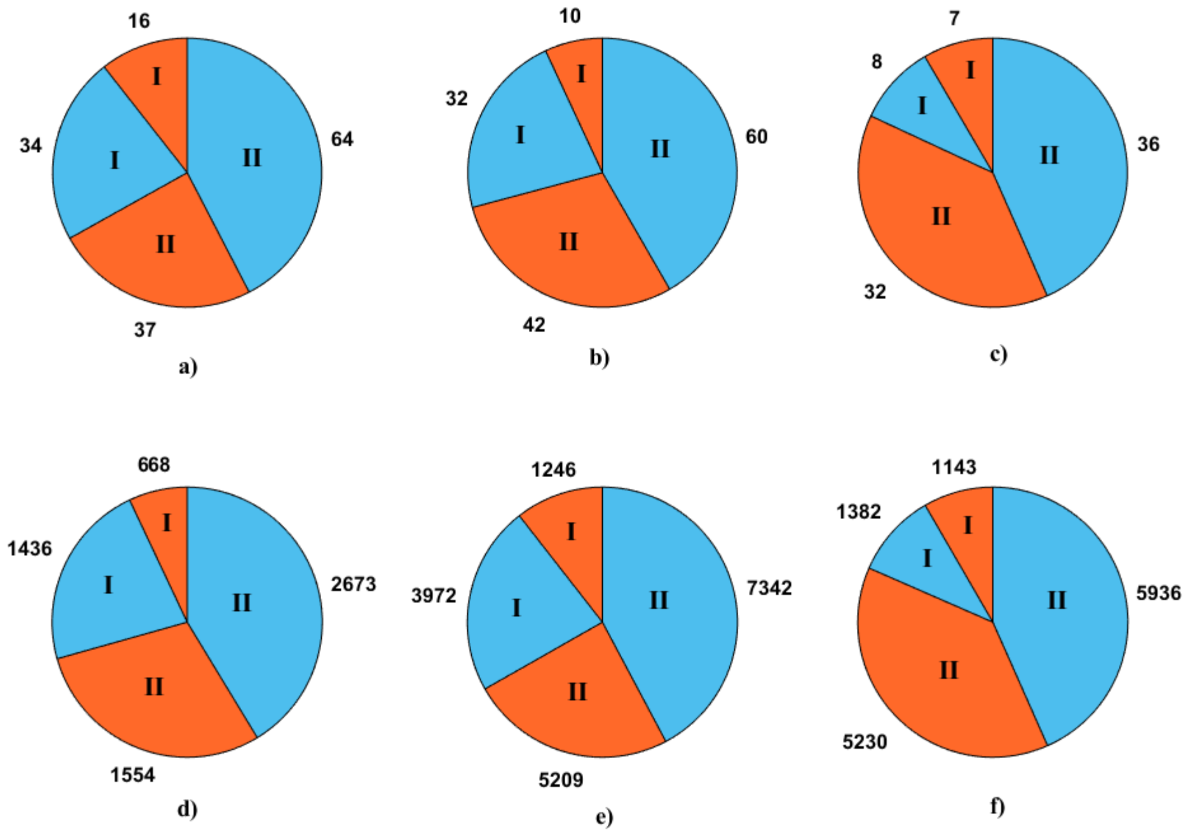

Figure 5. The numbers of: a) pepper, b) tomato and c) eggplant and the weights of: a) pepper, b) tomato and c) eggplant irrigated with conventional means (orange) and automatic controlled (blue) for the first (I) and the second (II) harvest periods.

4. Conclusion

In this study, the productivity of three crops, namely pepper, tomato and eggplant planted in Kızılcahamam, Ankara is experimentally compared using conventional and automatic controlled irrigation methods for two harvest periods. The crops are irrigated from May to June, June to July and July to August and harvested during July and August. Two 300-liter water tanks are used for the conventional and automatic controlled irrigation. The water requirement of the plants is determined using a remotely controlled plant humidty sensor. Only the root zone of the plant is irrigated using the drip irrigation system. As the plant humidity value decreases, the system automatically performs the irrigation process and when the humidity value determined for the plant is reached, the system automatically stops the irrigation process. In addition, the system can be controlled at the desired place and time with a mobile phone. With this control, up to 22% water savings are yielded with automatic controlled irrigation. The electrolyte leakage of plants irrigated by automatic controlled is observed to be less than those from plants irrigated by conventional means for all three plants. Finally, the numbers and the weights of the crops harvested in two periods are compared with each other and it is observed that up to 69% crops yield is observed from the first harvest period. As a result, it is observed that there is an increase in number and weight in the products irrigated with automatic controlled compared to conventional irrigation.

This system, which is applied to a small area, can also be applied to large agricultural areas without the need to use many humidity sensors. It can be improved by adding environmental elements such as humidity sensor and temperature sensor that can measure the ambient humidity value on the control unit of the irrigation system. The applied system is low-cost, increases productivity, reduces labor costs and provides water savings.

Author Contributions

Concept: A.B.A. (25%), H.M. (25%), S.K. (25%) and F.E. (25%), Design: A.B.A. (25%), H.M. (25%), S.K. (25%) and F.E. (25%), Supervision: A.B.A. (25%), H.M. (25%), S.K. (25%) and F.E. (25%), Data collection and/or processing: A.B.A. (25%), H.M. (25%), S.K. (25%) and F.E. (25%), Data analysis and/or interpretation: A.B.A. (25%), H.M. (25%), S.K. (25%) and F.E. (25%), Literature search: A.B.A. (25%), H.M. (25%), S.K. (25%) and F.E. (25%), Writing: A.B.A. (25%), H.M. (25%), S.K. (25%) and F.E. (25%), Critical review: A.B.A. (25%), H.M. (25%), S.K. (25%) and F.E. (25%), Submission and revision A.B.A. (25%), H.M. (25%), S.K. (25%) and F.E. (25%). All authors reviewed and approved final version of the manuscript.

Conflict of Interest

The authors declared that there is no conflict of interest.

Ethical Consideration

Ethics committee approval was not required for this study because of there was no study on animals or humans.

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