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Estimating Water Content of Leaves by Using Innovative Laser Sensor

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Abstract : The aim of this investigation is to use the applicable laser technology for automating drip irrigation systems, in order to save water and energy and increase crop production. In this respect a new instrument is designed and built in National Institute Laser Enhanced Science (NILES) Cairo University. The optical electronic instrument with Laser Control Unit (LCU) consists of laser source with wavelength 530 nm, sensor and micro control unit. The use of (LCU) depends on the optical properties of leaf (transmittance, reflectance and absorbance) of laser beam. The correlation between Leaf Water Content (LWC) and Laser Beam Transmitted (LBT) from leaves was used to detect when the automate irrigation system operate and how much water applied. A laboratory experiment was carried in (NILES) to test the (LCU), on many leaves of different vegetable crops such as cucumber and squash. The results showed that: 1) Laser beam transmitted increased while leaf water content decreased with time after irrigation. 2) for cucumber leaves the minimum value of LBT was 65 mV when the value of LWC was 91% meanwhile, the maximum value of LBT was 91mV when the value of LWC is 70%. 3) The data indicated that there were few differences between cucumber and squash in laser beam transmitted property and its relation with leaf water content, this may be due to the big similarity in the leaves properties between cucumber and squash.
Key words : *Laser Sensor, Water Content of Leaves, automate irrigation system, drip irrigation system, wavelength, cucumber and squash.*

Introduction

In recent few years the problem with the main water resources in Egypt (Nile) became series and complicated after establishing the Elnahda dame in Ethiopia. This essential subject in the main water recourse in Egypt must be solved by the scientific research. The future will require even great improvements as competitions for the limited water supplies continue. Now the saving of irrigation water is considered as the first strategy in Egypt's strategic plan 20-2030. The limited water resource, which in now under an unprecedented pressure by global population growth, climate change and demand from several economic sectors such as tourism, industry and agriculture. In Egypt more than 85% of water consumption by agriculture sectors.

In past few years, automatic irrigation system has seen a rapid growth in terms of technology. At present cost-saving technology, labor-saving are the addressing key issues in irrigation. The automated system has simpler features designed with the objective of low cost and effective with less power consumption using sensors for remote monitoring and controlling devices which are controlled via SMS using a GSM module. The proposing of agricultural solution for the farmer based on Wireless Sensor Networks, zigbee and GSM technology. Zigbee based low power handheld devices are employed to enable cost saving, and the valves are employed to save the water usage for irrigation [1,2]. For better drip irrigation plan, wireless was used to collect essential date such as chemical constituents of soil, water content, salinity and fertilizer. They[3] reviewed different monitoring systems and proposes an automatic monitoring system model using Wireless Sensor Network (WSN) which helps the farmer to improve the yield. Authors[4] summarized that in the near-infrared region of the spectrum, studies have primarily related water band indices (WI) to leaf area index (LAI). They identified three wavelength regions (950–970, 1150–1260 and 1520–1540 nm) that produced the best overall correlations with water content. They also developed and tested a new Canopy Structure Index (CSI) that combines the low absorption water bands with the simple ratio vegetation index (SR) to produce new index with a wider range of sensitivity to photosynthetic tissue area at all canopy thicknesses. CSI was better than either WI or SR alone for prediction of total area of photosynthetic tissues.

Healthy and stressed plants were measured with two hyperspectral images, Laser-induced fluorescence spectroscopy (LIFS), and Laser-induced fluorescence imaging (LIFI) systems in order to determine if the four handheld remote sensing instruments were equally capable of detecting plant stress and measuring canopy chlorophyll levels in Bahia grass. However unique capabilities of LIFS and LIFI instruments continue to argue for the development of Laser-induced fluorescence remote sensing technologies[5]. Saito[6] used the basic configuration of the Laser-induced fluorescence (LIF) system which consists of a Laser, a spectroscopic device, a detector and a PC for Tomato leaf growth monitoring. LIF spectrum of tomato leaf was generally separated into two wavelength regions from 400 nm to 650 nm (blue-green LIF) and from 650 nm to 800 nm (red & far-red LIF). The system made possible to show an intensity distribution as a visualized LIF image with any wavelengths. The intensity was gradually decreased from the root part toward the top part of the leaf. Wulf *et al.* [7] stated that Laser-induced fluorescence spectroscopy (LIFS) was non-destructively applied to apple fruit and carrot for determining changes in fruit and vegetable pigment contents. The samples were excited by short Laser pulses emitting at 337 nm, and recordings of fluorescence spectra which were carried out directly on the tissue surface and in fruit extracts in a wavelength range from 350 to 820 nm. It was found that changes in fluorescence intensity in the blue-green wavelength range can be attributed to variations in fruit polyphenol content. Mangangcha *et al.* [8] created the relationship between the optical properties and moisture content of the leaf using LED's in infrared region between 1300 nm to 1500nm since this range of wavelength falls in the water absorption band. Percentage moisture content at every stage of drying of the leaves and their transmittance and reflectance properties are analyzed. The conclusions presented could lead to the development of portable instruments for leaf water content estimation and other biological parameters rapidly and non-destructively. Thompson *et al.* [9] evaluated soil sensors for the measurement of Soil Matric Potential (SMP) with drip-irrigated vegetable crops, in a sandy loam soil in a greenhouse. Ranges of SMP were generated by applying three different irrigation treatments 100, 50 and 0% of crop water requirements, in melon. Watermark sensors and tension meters were positioned, at identical distances from irrigation emitters, at 10 cm soil depth, with four replicate sensors for each measurement. Breitenstein *et al.*[10] presented a novel, non-destructive method for determination of changes in leaf water content in the field based on terahertz (THz) technology. They founded that, the changes in leaf water content during drought stress induced dehydration as well as during the course of rapid re-hydration after re-watering vividly highlight the tremendous potential of this novel technique and its high reliability which agree with Gente and Koch [11] who mentioned that terahertz technology can provide a non-invasive tool for measuring and monitoring the water content of leaves and plants. Jyothipriya and Saravanabava[12] designed a Microcontroller for monitoring and controlling all the activities of drip irrigation system more efficiently, the system is based on Solenoid valve and Zigbee module and includes protection against single phasing, over-current, dry running**.** Saito *et al.* [13] stated that Broad LIF spectrum 400 nm to 800 nm gave information about pigments inside the leaves. Plant leaves can emit fluorescence in response to laser irradiation which is called Laser-induced fluorescence (LIF). The LIF spectrum varies its shape depending on molecule species and concentration containing in the leaves. Therefore, LIF will be a good indicator to monitor plant status. LIF spectrum of a poplar's green leaf representative LIF spectrum with two peaks at 685 nm and 740 nm and small ones at 460 nm and 530 nm are observed. Mobasheri and Fatemi[14] investigated the relationship between leaf Equivalent Water Thickness (EWT) and reflectance in wavelength. The results showed that band combinations such as ratio and normalized difference had higher regressions with leaf water content. In addition, the findings of this study showed that some parts of the near infrared (NIR) and short wave infrared (SWIR) of the spectrum provided higher accuracies in (EWT) assessment and correlations of more than 90% were achieved. Luciana *et al*.[15] used, a temperature and moisture sensors to measure the soil and weather conditions of the field. The temperature and moisture values from the sensors are sensed to the microcontroller and thus the current temperature and moisture are compared with predefined values. According to the temperature and moisture value, required amount of water is supplied to the crops.

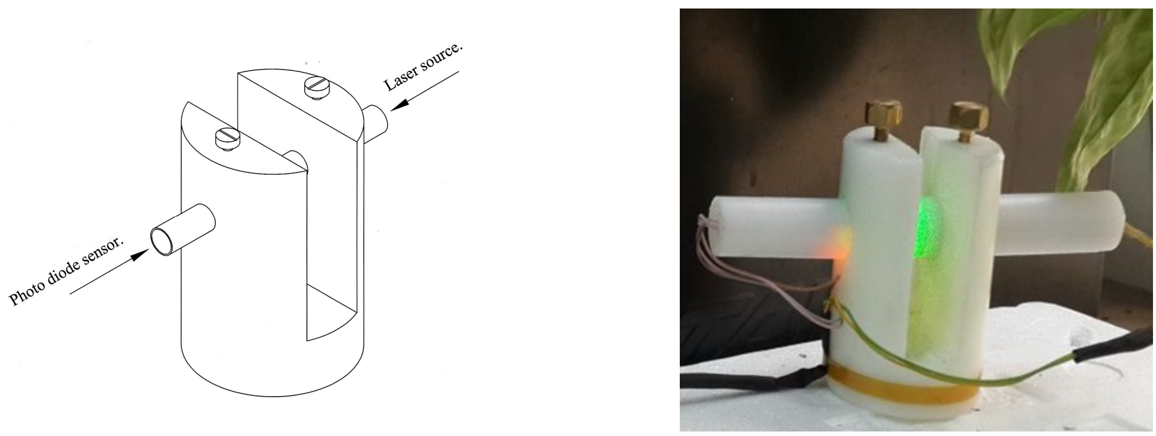
The main objective of this research is to use the high laser technology to measure the water stress in the leaf of plant; to save water, save energy, decrease labar cost and raise the water use efficiency; by using high laser technique to operate automate irrigation systems.

Materials and Methods

To achieve the research goal, the investigation plan will pass through the following stages: a) Inventing, designing and set up laser leaf sensor “LLS”; b) Perform some measurements to determine leaf water content “LWC” (%), and laser beam transmitted (mV) through plant leaf determination; c) Predict the relations between “LWC” and “LBT”. Laboratory experiments were executed during year 2014-2015 in laboratories of National Institute of Laser Enhanced Science (NILES), Cairo Univ., Egypt to justify the previous goals.

Laser leaf sensor “LLS”:

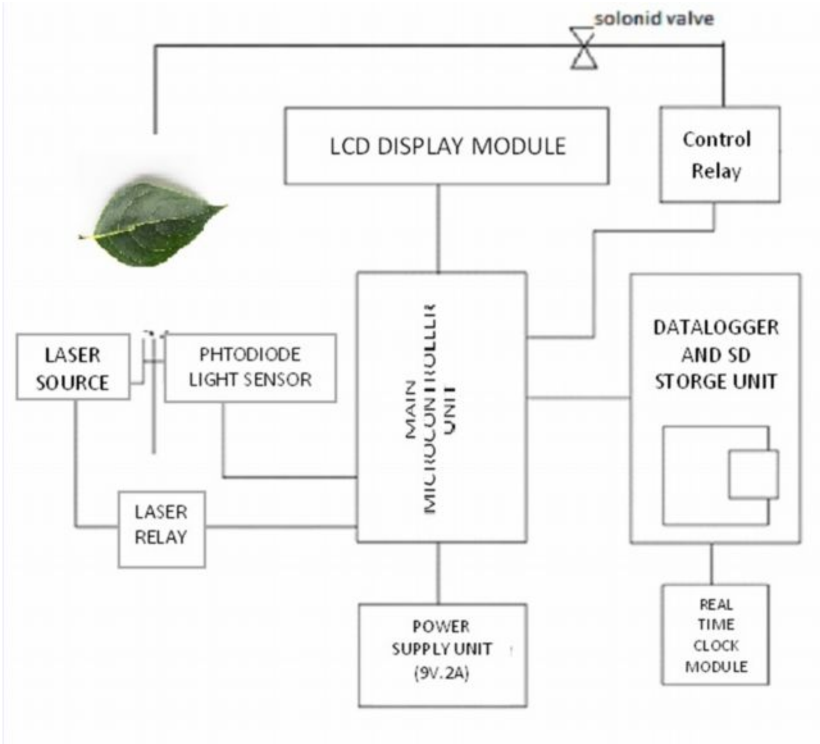
This module was designed depending on optical properties of laser beam transmittance through leaf to estimate its water content “LWC”. Laser leaf sensor “LLS” is the main part of laser control unit “LCU”. It has a cylindrical shape made from polyethylene “PE” with 90mm length and 60mm diameter with horizontal hole about 10mm diameter. A rectangular shape 69×20mm with 60mm depth was deducted longitudinally from cylinder core along vertical axis. Two tubes were inserting through the cylinder body holes with diameter of 10mm. continuous wave beam of laser light (green light) with wavelength 530 nm and Output power ≤ 4.25mV was fixed inside one of the horizontal tube. Photo diode sensor fixed inside the other horizontal tube (model SI S2684-254) with 252-256 nm for peak sensitivity wavelength and 8-12nm Output power. On the other hand, the distance between laser source and photo diode sensor can be adjustable to equal leaf thickness. Fig. (1)



(A) **(B)**

Fig. (1) Leaf laser sensor “LLS”; A) Sketch B) Photograph

Electric control unit is the second main part of “LCU”, this module represents record, stored and control data. It includes: main control unit, power supply unit (9V, 2A), “LCD” display module, data logger with SD storage unit and real time clock module. the analog reading of control unit split is presented into mV(5000 mV) with accuracy +5 mV/unit accuracy. Readings were taken each 100 µs (0.0001s) through every one hour period and stored in SD card for data logger module through data log files.



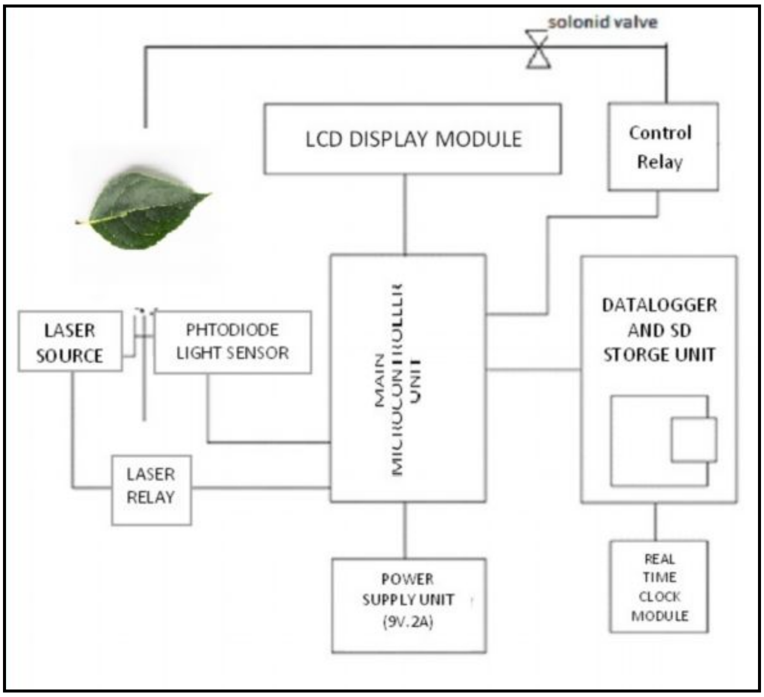


Fig. (2): Main components of electrical micro controller units.

The laser beam transmitted (LBT) from leaf of plant was calculated by equation (1) according to[8].

$$R + T + A = 1 \quad \ldots\ldots\ldots\ldots\ldots(1)$$

Where
T : transmittance , (mV).
A : absorbance, (mV).
R : reflectance, (mV).

Leaf water content (LWC): To calculate leaf water content W^i, equation (2) according to[16] was used:

$$W^i = \frac{W_i - W_{dry}}{W_i} \times 100 \quad \text{...............(2)}$$

Where

W^i : is average of the gravimetric water content for ten at each plant step.

W_i : is the moist weight measured at each step.

W_{dry}: is the dry weight measured at each step.

Leaf water content (LWC) and Laser beam transmitted (LBT) were measured after 2 hours from irrigation and the measurements was repeated each 4 hours for each day of the week. The average of measurements for the seven days at each week was calculated. The experiment started from week four until week nine since these weeks represent the initial and final ages for vegetation stage.

Results were analyzed by using of variance and correlation Analysis by using Statistic 8 Analytical Software (2003).

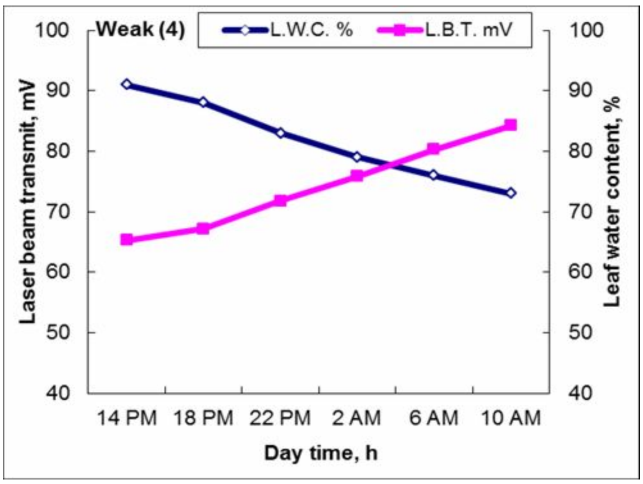
Results and Discussion

The water content is one of the most important properties of leaves. The leaves were cut from the plant when the average water content was around 85% at (time=0). The recorded data before irrigation showed that the average value of "LBT" were 89 mV when leaf water content 70%. After two hours from irrigation the Laser beam transmitted was 65.3 mV when leaf water content was 91%. Fig (3) shows the transmit of laser beam from the leaves of cucumber plant at the daily hours for different plant growth stages from weak 4 to weak 9.

The data presented the relationship between "LBT" and "LWC" for cucumber leaves. It is clear that, there is inverse relationship between "LBT" and "LWC", meanwhile leaf water content decreased the laser beam transmitted increased. The average values of "LBT" were 65.3, 67.2, 71.8, 75.8, 80.3 and 84.7 mV while the average values of leaves water content "LWC" were 91, 88, 83, 79, 76 and 73% after two hours from irrigation and each 4 hours daily respectively. It was noticed that the water content is gradually decreased with time after irrigation and the average of decreased percentage was about 4-5% for each four hours after irrigation.

On the same time the "LBT" increased with time after irrigation since the average of "LBT" was about 4-5 mV for each four hours after irrigation. It was noticed some differences for "LBT" and "LWC" between week 4 and week 9 at each stage of plant growth, since The average value of "LBT" was 65.3 mV at 91% of "LWC" at week 4, while the average value of "LBT" was 64.7 mV with "LWC" of 94% at week 9.

The data illustrated in Fig (4) present the relationship between "LBT" and "LWC" for squash crop at daily hours. The average values of LBT were 65 mV at 75% of LWC at week 4, while the average value of LBT was 85 mV at 95% of LWC at week 9. The data indicated that there is little difference between cucumber and squash, this may be due to the big similarity in the leaves properties. It was clear that the average values of "LBT" and "LWC" for squash crop take the same trend of cucumber plant.



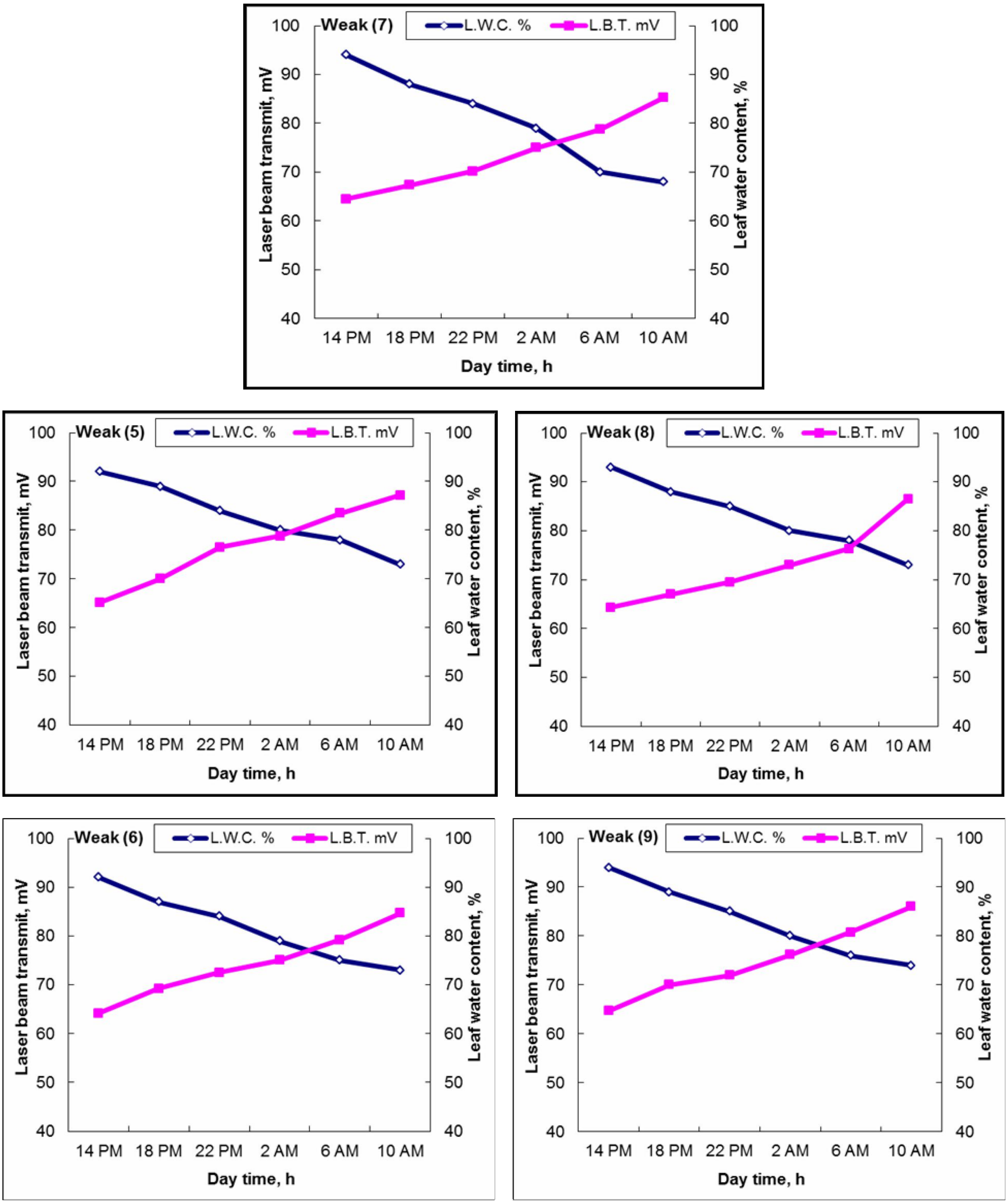


Fig (3): The relationship between leaf water content (LWC) and laser beam transmitted (LBT) of cucumber leaves for different day times at 4, 5, 6, 7, 8 and 9 weeks during growths plant period.

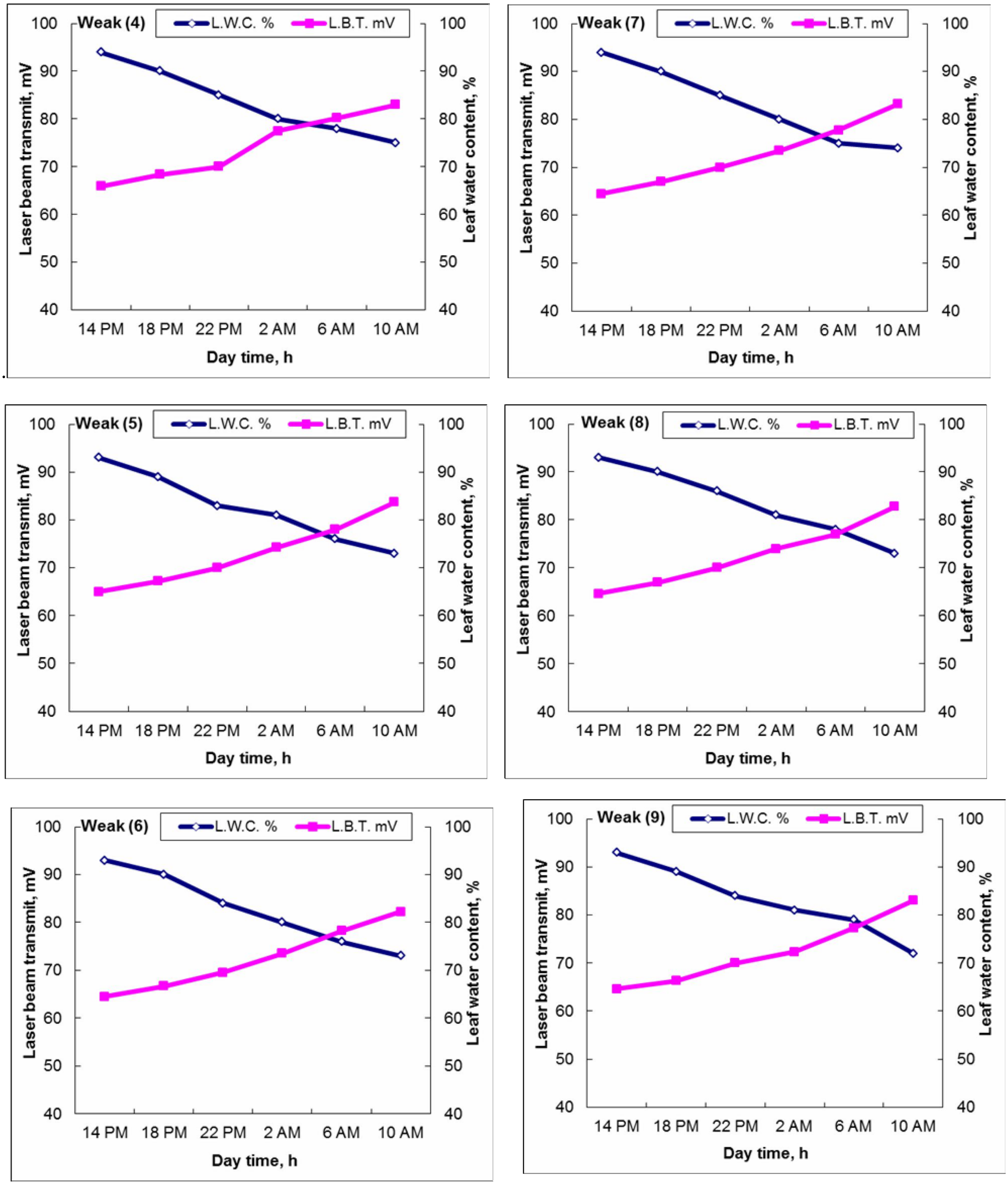


Fig (4): The relationship between leaf water content (LWC) and laser beam transmitted (LBT) of squash leaves for different day times at 4, 5, 6, 7, 8 and 9 weeks during growths plant period.

Statistical analysis is used to test the coloration between leaf water content “LWC” and laser beam transmitted “LBT” from the leaf data is presented in table (1). The statistical analysis indicates that there is high negative significant correlation between the “LWC” and “LBT”. The data indicated that there were few differences between cucumber and squash in laser beam transmitted property and its relation with leaf water content, this may be due to the big similarity in the leaves properties between cucumber and squash. It is clear that the laser beam transmitted increased as the leaf water content decreased.

Table (1) : correlation coefficient "LBT" and "LWC" with time for cucumber and squash plant.

Time Weeks	Cucumber	Squash
	Correlation coefficient	Correlation coefficient
4	- 0. 99**	- 0.88**
5	- 0. 98**	- 0.97**
6	- 0. 98**	- 0.96**
7	- 0.92**	- 0.96**
8	- 0.96**	- 0.98**
9	- 0.92**	-0.98**

** Significant at 1% level probability.

Conclusion

1. There is negative correlation between laser beam transmitted and leaf water content, the "LBT" increased as the "LWC" decreased in the leaf of plant.
2. The average values of "LBT" from different leaves were ranged between 65-85 mV, while the "LWC" ranged between 90 – 75%.
3. Finally the values of laser beam transmitted from leaves which recorded by Laser Control Unit "LCU" can be used as for operate the automated drip irrigation system and deciding when and how much water will be applied.

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