International Journal of Applied Engineering & Technology

ANALYSIS OF EVAPOTRANSPIRATION AND DEVELOPING CROP COEFFICIENT FOR PLANTATION SUGARCANE USING LYSIMETER: A DEEP LEARNING TECHNIQUE

Kavya B M[1] and Dr. T Mahadevaiah[2]
[1, 2]BGSIT, Adichunchanagiri University, B G Nagara

ABSTRACT
Water supply for irrigation must correspond to demand. The environmental demand for surface water must be understood by a producer. The main cause of this surface water loss is evapotranspiration (ET). Evaporation of soil moisture, standing water, and transpiration all contribute to evapotranspiration, which is the atmospheric demand for moisture. Different five principles methods, including the lysimeter technique, the Hargreaves class 'A' pan method, the field plot method, the Blaney-Criddle method, and the penman formula, can be used to measure evapotranspiration. All of the above mentioned techniques can measure ET using various input parameters. The primary methodology in this review is the lysimeter. This essay discusses the functions of lysimeters and reviews on their use in semiarid environments, as well as reviews on the evapotranspiration (ET) processes of various crops and sugar cane.

Keywords: sugar Cane, Lysimeter, Evapotraspiration.

INTRODUCTION
Evapotranspiration (ET) is a crucial component of the Earth's hydrological cycle, representing the combined processes of water evaporation from the Earth's surface and water transpiration from plants. It's a fundamental concept in hydrology, climatology, and agriculture. Evapotranspiration plays a significant role in the movement of water and energy between the Earth's surface and the atmosphere. Here are the key aspects of evapotranspiration.

A. Evaporation:
Definition: Evaporation is the process by which liquid water is converted into water vapor and released into the atmosphere. This occurs primarily from open water bodies (e.g., lakes, rivers, and oceans) and moist surfaces (e.g., soil and wetlands).

Factors Affecting Evaporation: Temperature, humidity, wind speed, solar radiation, and the availability of water are critical factors influencing the rate of evaporation. Higher temperatures, lower humidity, and increased wind speed generally lead to higher evaporation rates.

B. Transpiration:
Evapotranspiration:

Evapotranspiration is the sum of all processes by which water moves from the land surface to the atmosphere via evaporation and transpiration. Evapotranspiration includes water evaporation into the atmosphere from the soil surface, evaporation from the capillary fringe of the groundwater table, and evaporation from water bodies on land. Evapotranspiration also includes transpiration, which is the water movement from the soil to the atmosphere via plants. Transpiration occurs when plants take up liquid water from the soil and release water vapor into the air from their leaves.

C. Transpiration:
The release of water vapor (gas) from plant leaves. Transpiration has three main steps.

- Roots uptake water from the soil
- Water moves through plant tissues, serving critical metabolic and physiologic functions in the plant.
- Leaves release water vapor into the air through their stomata

D. Amount of water do plants transpire:

Plant transpiration is pretty much an invisible process. Since the water is evaporating from the leaf surfaces, you don't just go out and see the leaves "breathing". Just because you can't see the water doesn't mean it is not being put into the air, though. One way to visualize transpiration is to put a plastic bag around some plant leaves. As this picture shows, transpired water will condense on the inside of the bag (this photo shows transpiration after 1 hour). During a growing season, a leaf will transpire many times more water than its own weight. An acre of corn gives off about 3,000-4,000 gallons (11,400-15,100 liters) of water each day, and a large oak tree can transpire 40,000 gallons (151,000 liters) per year.

Since water vapor also evaporates from the soil, we would have seen even more water vapor captured if we had wrapped the plastic bag around the soil as well.

E. Area Selection

This survey is made in the fields lacated near Pandavapura of Mandya district, Karnataka. As the area is a Semi Arid and there is 5,325 hectares of land completely used for Sugarcane Crop. farmers in Mandya district have been proved to be efficient. It has been also found from the impact analysis that among the inputs only labour has made significant positive impact on technical efficiency of growing sugarcane.

F. Effects of transpiration:

Plants put down roots into the soil to draw up water and nutrients into its stems and leaves. Some of this water is returned to the air by transpiration. Transpiration rates vary widely depending on weather and other conditions, such as

Type of plant: Plants transpire water at different rates. Some plants which grow in arid regions, such as cacti and succulents, conserve precious water by transpiring less water than other plants.

Soil type and saturation: Clay particles are small (smaller than 0.002 mm), holding onto water whereas sand particles which are large (0.05-2 mm) release water readily (think of how water disappears into the sand quickly at the beach). When moisture is lacking, plants can begin to senesce (premature aging, which can result in leaf loss) and transpire less water.

G. Sunlight availability and intensity

Precipitation: During dry periods, transpiration can contribute to the loss of moisture in the upper soil zone, which can have an effect on vegetation and food-crop fields.

Humidity: As the relative humidity of the air surrounding the plant rises the transpiration rate falls. It is easier for water to evaporate into dryer air than into more saturated air.

Temperature: Transpiration rates go up as the temperature goes up, especially during the growing season, when the air is warmer due to stronger sunlight and warmer air masses. Higher temperatures cause the plant cells which control the openings (stoma) where water is released to the atmosphere to open, whereas colder temperatures cause the openings to close.

Wind & air movement: Increased movement of the air around a plant will result in a higher transpiration rate. Wind will move the air around, with the result that the more saturated air close to the leaf is replaced by drier air.

H. Transpiration affect on groundwater:

In many places, plant roots are found in the top layer of soil, above the water table. The top layer of soil is often wet to some extent, but is not totally saturated. Soil below the water table is very wet.

The top layer of soil gets wet when it rains (a form of precipitation), but if there is no more precipitation, the soil will dry out. Therefore, the plants are dependent on water supplied by precipitation since the water table is usually below the depth of the plant roots.

As this diagram shows, in places where the water table is near the land surface, such as next to lakes and oceans, plant roots can penetrate into the saturated zone below the water table, allowing the plants to transpire water directly from the groundwater system. Here, transpiration of groundwater commonly results in a drawdown of the water table much like the effect of a pumped well (cone of depression—the dotted line surrounding the plant roots in the diagram).

Evapotranspiration (ET) is a crucial component of the Earth's hydrological cycle, representing the combined processes of water evaporation from the Earth's surface and water transpiration from plants. It's a fundamental concept in hydrology, climatology, and agriculture.

Definition: Transpiration is the process by which water is absorbed by plant roots from the soil, transported through the plant's vascular system, and released into the atmosphere through small openings called stomata on the plant's leaves. It's a vital part of a plant's life processes.

Factors Affecting Transpiration: Transpiration rates are influenced by factors such as plant type, plant size, growth stage, environmental conditions (temperature, humidity, wind, and light), and soil moisture availability.

I. Components of Evapotranspiration:

Reference Evapotranspiration (ETo): ETo represents the potential rate of evapotranspiration from a reference grass crop under standard meteorological conditions. It is used as a baseline to estimate crop-specific evapotranspiration.

Actual Evapotranspiration (ETa): ETa is the actual rate of evapotranspiration occurring in a specific area or with a particular plant or crop. It considers the unique characteristics of the vegetation and local weather conditions.

J. Measurement and Estimation:

Evapotranspiration can be measured using various methods, including lysimeters, eddy covariance towers, Bowen ratio systems, and remote sensing technologies. However, measuring ET directly can be challenging and expensive.

Mathematical models, such as the Penman-Monteith equation, Hargreaves equation, and Priestley-Taylor equation, are often used to estimate evapotranspiration based on meteorological data.

K. Importance:

Evapotranspiration is a critical component of the water cycle, influencing the distribution and availability of water resources in a region.

It has significant implications for agriculture, as it represents the water needs of crops. Efficient irrigation practices rely on accurate estimates of crop evapotranspiration.

Evapotranspiration also impacts local and regional climates, contributing to temperature regulation and the formation of weather patterns.

L. Environmental Impact:

Understanding evapotranspiration is essential for managing water resources sustainably, especially in regions with water scarcity.

Changes in land use, deforestation, and climate change can alter evapotranspiration patterns, impacting ecosystems and water availability.

METHODOLOGY

Measuring evapotranspiration (ET) of sugarcane using a lysimeter is a valuable method for understanding the water needs of the crop and optimizing irrigation practices. Here's a step-by-step procedure and methodology to find evapotranspiration of sugarcane using a lysimeter:

Lysimeter Selection and Installation

- Lysimeter Calibration
- Instrumentation and Data Logging
- Initial Soil Moisture Measurements
- Planting Sugarcane
- Data Collection
- Crop Canopy Measurements
- Calculating Evapotranspiration
- Data Analysis

Reporting and Interpretation

1. Lysimeter Selection and Installation:
Choose appropriate lysimeters for your study. Lysimeters for ET measurements often consist of large containers or columns filled with soil representative of the sugarcane field. Ensure that lysimeters are properly sealed to prevent lateral water movement.

Install the lysimeters within or adjacent to the sugarcane field you want to monitor. They should be representative of the soil and environmental conditions in the field.

2. Lysimeter Calibration:
Calibrate the lysimeters by determining their water-holding capacity. This involves saturating the lysimeters with water and measuring the change in weight to calculate their storage capacity.

3. Instrumentation and Data Logging:
Install appropriate sensors and data loggers within the lysimeters to measure soil moisture content, temperature, and other relevant parameters at multiple depths.

Set up meteorological instruments (e.g., weather stations) near the lysimeters to collect data on weather conditions, including temperature, humidity, wind speed, and solar radiation.

4. Initial Soil Moisture Measurements:
Before planting sugarcane or at the beginning of the growing season, measure the initial soil moisture content within the lysimeters at different depths.

5. Planting Sugarcane:
Plant sugarcane in the designated field according to standard agricultural practices.

6. Data Collection:
Throughout the growing season, collect data from the lysimeters and meteorological instruments.

Data should include:

Soil moisture content at various depths within the lysimeters.

Meteorological data, especially temperature and solar radiation, which are crucial for calculating ET.

7. Crop Canopy Measurements:
Periodically measure the leaf area index (LAI) or crop canopy cover of the sugarcane using appropriate methods. This data will help estimate the transpiration component of ET.

8. Calculating Evapotranspiration:

Calculate ET using the lysimeter data and meteorological information. The Penman-Monteith equation is a commonly used method for estimating ET:

$ET = (\Delta S + R - G) / (\rho * \lambda)$ Where:

ET = Evapotranspiration (mm/day)

ΔS = Change in water storage in the lysimeter (mm/day)

R = Net radiation ($MJ/m^2/day$)

G = Soil heat flux ($MJ/m^2/day$)

ρ = Air density (kg/m^3)

λ = Latent heat of vaporization (MJ/kg)

9. Data Analysis:

Analyze the collected data to understand how ET varies over time and in response to environmental conditions and crop growth stages.

10.Reporting and Interpretation:

Prepare a report summarizing the ET findings, including variations over the growing season and the influence of weather conditions and crop development.

11.Recommendations:

Use the ET data to optimize irrigation scheduling and water management practices for sugarcane cultivation, ensuring efficient water use.

Regular monitoring and accurate data collection are critical for obtaining reliable ET measurements using lysimeters. The Penman-Monteith equation provides a comprehensive approach to estimate ET, considering both the crop's transpiration and the soil's evaporation. Adjustments may be needed based on local conditions and equipment specifications.

EXPERIMENTAL SET UP

These experiments are done in the fields located near Visvesvaraya Channe form (V C form) of Mandya district, Karnataka. As the area is a Semi-Arid and there is 5,325 hectares of land completely used for Sugarcane Crop.

Lysimeter is for most devices, typical tankers or container (net area of 2m2, 1m*2m with a boundary of 6*6m) that permit measurement of vertically percolated volume of water beyond the crop root zone from the lysimeter drainage hole. From the lysimeter, the soil samples were taken to analysis the most important physical properties related to irrigation. The soil physical properties considered were bulk density and soil texture but soil moisture content at field capacity and wilting point were taken. The sugarcane variety used for the experiment was taken from sugar factory. In the lysimeter including the boundary area, furrow layout was prepared with a furrow width of 1m. The sugarcane setts with two buds were planted in rows in the lysimeter as well as the boundary area. The lysimeter layout on which the experiment conducted was presented in the Figure below

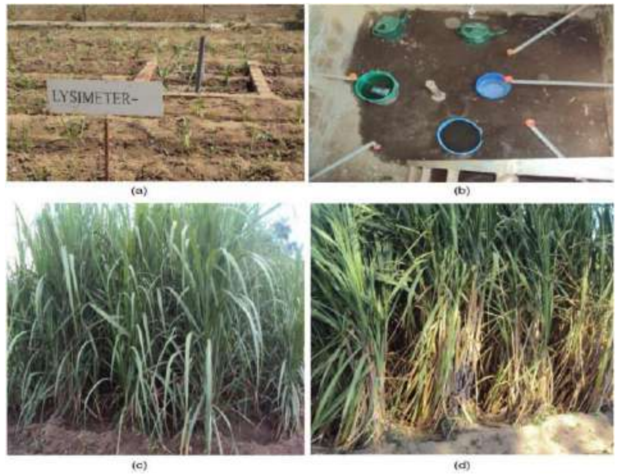

Figure 1. Partial view of lysimeter: A) Soil ground where lysimeter is installed, B) Lysimeter drainage hole C) Sugarcane at tillering stage, D) Sugarcane breeds in the lysimeter

A. Lysimeter characteristics:

Three weighing lysimeters (CTC9005HP, RB966928, and SP87365) were built and installed in the greenhouse to support three trays composed of 54 tubes of 125 cm^3 of sugarcane PSPs, totalizing 162 plants per lysimeter.

Lysimeters were constructed by a rectangular tank of 1179 mm length, 586 mm width (0.6909 m^2), and 400 mm depth. The tank was made of carbon steel sheets of 1.58 mm thickness, welded and painted with gray epoxy and paint to avoid material oxidation (Fig. 1). A liquid level indicator was installed to indicate the water level storage and drainage requirement in the tank. The tank was supported by three retractable threaded rods, under which the load cells were threaded by hangers. The system was sustained by a rectangular steel sheet base of 600 mm length, 400 mm width, and 12.7 mm thickness, which was laid on the greenhouse ground by four 150 mm length and 20 mm diameter pointed rods, which were located at the edges of the underside base to secure the lysimeters to the ground.

Lysimeters were installed with positional adjustments to ensure the tank free fluctuation above the load cells, avoiding any external interference. The datalogger, multiplexer, and solar panel were used as data acquisition systems and were fixed on a greenhouse support pole with prefabricated supports. After structural installation, cable connections between the load cells, junction box, datalogger, multiplexer, battery, and solar panel were established. Lysimeters were previously calibrated following the methods of Faria et al. (2006) and Mariano et al. (2015). Calibration revealed, for the three lysimeters, a high correlation (R^2 = 1.0000) between the equivalent mass (mm) and electrical signal (mV), great measurement accuracy, evidenced by a high Willmott's index of agreement (d = 1.0000), mean absolute error of 0.0272 to 0.0382, and mean square error of 0.0011 to 0.0024. A low variation in the angular coefficient (1.0236 mm mV^{-1}) of linear regressions reveals that the lysimeters measure homogeneity. Therefore, the equipment was assumed to be adequate for sugarcane PSP ETc with a 0.1 mm accuracy, suitable for the applications of this study.

The load cells (GL-30 Alfa Instrument), were made of aluminum with a 30 kg nominal capacity, 2.0000 +/- 10% mV V^{-1} sensibility, and 0.03% accuracy at the full scale. Electrical signals produced by the three load cells of each lysimeter were conducted to a junction box (4134 A; Alfa) and sent to a data acquisition system, programmed to take readings every 10 min. That system included a differential channel multiplexer (AM 416 Relay Multiplexer) and a datalogger (CR10). The power supply was made using a battery with 12 V tension and 7 A current, as well as a solar panel (SP20R-PW). Data storage was transferred directly to the microcomputer, or indirectly to a memory module, through PC200 W software.

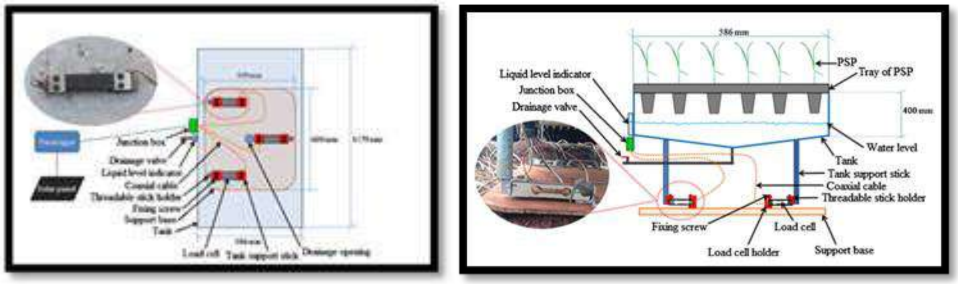

Fig. 2. Front and top view sketch of the lysimeters, highlighting a picture of the study load cell.

B. Treatments

Three sugarcane cultivars were chosen to compose the treatments of study (CTC9005HP, RB966928, and SP87365). The CTC9005HP cultivar was developed by V C form and is an early-to-medium maturation cultivar adapted in high fertility soil. This cultivar has a high multiplication rate due to many buds per unit area, around 1.65 million buds per hectare. The RB966928 cultivar has a high sucrose content, tolerance to most sugarcane diseases, good sprouts on plants and ratoons, high adaptation to mechanical harvesting, rare flowering, uncommon stool tipping, and medium herbicide tolerance. This cultivar is recommended for medium-to-high fertility soils and has an early maturation cycle. SP87365 stands out for its great yield, high tolerance to sugarcane borer (Diatraeasaccharalis), and low herbicide and hydric deficit tolerance. This cultivar is recommended for high fertility soils and has a medium maturation cycle.

C. Lysimeters characteristics:

Three weighing lysimeters (CTC9005HP, RB966928, and SP87365) were built and installed in the greenhouse to support three trays composed of 54 tubes of 125 cm^3 of sugarcane PSPs, totalizing 162 plants per lysimeter.

Lysimeters were constructed by a rectangular tank of 1179 mm length, 586 mm width (0.6909 m^2), and 400 mm depth. The tank was made of carbon steel sheets of 1.58 mm thickness, welded and painted with gray epoxy and paint to avoid material oxidation (Fig. 1). A liquid level indicator was installed to indicate the water level storage and drainage requirement in the tank. The tank was supported by three retractable threaded rods, under which the load cells were threaded by hangers. The system was sustained by a rectangular steel sheet base of 600 mm length, 400 mm width, and 12.7 mm thickness, which was laid on the greenhouse ground by four 150 mm length and 20 mm diameter pointed rods, which were located at the edges of the underside base to secure the lysimeters to the ground. Lysimeters were installed with positional adjustments to ensure the tank free fluctuation above the load cells, avoiding any external interference. The datalogger, multiplexer, and solar panel were used as data acquisition systems and were fixed on a greenhouse support pole with prefabricated supports. After structural installation, cable connections between the load cells, junction box, datalogger, multiplexer, battery, and solar panel were established. Lysimeters were previously calibrated following the methods of Faria et al. (2006) and Mariano et al. (2015). Calibration revealed, for the three lysimeters, a high correlation ($R^2 = 1.0000$) between the equivalent mass (mm) and electrical signal (mV), great measurement accuracy, evidenced by a high Willmott's index of agreement (d = 1.0000), mean absolute error of 0.0272 to 0.0382, and mean square error of 0.0011 to 0.0024. A low variation in the angular coefficient (1.0236 mm mV^{-1}) of linear regressions reveals that the lysimeters measure homogeneity. Therefore, the equipment was assumed to be adequate for sugarcane PSP ETc with a 0.1 mm accuracy, suitable for the applications of this study.

The load cells were made of aluminium with a 30 kg nominal capacity, 2.0000 +/- 10% mV V^{-1} sensibility, and 0.03% accuracy at the full scale. Electrical signals produced by the three load cells of each lysimeter were conducted to a junction and sent to a data acquisition system, programmed to take readings every 10 min. That system included a differential channel multiplexer (AM 416 Relay Multiplexer; Campbell Scientific, Logan, Utah, USA) and a datalogger (CR10; Campbell Scientific, Logan, Utah, USA). The power supply was made using a battery with 12 V tension and 7 A current, as well as a solar panel (SP20R-PW; Campbell Scientific, Logan, Utah, USA). Data storage was transferred directly to the microcomputer, or indirectly to a memory module, through PC200 W software (Campbell Scientific, Logan, Utah, USA).

D. Evaluations:

- Crop evapotranspiration (ETc) was determined daily, according to Eq. (1).

$$ETc_x = S_{x+1} - S_x + \sum_{i=1}^{n} I_{xi} - \sum_{i=1}^{n} D_{xi}$$ Eq-(1)

ETcx: crop evapotranspiration at lysimeter on day “x”, mm;

Sx+1: water storage at lysimeter at 0 h on subsequent day of day “x”, mm;

Sx: water storage at lysimeter at 0 h on day “x”, mm;

Ix: irrigation depths on day “x”, mm;

Dx: drainages of lysimeter on day “x”, mm.

- Evapotranspiration (ETo) was calculated daily by the Penman–Monteith equation,

$$ETo = \frac{0.408\, s(Rn - G) + \frac{\gamma\, 900 U_2 (e_s - e_a)}{T+273}}{a + \gamma(1 + 0.34U_2)}$$ Eq- (2)

where,

ETo: reference evapotranspiration, mm d−1 ;

s: slope of saturation vapor pressure curve, kPa °C−1 ;

Rn: net solar radiation, MJ m−2 d-1;

G: soil heat flux, MJ m−2 d-1 (negligible to daily values);

γ: psychometric constant, 0.063 kPa °C−1 ;

U2: wind speed at 2 m from the ground, m s−1 ;

es: saturation vapor pressure, kPa;

ea: actual evapor pressure, kPa;

T: mean air temperature, °C.

- Crop coefficient (Kc) values were estimated by the relationship between ETc and ETo during the crop cycle, according to Eq. (3).where,

$$Kc = \frac{ETc}{ETo}$$ Eq-(3)

Kc: crop coefficient, dimensionless;

ETc: crop evapotranspiration, mm d−1 ;

ETo: reference evapotranspiration, mm d−1 .

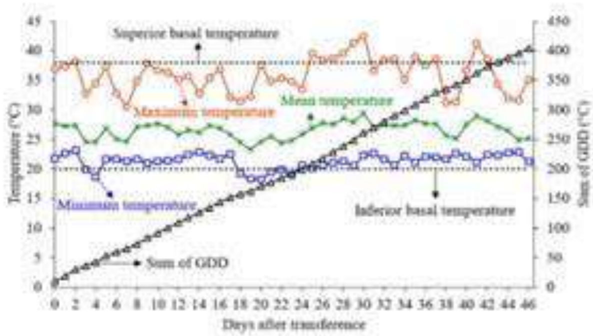

Fig. 3. Mean, maximum, and minimum air temperature, basal temperature, and sum of growing degree-day (GDD) during the experimental period

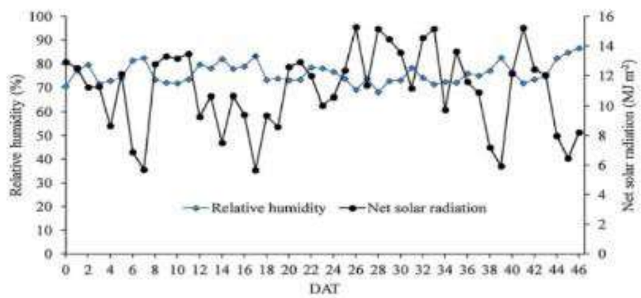

Fig. 4. Relative humidity and net solar radiation recorded during the experimental period DAT (Days After Transference)

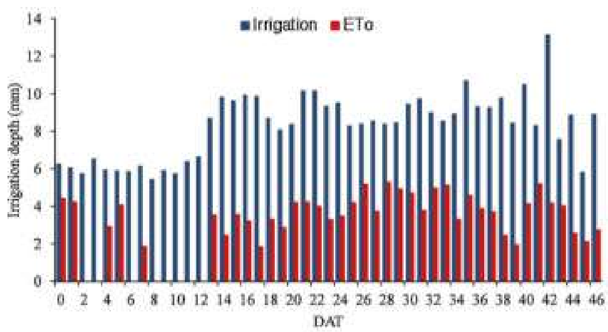

Fig. 5. Irrigation depth and reference evapotranspiration (ETo) during the experimental period. DAT, days after transference.

During the experimental period, the mean air temperature was 26.5 °C, mean maximum air temperature was 35.2 °C, and mean minimum temperature was 20.9 °C. On 13 days, the maximum temperature exceeded the superior basal temperature (38 °C), and on 8 days, the minimum temperature was lower than the inferior basal temperature (20 °C). At the end of experimental period, the sum of GDD reached 403.4 °C (Fig. 3). The mean relative humidity was 75.9%, with a variation of 68.2% to 86.7%. The mean net solar radiation was 11.1 MJ m^{-2} d^{-1} , with a variation of 5.7 to 15.3 MJ m^{-2} d-1 (Fig. 4). The mean wind speed from 2 m above the ground was 0.271 m s-1, with a variation of 0.024 to 0.912 m s-1. The irrigation was applied by a 14 m length sprinkler bar with 33 nozzles (TT TEEJET 11008VS; TeeJet, Springfield, Illinois, USA), with 430 mm spaces at a height of 1.5 m from the ground. Irrigation depth was defined by the bar speed, which was limited at 8 m min−1 with the nozzle flow fixed at 2.61 min−1 , defining irrigation depths greater than 0.67 mm in each application. The total applied irrigation depth during the experimental period was 389.2 mm, ranging from 5.4 to 13.2 mm d−1 , with a mean of 8.3 mm d−1 . The total ETo was 175.7 mm, ranging from 1.9 to 5.3 mm, with a mean of 3.7 mm d−1 . Since the irrigation was greater than the ETo, there was no water deficit during the experimental period (Fig. 5).

This confirmation guaranteed the water supply for crop evapotranspiration at a maximum rate, which is required for Kc determination.

Table 1.

Crop evapotranspiration (ETc) and reference evapotranspiration (ETo) during the experimental period for cultivars CTC9005HP, RB966928, and SP87365. DAT, days after transference.

DAT	ETo (mm d^{-1})	ETc (mm d^{-1})		
		CTC9005HP	RB966928	SP87365
0–7	3.5	3.6	3.6	3.6
8–6	3.2	3.9	3.9	4.0
17–21	3.3	4.3	4.0	4.2
22–26	4.0	5.2	5.2	5.3
27–31	4.5	6.6	6.4	6.2
32–36	4.4	6.6	6.4	6.3
37–41	3.5	4.4	4.6	4.9
42–46	3.1	4.2	4.2	4.3
Mean	3.7	4.9	4.8	4.9
Sum	144.5	190.0	187.3	190.6

E. Acquisition of Data and Control System

The lysimeter weighing system consisted of three load cells. The load cells had a sensitivity of 2m V/V. The maximum holding load for each group of load cells was about 500 kg, and its weighing precision was 20 g, which was precise enough for the correct measurements. The data obtained from the load cells were recorded by axcluma micro-sd card reader module, Model no (BE-000011) and it supported micro sd card and micro sdhc card (high-speed card). The level conversion circuit board that can interface the level 5 V or 3.3 V power supply was 4.5 V to 5.5 V. The 3.3 V voltage regulator circuit board communication interface is a standard spi interface with 4 m2 screw positioning holes for easy installation of the control interface. A total of six pins (gnd, vcc, miso, mosi, sck, cs), gnd to ground, vcc is the power supply, miso, mosi, sck is the spi bus, cs is the chip select signal pin 3.3 V regulator circuit: Ldo regulator output 3.3 V as level converter chip, micro sd card supply level conversion circuit. Figure 5a represents the Arduino display box fixed at the side wall of cultivation tank and Figure 5b represents the circuit diagram of sd card reader module, a component of arduino assembly. Figure 5c represents Chrysanthemum grown on a lysimeter

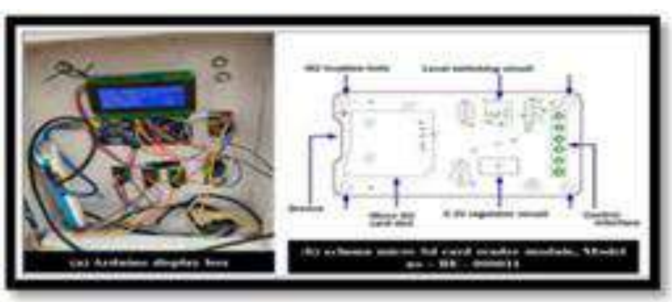

Fig. 5. (a) Arduino display box, (b) Sd card reader module

All components are controlled by arduino mega 2560, a microcontroller board based on atmega 2560. It has 54 digital I/O pins (of which 15 can be used as pwm outputs), 16 analog inputs, 4 uarts (hardware serial ports), a 16 MHz crystal oscillator, a usb connection, a power jack, an icsp header, and a reset button. Simply plug in a USB cord to a computer or power it with an AC-to-DC adapter or battery to get started. Most shields designed for the

Arduino duemilanove or diecimila are compatible with Mega. The updated version of aruduino mega is mega 2560.

RESULT:

This results section should reveal concise and precise explanations of the experimental results, their interpretation and more importantly, experimental conclusions that can be drawn.

A. Calibration Process for Lysimeters

Before installation of the lysimeter, a calibration routine of the lysimeter's loadcells was followed to confirm its proper functioning and accuracy. A combination of thirty-two known weights were placed one by one in the cultivation tank of the lysimeter, and corresponding output weights were recorded. The weight changes recorded by the loadcells were then examined and compared to the known weight changes. A regression equation has been developed to use this equation in the Arduino program for estimation of actual change in weight of lysimeter and results in accurate measurements from lysimeter. All loadcells accurately accounted for the change in weight for both increasing and decreasing cases. The description of the statistical analysis in the calibration process before installation of the lysimeter is shown in Table 3. The average error magnitude is shown by MAE and RMSE; however, they do not provide information on the average difference before and after calibration. The bias of the error is described by the MBE. However, its importance depends on the size of the data being examined. A negative MBE occurs when predictions are smaller in value than observations.

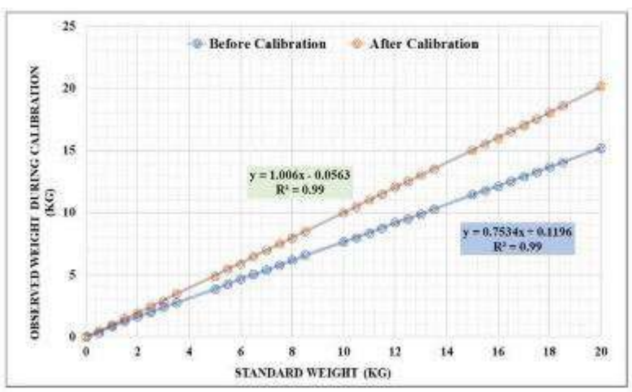

Fig. 6. Calibration results for the lysimeter before plantation of the Sugarcane crop.

Table. 2. Descriptions of statistical analysis in the calibration process of the lysimeter.

Statistical Indices	D	RMSE	RMAE	MBE	MSE	MAE	RE
Before Calibration	0.99	2.02	0.20	−1.33	4.18	1.33	0.10
After Calibration	1.00	0.04	0.02	0.00	0.00	0.02	0.00

Note: D—Index of Agreement. RMSE—Root Mean Squared Error, RMAE—Square Root of the Mean Absolute Error, MBE—Mean Bias Error, MSE—Mean Squared Error, MAE—Mean Absolute Error, RE—Relative Error.

B. Operation Results

Table. 3. Results for the water balance generated from the smart weighing lysimeter.

	Components	2022–2023					
		Water Film (mm)	Mass (g)	Difference In-O (g, mm)			
In	R	0	0	+8976 +8.9			
	I	153.9	153,961				

	Components	2022–2023		
		Water Film (mm)	Mass (g)	Difference In-O (g, mm)
	C	7.7	7698	
O	ET_c	152.6	152,683	
	D	0	0	

Note: In—Inputs, O—Outputs, R—Rainfall, I—Irrigation, C—Condensation, ET_c—Crop evapotranspiration, D—Drainage.

The factors involved in the irrigation process in the plant–water–soil system were determined using variations in weight. The water balance showed precise measurements of water losses throughout the entire crop season using a developed lysimeter (Table 4). The cultivation tank's weight increased due to irrigation, but it then fell as the crop began to take water, as expected. When the water first began to drain through the soil, the weight of the cultivation tank was reduced rapidly, followed by a gentler decline due to the water consumption by the crops. There was no scenario of precipitation events inside the greenhouse to increase the water content beyond the field capacity. Weight fluctuations were identified in the cultivation tank of the installed lysimeter. The results revealed that there was a slight increase at night, which may be due to condensation and diminished during the day. The hourly recorded weights of cultivation tanks inside greenhouses at different plant growth stages.

C. Crop Evapotranspiration (ETc)

The measured crop evapotranspiration (ET_c) obtained from the lysimeter and the reference evapotranspiration (ET_o) acquired from a pan evaporimeter installed inside the greenhouse for the chrysanthemum crop is described in . The values of ET_c and ET_o varied from a low of 1.70 and 1.84 mm/day during the vegetative stage to a high of 10.19 and 13.52 mm/day flowering stage. The average values of the ET_c were 1.19, 4.96 and 3.17 mm/day in the initial stage, mid-season stage, and late season stages, respectively. Similarly, the values of ET_o were 1.29 mm/day in the initial stage, 6.41 mm/day in the mid-season stage and 4.89 mm/day in the late season stages. Overall, the values of ET_c were somewhat close to the ET_o values. However, the values of ET_o were overestimated by 0.15 mm in 2022–2023 to the values of ET_c and are represented in

D. Soil moisture analysis

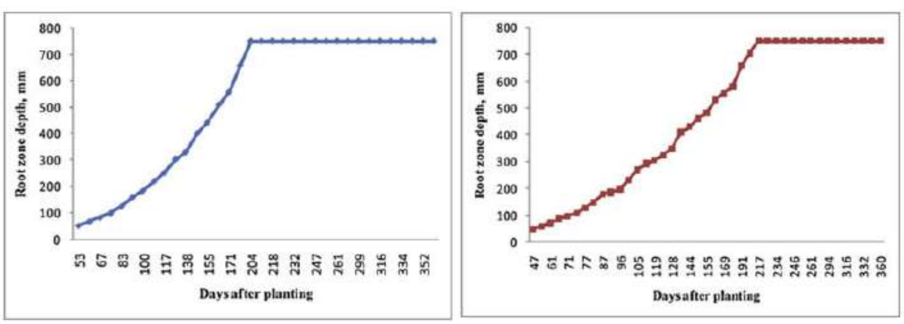

Fig. 7. Measured root zone depth (mm) of sugarcane during 2022 and 2023 season respectively.

The root zone depth at the time of transplanting was 50 mm at 53 and 47 DAP in 2022 and 2023, respectively (Fig. 8). During both the years, the root length of sugarcane increased linearly with advancement in age of crop. The rate of root length expedites at the end of tillering stage (115–125 DAP). Thereafter, effective root zone increased approximately up to 204 days and 217 days in 2022 and 2023, respectively and then root zone becomes constant at 750 mm and subsequent samples were taken up to 750 mm.

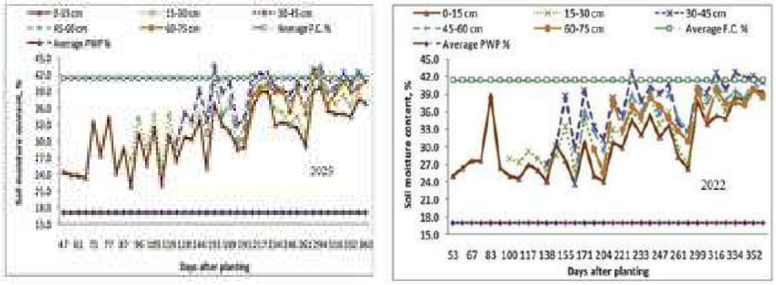

Fig. 8. Moisture content in the soil profile for sugarcane during the 2022 and 2023 growing seasons.

The soil moisture content increased with crop evapotranspiration during the growth period. The moisture content found increased with increase in soil layer depth upto 45 cm and thereafter it slightly decreased at 60 cm and lowest moisture content was observed at 75 cm depth (Fig. 9). During tillering stage, more soil moisture depletion was observed, however, when plant canopy fully developed after tillering, the soil moisture depletion was uniform in all layers. The particular growth stage and incident of rainfall greatly influenced the soil moisture content. Invariably of growth stages and barring rainfall events, the moisture content was closer to field capacity.

Table 4. Field water balance components (mm) during the growth stages for sugarcane observed at the experimental site in a subtropical climate, India.

Growth stage	Days	2021				2022				Average			
		I	Pe	ΔS	ETc	I	Pe	ΔS	ETc	I	Pe	ΔS	ETc
Initial	55	52.1	–	–	52.1	49.3	–	–	49.3	50.7	–	–	50.7
Tillering	75	211.3	53.2	2.8	267.3	277.6	0	−16.5	261.1	244.4	26.6	−6.9	264.2
Grand growth	170	799.4	243.8	−104.5	938.7	372.4	534.3	−72.2	834.5	585.9	389.1	−88.4	886.6
Maturity	65	110.5	16.2	2.0	128.7	109	0	37.1	146.1	109.8	8.1	19.6	137.4
Total	365	1173.3	313.2	−99.7	1386.8	808.3	534.3	−51.6	1291	990.8	423.8	−75.7	1338.9

Pe = Effective rainfall, I = Irrigation, ETc = Crop evapotranspiration (I + Pe + ΔS), ΔS = Soil moisture storage change.

The rainfall received during 2022 and 2023 was 313.2 mm (38 rainy days) and 534.3 mm (40 rainy days), respectively. In both the years all rainfall received was effective (Table 5). The occurrence of rainfall affected the depth of irrigation in different growth stages. In 2022, the effective rainfall was 43.6 % less than average rainfall (555 mm) therefore; more irrigation water applied in that season. However, in 2023, effective rainfall (534.3 mm) contributed almost 41 % of crop consumptive use and therefore demands of irrigation water reduced to half in 2023.

The total depths of water use during 2022, 2023 and average of two seasons were 1386.8 mm, 1291 mm and 1338.9 mm respectively (Table 5). The sugarcane evapotranspiration (ETc) varies considerably from place to place depending on weather conditions, texture of soil and duration of the crop. Numerous approaches have been used by different researchers to measure or estimate sugarcane evapotranspiration. Nevertheless, its estimate largely depends upon type of approach used by researchers.

Five-day moving means of daily ETo and ETc measured by the three lysimeters were similar during the first week of the experimental period (0 to 7 DAT), with means varying from 3 to 4 mm, which were lower than the measurements taken during the remaining period, due to lower leaf area, temperature, and solar radiation. After the second week, there was a detachment of ETc curves from ETo

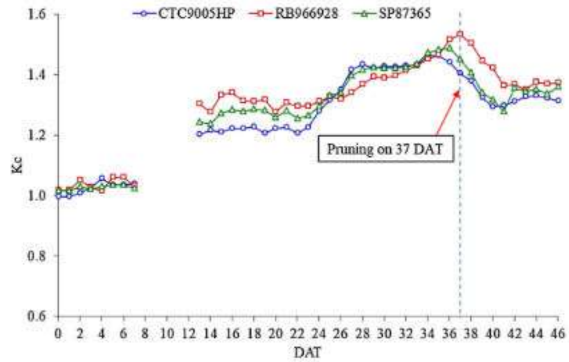

Fig. 9. Crop coefficient (Kc) for the cultivars CTC9005HP, RB966928, and SP87365 during the experimental period. DAT, days after transference

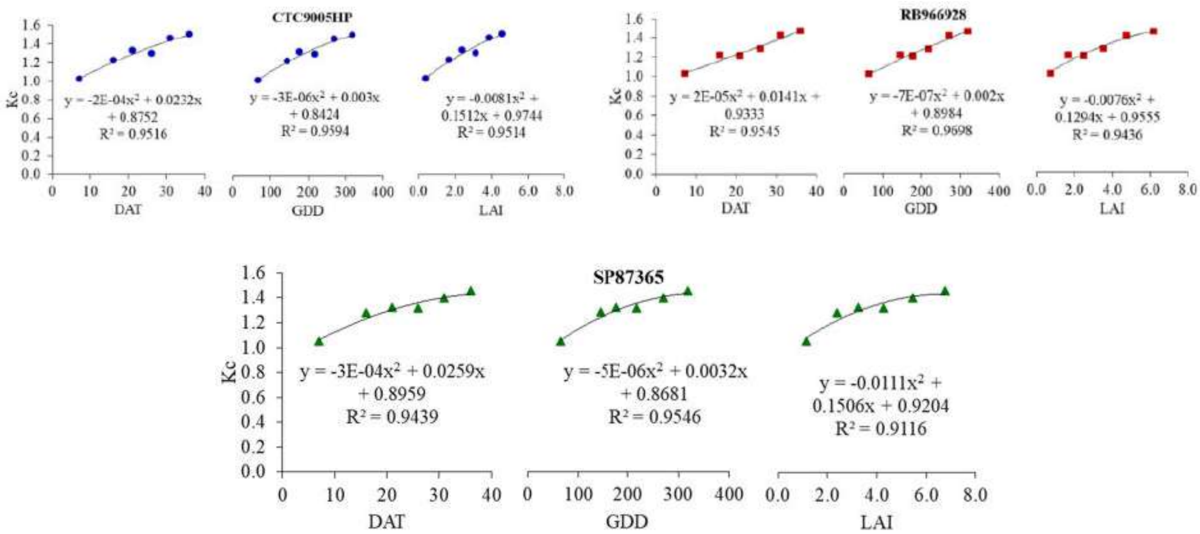

Fig. 10. Crop coefficient (Kc) for cultivars CTC9005HP, RB966928, and SP87365 as a function of days after transference (DAT), growing degree-days (GDD), and leaf area index (LAI).

Table 5. Evapo-Transpiration Estimation using Lysimeter

Date	Rainfall(mm)	Soil tank weight(kg)	Change in weight(kg)	ET(mm/day)	Remarks
28-june-2023	0.00	1862.5	0		Non rain day
29-june-2023	0.00	1851.3	11.2	11.2*0.6+0.0=6.70	
30-june-2023	5.20	1855.6	-4.3	(-4.3*0.6)+5.2=2.60	Rainy day
02-july-2023	0.00	1851.3	0		Non rain day
03-july-2023	12.00	1865.3	-14	(-14*0.6)+12=3.6	Rainy day

Table 6. ET/mm/day and Water Requirement of different crops.

S.No.	Crop	ET/mm/day
1	Rice	4.5-5.5
2	Wheat	4.41-5.86
3	Sugarcane	4.5-4.6

4	Ground Nut	-
5	Soybean	5-8.4

E. Crop coefficients of sugarcane

The Kc values with confidence bounds for both the years are shown graphically in the form of polynomial equation, with respect to the ratio of days to total crop period (Fig.12). The average Kc of two years ranged from 0.31 to 1.29 (Table 8). In both the seasons, Kc consistently increased from 0.43 to 1.03 during 50–130 days after planting (DAP). Thereafter, it showed gradual increases due to crop development in form of cane elongation (mid season stage). During the mid-season i.e. 130–300 DAP, Kc increased from 1.08 and then remain same in the range of 1.13-1.04 with peak value as 1.29. The highest Kc value occurred during 200–220 DAP. The Kc values during the late season (300–360 DAP) decreased gradually from 1.04 to 0.56. Thompson and Boyce (1971) in a lysimeter study observed that ETc rates declined by about 30 % after crops lodged, an effect that lasted upto crop maturity.

The two years average Kc values are represented in the form of following second order polynomial equation.

$$Kc_t = -4.695\left(\frac{t}{T}\right)^2 + 5.566\left(\frac{t}{T}\right) - 0.360$$

Average estimated crop coefficients (Kc) of sugarcane from best fit regression equations of 2022 and 2023 (Table:7) are estimated using the above Equation with regression analysis.

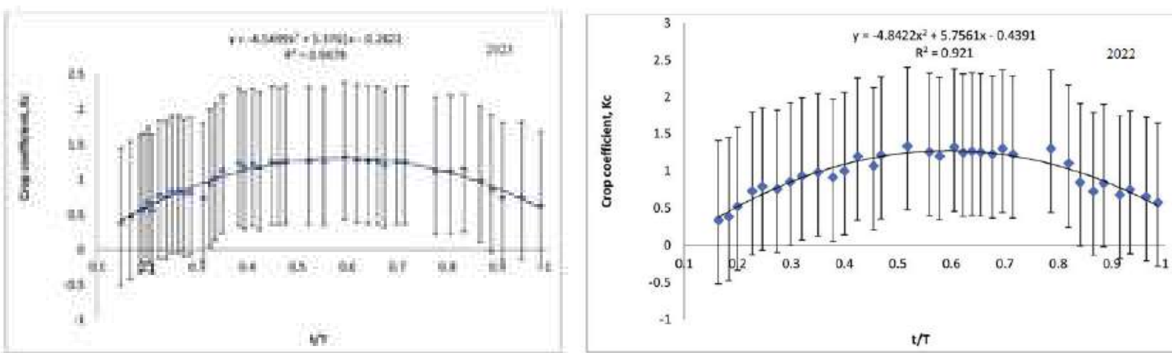

Fig. 11. (A) and (B) 2nd order polynomial crop coefficient curve for sugarcane crop during 2022 and 2023 season

Table 7. Average estimated crop coefficients (Kc) of sugarcane from best fit regression equations of 2022 and 2023.

S. No.	Period, days	Average estimated Kc	Growth stagewise Kc	FAO-56 Kc	Growth stagewise FAO Kc
1	0-40	0.40	-	0.4	-
2	40-50	0.31	-	0.55	-
3	50-60	0.43	0.70 (Tillering stage)	0.65	0.90 (Tillering stage)
4	60-70	0.53		0.75	
5	70-80	0.63		0.85	
6	80-90	0.73		0.95	
7	90-100	0.81		1.05	
8	100-110	0.89		1.15	
9	110-120	0.96		1.25	
10	120-130	1.03		1.25	
11	130-140	1.08	1.20 (Grand growth stage)	1.25	1.25 (Grand growth stage)
12	140-150	1.13		1.25	
13	150-160	1.18		1.25	
14	160-170	1.21		1.25	
15	170-180	1.24		1.25	
16	180-190	1.26		1.25	
17	190-200	1.28		1.25	
18	200-210	1.29		1.25	
19	210-220	1.29		1.25	
20	220-230	1.28		1.25	
21	230-240	1.27		1.25	
22	240-250	1.25		1.25	
23	250-260	1.22		1.25	
24	260-270	1.19		1.25	
25	270-280	1.15		1.25	
26	280-290	1.10		1.25	
27	290-300	1.04		1.25	0.98 (Maturity stage)
28	300-310	0.98	0.78 (Maturity stage)	1.17	
29	310-320	0.91		1.09	
30	320-330	0.83		1.02	
31	330-340	0.75		0.94	
32	340-350	0.66		0.86	
33	350-360	0.56		0.79	

F. Two days of the evaluation of the lysimeters on sugarcane crop.

On the two days of the evaluation of the lysimeters, two irrigation events occurred on 12/01/2022 (7:40 a.m. and 2:40 p.m.), as well as on 13/01/2023 (10:40 a.m. and 12:00 p.m.). These irrigation events promoted increase in the EM of the lysimeters, while ETc caused a decrease in EM of the lysimeters, especially at the time of higher atmospheric demand of the day (11:00 a.m. to 01:00 p.m.) (Figure12).

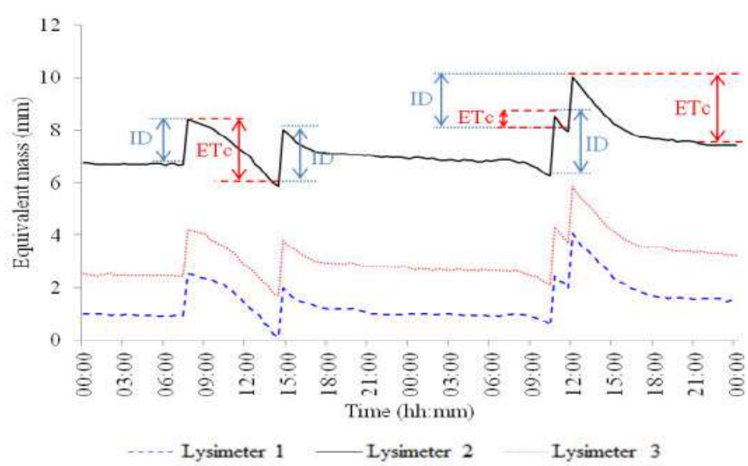

Fig. 12. Equivalent-mass (mm) registered by the three lysimeters during the test period, highlighting irrigation depths (ID) and crop evapotranspiration (ETc).

On the two days of the evaluation of the lysimeters, two irrigation events occurred on 10/03/2022 (7:40 a.m. and 2:40 p.m.), as well as on 10/02/2023 (10:40 a.m. and 12:00 p.m.). These irrigation events promoted increase in the

EM of the lysimeters, while ETc caused a decrease in EM of the lysimeters, especially at the time of higher atmospheric demand of the day (11:00 a.m. to 01:00 p.m.) (Figure 13).

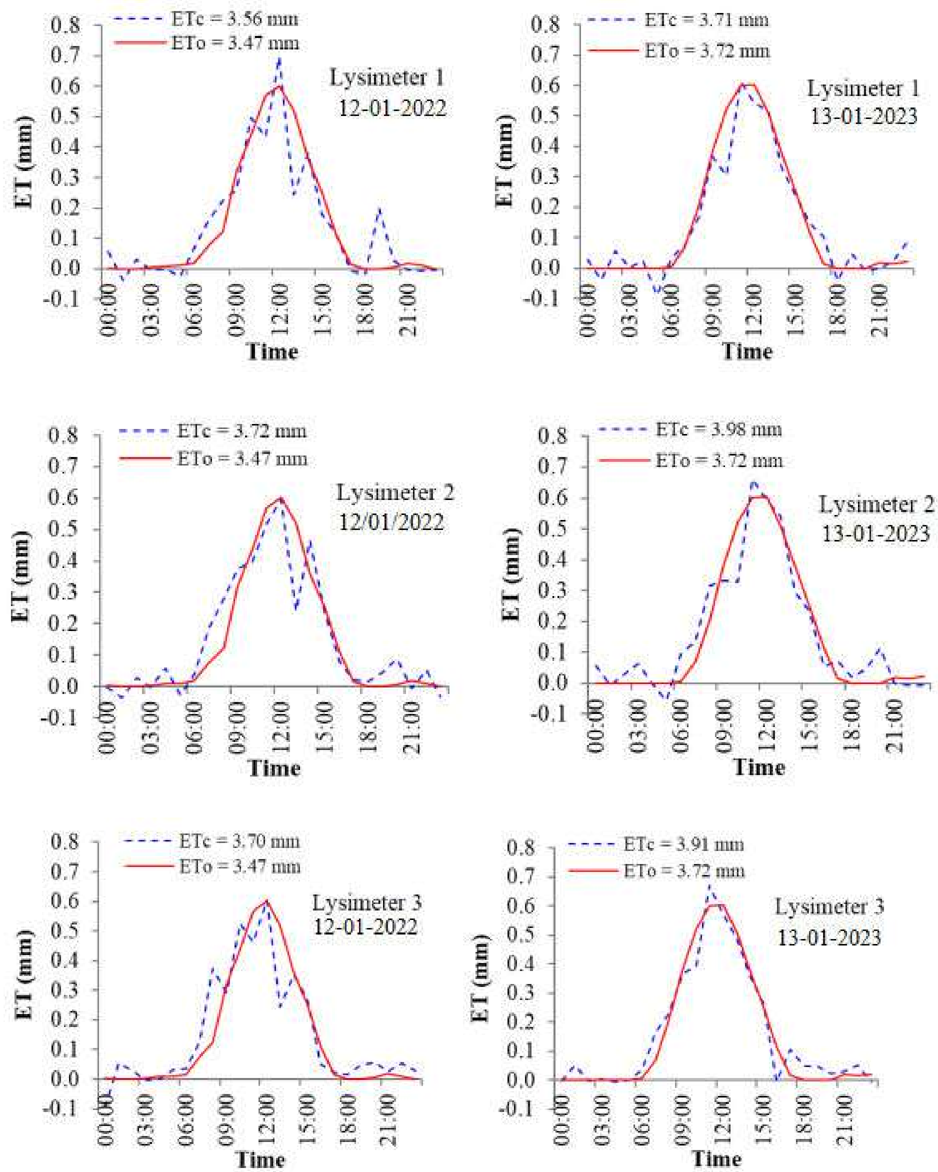

Fig. 13. Hourly values of crop evapotranspiration (ETc) compared to reference evapotranspiration (ETo – Penman Monteith) for the three lysimeters during test.

The ETc of the first day of test (12/01/2022) totalled 3.56 mm for Lysimeter 1, 3.72 mm for Lysimeter 2 and 3.70 mm for Lysimeter 3, presenting a variation of 0.16 mm between lysimeters. The ETo on this day, calculated by the Penman - Monteith method (Allen et al., 1998), generated a value of 3.47 mm. As for the second day of the test (13/01/2023), the ETc totalled a value of 3.71 mm for lysimeter 1, 3.98 mm for lysimeter 2 and 3.91 mm for lysimeter 3, generating a variation of 0. 27 mm between lysimeters, while the ETo on this day generated a value of 3.72 mm (Figure 14)

CONCLUSIONS:

Overall, the developed lysimeter performed satisfied and the weighing system provided reliable data that can be used to determine crop water requirements. The purpose of this work is to develop a convenient lysimeter and to improve the limitations of traditional lysimeters. The following key findings have been drawn from this work.

1. The developed weighing type lysimeter is cheap, lightweight, portable and has automation features.
2. The development of a temperature gradient at the lysimeter sides and edge is a cause for concern. However, since the growth of flowers in this region is done during the winter months in a greenhouse with relatively uniform temperatures under structure, it has no significant impact on the results of the crop grown in this lysimeter.
3. Water requirements of Sugarcane crop varies with climate, soil type and crop variety.
4. Irrigation decision support driven by timely and accurate estimation of actual ETc have the potential to reduce water consumption in irrigated Sugarcane, while simultaneously improving yield.
5. Sugarcane evapotranspiration ranged from 1.63 to 7.13 mm/day7.13 mm/day during the early and peak growth stages, respectively.
6. When compared to Food and Agricultural Organization (FAO) of the United Nations references, the sugarcane crop coefficients in this study were 2%, 1%, and 30% greater during emergence, grand formation, and ripening, respectively, but 33% lower at tillering.
7. The crop evapotranspiration of sugarcane was 1339.4 mm including irrigation water requirement and effective rainfall as 991 mm and 424 mm respectively. The determined sugarcane Kc values for tillering (development stage), grand growth (mid-season) and maturity stage (end season) was 0.70, 1.20 and 0.78, respectively.
8. The Kc values are 16.6 % lesser than those suggested by FAO-56 for sugarcane. The study pointed out that FAO-Kc could lead to over estimation in irrigation scheduling of sugarcane in semi-arid conditions and the use of Kc values developed in this study would lead in correction of water requirement.

REFERENCES

[1] Surendra Halasuru Jayaram., Darshan Hebballi Thippeswami., Gagan Boraiah Rajashekar., Likith Raj., Shreyas Gowda Estimation of Evapotranspiration for Onion Crop in Semi-Arid Region: Experimental Field Setup Using Lysimeter. Urban and Regional Planning. Vol. 3, No. 1, 2018, pp. 1-5. doi: 10.11648/j.urp.20180301.11

[2] JiaqiGao, Miao Qiao., XinfaQiu., Yan Zeng., HuanhuanHua., Xiuzhi Ye., and Mustapha Adamu., Estimation of Actual Evapotranspiration Distribution in the Huaihe River Upstream Basin Based on the Generalized Complementary Principle., Advances in Meteorology Volume 2018, Article ID 2158168, 9 pages

[3] KoffiDjaman., HosseinTabari., Alpha B. Balde., LamineDiop., Koichi Futakuchi., Analyses, calibration and validation of evapotranspiration models to predict grass-reference evapotranspiration in the Senegal river delta., Journal of Hydrology: Regional Studies 8 (2016) 82–94

[4] Jannis Groh., Jan Vanderborght., Thomas Pütz., Hans-Jörg Vogel., Ralf Gründling., Holger Rupp., Mehdi Rahmati., Michael Sommer., Responses of soil water storage and crop water use efficiency to changing climatic conditions: A lysimeter-based space-for-time approach., efficiency of changing conditions: A lysismeter-based space-for-time approach, hydrology and Earth System Sciences, 105197/hess-2019-411Preprint. Discussion started: 27 August 2019

[5] J. H. Abdulkareem 1., A. Abdulkadir and N. Abdul., A Review a different types of Lysimeter used in Solute TrasparentStudies International Journal of Plant & soil Science 8(3): 1-14, 2015; Article no. IJPSS. 18098 ISSN: 2320-7035.

[6] Fabio Ricardo Marin(1), Maria Leonor Lopes-Assad(2), Eduardo Delgado Assad(1), Carlos EdardoVian (3) and Marcelo Cabral Santos (3)., Sugarcane crop efficiency in two growing seasonsin Sao Paulo State, Brazil, Article in PesquisaAgropecuariaBrasieira. November 2008. Pesq- Agropee. Bras., Brasilia, v.43, n.11, p.1449-1455, Nov, 2008

[7] Amulya G V1, Chetan Kumar M2, Vanu Patil3, A Study on Crop Water Requirement for Sugarcane crop in BelavanurVillage, Davangere District, A Study on Crop Water Requirement for Sugarcane crop in BelavanurVillage, Davangere District, International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056, Volume: 07 Issue: 06 | June 2020 www.irjet.net p-ISSN: 2395-0072

[8] Ali Rashid Niaghi1*, Oveis Hassanijalilian1, Jalal Shiri2, Evaluation of Machine Learning Techniques for Daily Reference Evapotranspiration Estimation, Preprints 2019, 2019080097 (doi: 10.20944/preprints201908.0097.v1).

[9] Muhammad Adnan, Abaid-ur-Rehman, M. Ahsan Latif, Maria Nazir, Estimating Evapotranspiration using Machine Learning Techniques, (IJACSA) International Journal of Advanced Computer Science and Applications, Vol. 8, No. 9, 2017

[10] Lucas Borges Ferreira, Fernando Franca da Cunha, Multi-step ahead forecasting of daily reference evapotranspiration usingdeep learning, Department of Agricultural Engineering, Federal University of Viçosa, Av. Peter Henry Rolfs, s/n, CEP: 36570 000 Viçosa, MG, Brazil journal homepage: www.elsevier.com/locate/compag

[11] M. Alazarda,b,∗, C. Leduca, Y. Travic, G. Bouletd, A. Ben Saleme, Estimating evaporation in semi-arid areas facing data scarcity: Example of the El Haouareb dam (Merguellil catchment, Central Tunisia), Journal of Hydrology: Regional Studies 3 (2015) 265–284.