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Research Paper

Estimation of crop evapotranspiration and crop coefficient for coriander by using Portable Automatic Closed Canopy Chamber

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ABSTRACT

An experiment was carried out to determine crop evapotranspiration and crop coefficient of Coriander crop by using Portable Automatic Closed Canopy Chamber (PACCC), Micro-Lysimeter (MLs) and field water balance (FWB) methods. The results revealed that there was no significant difference in the coriander crop evapotranspiration measured by the MLs inside and outside the PACCC and no significant difference among the crop evapotranspiration measured by the PACCC, MLs and FWB at 95 percent confidence level was found. It is indicating that, there are no effects of the change in micro-climate for a short period of 2 minutes in the chamber and on the plant physiological processes. During validation of PACCC, the average crop coefficients measured by MLs were varied from 0.66 to 1.26 for coriander crop. However, the stage wise crop coefficients of corianders measured by FWB were varied from 0.67 to 1.28 during field testing of PACCC. The result showed that the PACCC can be used for measurement of crop evapotranspiration in the field condition.

Keywords: Coriander, Evapotranspiration, Crop coefficient, Portable Automatic closed canopy chamber, Micro-Lysimeter, Field Water Balance, Calibration.

Judicious irrigation scheduling besides other crop management practices plays a vital role in enhancing the water productivity in agriculture. Scheduling the time and quantity of irrigation water application is primarily governed by the crop evapotranspiration. Evapotranspiration (ET_c) is considered to be the dominant component of the hydrologic cycle due to the fact that about 60% of annual precipitation falling over the land surface is returned to atmosphere as ET_c (FAO. 2003). Actual evapotranspiration plays an important role on the eco-hydrological processes. (Rank *et al.,* 2023 a & b). The water resources in the study area are limited. The judicious use of water through irrigation water management can be the best option in the water scared region as out of 80% of available freshwater of India is used in agriculture (Government of Gujarat, 2023). Meteorological parameters have a significant impact on water dynamics within vegetation, affecting natural processes like evaporation, evapotranspiration, rainfall, and runoff. It is crucial to manage these processes effectively to enhance productivity and ensure the sustainability of water resource management. (Rank *et al.,*2023 a & b). With an ever-increasing population, the need to enhance productivity from limited resources becomes crucial. This can only be achieved through the implementation of various technological interventions in water management (Rank *et al.,* 2019).

The optimum irrigation water management requires empirical based knowledge on stage wise crop evapotranspiration. However, it is challenging task to calculate actual crop evapotranspiration due to scarcity of adequate information for applying energy balance model, complexity in ecosystem, uncertainty in input data (Ryken *et al.,* 2022). The cost and complexity of large lysimeter installations are often expensive, and micro-lysimeters are more suited to measurement of bare soil evaporation (Kumar and Rank, 2021). The water balance method is also difficult to apply successfully in some circumstances, particularly during wet periods where shallow water tables are present creating uncertainty about direction of water movement. A common strategy is to use a canopy chamber to sample the air. There are many categories of chamber design, such as leaf chambers for plant physiology studies and canopy chambers for field crop studies. One obstacle in the use of manual ET chambers is the difficulty in extrapolating point measurements in time and space. Long-term day or night time measurements

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using manual chambers are difficult because of the need to have an operator onsite. In order to overcome these problems, Automatic Closed Canopy Chamber was developed and validated for actual crop evapotranspiration measurement by Kumar and Rank (2021). In the present study, an attempt has been made to measure daily crop evapotranspiration and stage wise crop coefficients of coriander crop using Portable Automatic Closed Canopy Chamber developed by Kumar and Rank (2021) and compare that of by Micro-Lysimeter and Field Water balance methods.

MATERIALS AND METHOD

Study area

The experiment was conducted at the Instructional farm of College of Agricultural Engineering and Technology, Junagadh Agricultural University, Junagadh. It is located at 21.5º N latitude and 70.1º E longitude with an altitude of 82 m amsl. The climate of the study area is subtropical and semi-arid type with an average annual rainfall of 1000 mm and an average annual pan evaporation of 2344mm (6.41 mm/day) (Paswan *et al.,* 2020). The area is characterized by climatic condition of fairly cold and dry winter, hot and dry summer and warm and moderately humid during monsoon.

Portable automatic closed canopy chamber (PACCC)

The designed and developed portable ACCC and Micro lysimeters (MLs) by Kumar and Rank (2021) were used in the present study. The methodologies adopted by them for the calibration, validation and testing of ACCC and its comparison with micro-lysimeter and field water balance were used. The irrigation to coriander crop sown in the experimental field was applied through drip irrigation at 3 days interval as per the soil moisture depletions. The soil samples were taken before irrigation and at field capacity. The maximum effective root zone depth of coriander was taken as 20 cm. The Validation of portable ACCC was done as per the methodology described by Kumar and Rank (2021). The validation of automatic closed canopy chamber is shown in Fig. 1. Portable ACCC was placed in different plots having coriander crops once in two weeks. The chamber was placed in such a way that crops inside the chamber should not disturb. The evapotranspiration of field crops was measured under closed condition of chamber for 2 minutes by automatic closed canopy chamber. The measurement of evapotranspiration of field crops in the Portable ACCC is shown in Fig. 2.

Portable ACCC was placed in different plots having coriander crops once in two weeks. The evapotranspiration of field crops was measured under closed condition of chamber for 2 minutes. The ET_c rate was estimated using the logged data of increasing rate of humidity and temperature sensed by the humidly and temperature sensor respectively inside the chamber as described by (Stannard, 1988, Kumar and Rank, 2021).

$$ET_c=86.4\ \frac{MVC}{A}F_a;\ F_a=\frac{SSA_c\ x\ PD}{N_{pc}} \tag{1}$$

Where, ET = Evapotranspiration rate (mm/day), M = Maximum slope of water vapour density time series (g/m^3 s), V = Volume of chamber, (m^3), C = Calibration factor of the chamber (unitless), A = Land surface area covered by the chamber (m^2), 86.4 is a factor that converts g/m^3 s to mm/day using the density of water, and F_a is an area correction factor, SSA_c is the soil surface area (sq. cm) in the field covered under PACCC, PD is the plant density in the field (crop plants per sq.cm.) and N_{pc} is the number of plants covered under the ACCC.

ET_c measurements by PACCC and micro-lysimeters

The PACCC was put on tray having 4 micro-lysimeters. The ET values were estimated using data of water vapour flux measured and recorded by the temperature – RH sensor were compared with the ET values measured through micro-lysimeters and the performance was analysed. Two sets of 4 micro-lysimeters were used for estimating the crop evapotranspiration of coriander, one set inside the PACCC and another set outside it to have continuous exposure of open atmosphere. The input of irrigation was kept similar in both the sets. Using the water balance of each micro-lysimeter, the coriander ET_c was measured for both sets. The weight of soil filled lysimeter was recorded before irrigation and after 24 hours of irrigation. The weight loss of soil filled micro-lysimeter was considered as crop evapotranspiration. The irrigation water was applied at 3 days interval. The coriander crop evapotranspiration measured by micro-lysimeters is shown in Fig. 3.

The crop evapotranspiration was calculated using Eq.2. The ET_c measured by automatic closed canopy chamber was compared with that obtained by the water balance in micro-lysimeters.

$$ET_C=I+R-\frac{dw}{A}+\frac{(W_1-W_2)}{A} \tag{2}$$

Where, ET_c = Crop evapotranspiration (mm), I = Irrigation input to micro-lysimeters (mm), R = Rainfall input to micro-lysimeters (mm), dw = Amount of water drained is assumed to be zero (lit.), W_1 & W_2 = Initial and final weight of micro-lysimeters at required intervals (kg) and A = Cross sectional area of micro-lysimeters (m^2).

ET_c measurements by field water balance method

The field water balance method uses soil moisture, precipitation, irrigation and drainage data to estimate crop ET. The soil water content in the field plot was measured by gravimetric method. Soil samples were taken at different depths according in field. Soil water storage in the root zone was computed. The water was given in precise amount to prevent drainage. The ET_c of crop was estimated by water balance method using eq. (3).

$$ET_C=I+P-\frac{R}{A}-D+(\theta_1-\theta_2)\times Z\times 1000 \tag{3}$$

Where, I = Irrigation application (mm), P = Precipitation (mm), D = Drainage is assumed to be zero (mm), R = Surface runoff is assumed to be zero (liter), $(\theta_1-\theta_2)$ = Change in volumetric soil moisture content between irrigations infractions and Z = Root zone depth (m).

Crop coefficient

Fundamentally, the crop coefficient is defined as the ratio of crop ET (ET_c) to some reference ET (ET_r) as defined by weather data. The daily reference evapotranspiration (ET_r) during the experimental period was determined using Penman-Monteith approach following the methodology suggested by Allen *et al.,* (1998) in FAO 56.

Table 1: The statistical comparison of coriander ET_c measured by different methods

SN	ET_c measured by	Statistical measures						
		Mean	Variance	N	HPD	ndf	$T_{cal.}$	$T_{tab.}$
1	MLs inside the PACCC	3.14	0.98	8	0	14	0.26	2.14
	MLs in open atmosphere	3.00	1.34	8				
2	PACCC	2.65	0.68	8	0	14	1.08	2.14
	MLs	3.14	0.99	8				
3	PACCC	3.33	1.48	8	0	14	0.27	2.14
	FWB	3.50	1.58	8				

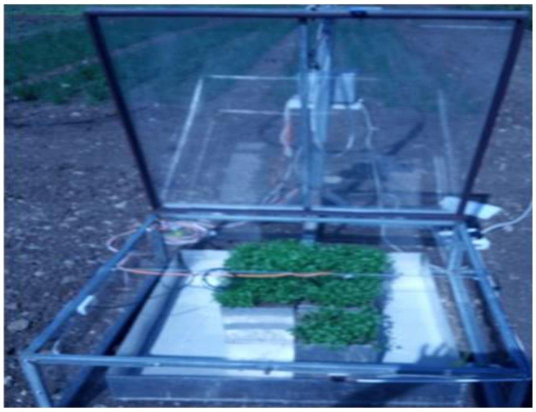

Fig. 1: Validation of PACCC

Fig. 2: Measurement of coriander ET_c in field by PACCC

Fig. 3: ETc measurements by micro-lysimeters

Statistical analysis

A two-sample t test was used to compare the 2 sets of data to check whether they are significantly different or not (Panse and Sukhatme, 1967).

RESULTS AND DISCUSSION

The calibration of automatic closed canopy chamber was done by evaporating a known mass of water after placing the chamber over the water to determine evaporation rate based on temperature and relative humidity measurement. The slope of best fit line of actual evaporation from pan inside the PACCC and evaporation measured by PACCC was taken as the calibration factor (1.66).

Validation of the automatic closed canopy chamber (PACCC)

Two sets of 4 micro-lysimeters were used for estimating the crop evapotranspiration of coriander, one set inside the PACCC and another set outside it to have continuous exposure of open atmosphere. The input of irrigation was kept similar in both the sets. Using the water balance of each micro-lysimeter, the coriander ET_c was measured for both sets. From Result, no significant effect of change in micro-climate for short period in chamber on plant physiology was noticed. The ET_c by micro-lysimeter inside the PACCC and open atmosphere were recorded for statistical comparison. Statistical analysis of ET_c by micro-lysimeter inside the ACCC and open atmosphere was carried out to check whether these two values are statistical at par or not (Table 2). The Table 2 showed that there are non-significance difference between ET_c by MLs inside the PACCC and open atmosphere at 5% significant level. It indicated that the change in micro-climate inside the ACCC did not affect the plant growth physiological process

Comparison of ET_c by micro-lysimeters and field water balance (FWB) method

The present investigation was carried out in Rabi Season (7 December 2019 to 30 March 2020). The coriander crop was sown in MLs as well as in field plots. The field water balance method

Table 2: Crop evapotranspiration (mm/day) measured by PACCC, MLs and FWB for coriander crop

Date	ET_c by ACCC	ET_c by MLs	ET_c by FWB
22-Dec-19	2.0	2.1	1.74
18-Jan-20	3.6	4.12	3.78
24-Jan-20	2.4	3.2	3.4
20-Feb-20	3.6	3.93	3.74
26-Feb-20	3.0	3.6	3.76

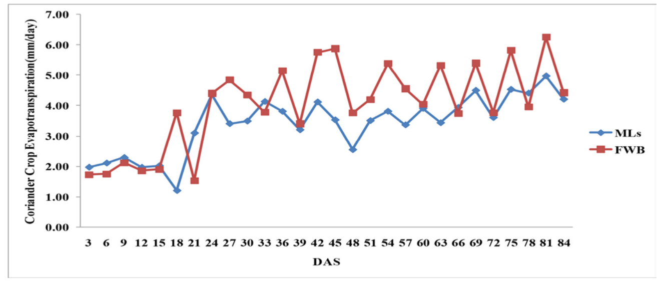

Fig. 4: Coriander ETc by MLs and FWB

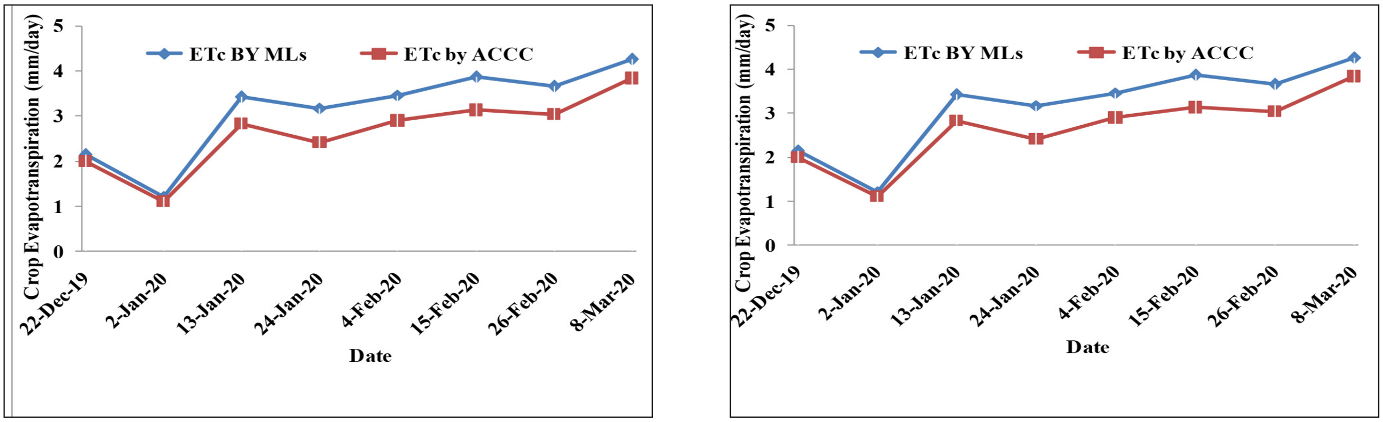

Fig. 5: Comparison of coriander ET_c by PACCC and MLs

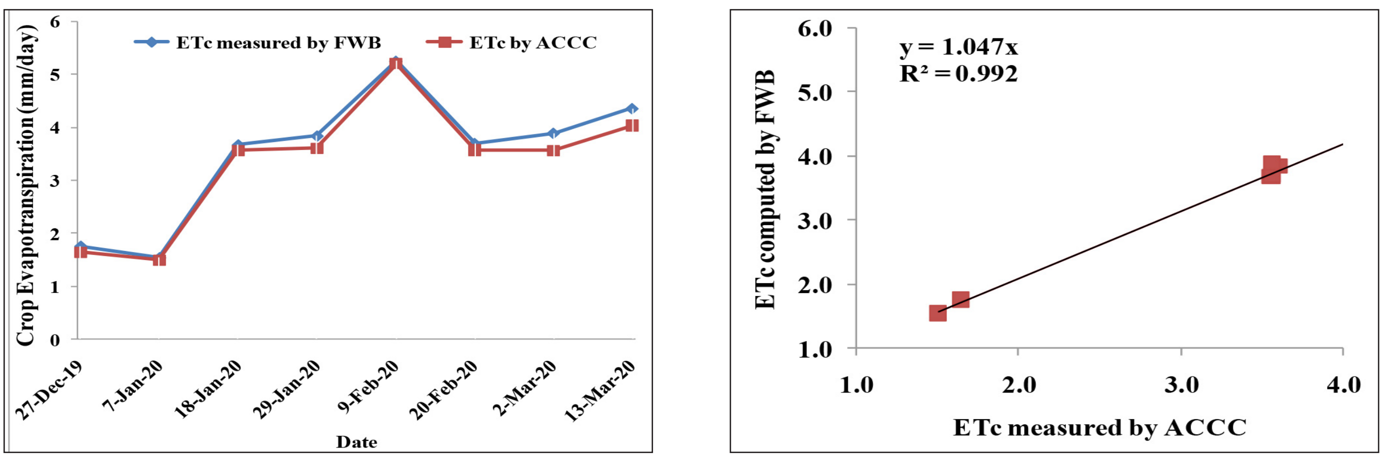

Fig. 6: Comparison of coriander ET_c by PACCC and FWB

was adopted to measure the ET_c. The drainage was also considered as zero because precise amount of water was applied inside the MLs as well as field plots. Fig. 4 shows pattern of variation of coriander crop ET_c measured by MLs and FWB with respect to days after sowing. ET_C measured by MLs and FWB ranged from 1.20 to 4.96 mm/day and 1.53 to 6.25 mm/day, respectively. No significant variation was found in coriander crop ET_c measured by MLs and FWB from sowing to 15 DAS. This implies that least leaf area index was observed due to presence of less than 10% of vegetation which reduces the ET_c. In development stage, coriander plant reaches from 10% of vegetation to flowering stage. ET_c increased rapidly in development period due to more leaf area index than initial stage. Peak value of coriander crop ET_c was found in mid-season stage. This implies that crop is under flowering stage to yielding stage which requires maximum water. Peak ET_c measured by MLs and FWB reached at 81 DAS and then decline following the general decrease in evaporative demand as the season advanced.

Comparison of coriander ET_c measured by PACCC in field and MLs

The coriander ET_c measured by PACCC in the field at 11 days interval and its comparison with that of MLs is shown in Fig. 5. It can be seen that MLs slightly overestimates ET_c throughout the crop period. In fact, the maximum difference between the coriander ET_c measured by MLs and PACCC was only 0.74 mm/day. The similar results were found by Kumar and Rank (2021) for the fenugreek crop also. It confirms that PACCC can be used to estimate crop ET_c reasonably under field condition. The ET_c of coriander crop measured by PACCC and MLs was statistically analyzed and non-significant result was found (Table 1). Hence, the data of ET_c computed by MLs and that of PACCC are matching with each other without any significant differences.

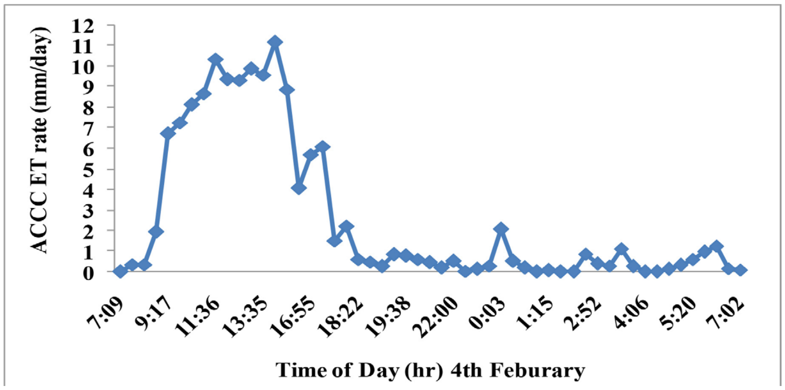

Fig 7: Diurnal variation of coriander ET_c rate on 4th February 2020

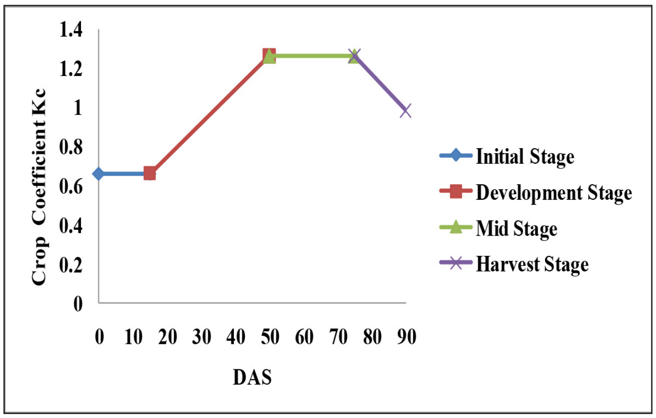

Fig. 8: The seasonal variation of coriander K_c by MLs under validation of PACCC

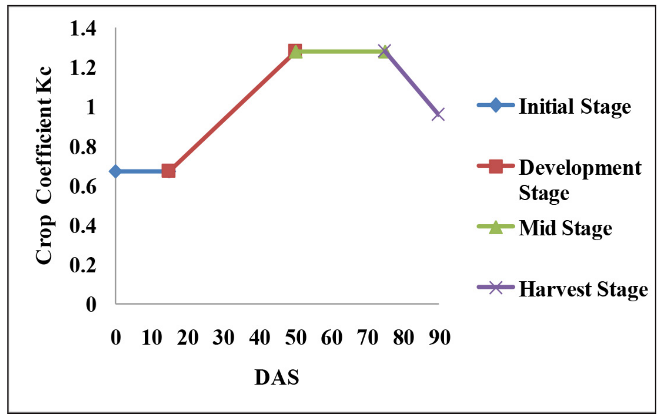

Fig. 9: The seasonal variation of coriander K_c by FWB under field testing of PACCC

Comparison of coriander ET_c by PACCC and FWB

Comparison of coriander crop evapotranspiration measured by PACCC and FWB during Rabi season is represented in Fig. 6. It can be seen that FWB overestimates ET_c throughout the crop period. This may be due to unsaturated flow below root zone. However, the maximum difference between coriander ET_c measured by FWB and PACCC was 0.4 mm/day which was somewhat less than 0.9 mm/day found by McLeod *et al.*, (2004) for pasture. From Fig. 6, it can be seen that coriander ET_c measured by PACCC and FWB is reasonably agreed with each other during Rabi Season. The crop evapotranspiration measured by PACCC matched well with crop evapotranspiration measured by FWB during entire growth period of crop. In fact, the FWB method overestimate coriander ET_c by 4.7% as compared to that of by PACCC. Similar study has been conducted by Luo (2018) and found that the difference between ET_c measured by FAB and chamber method were within 10%. McLeod *et al.*, (2004) also observed a reasonable agreement between crop evapotranspiration measured by FWB and canopy chamber method. The coriander ET_c measured by PACCC and FWB were statistically analyzed and found non-significance difference at 5% significant level. However, the difference in mean coriander crop evapotranspiration measured by FWB and PACCC was 0.16.

Diurnal variation of coriander ET_c by PACCC

The diurnal variation of coriander crop evapotranspiration rate under validation of PACCC is shown in Fig. 7. It is revealed that the ET_c rate of coriander increases as sun rises and reaches the peak at 14:09 hrs and then continuously decreases with time. The ET_c rates were found constant during the night time indicating the major contribution of soil evaporation component. It was found that during night time, ET_c was very less as compared to that of day time. This is consistent with the previous study with the enclosed portable chamber (Stannard, 1988). Some times during night, ET_c measured by PACCC during had significant proportion of daily ET_c. It may be due to heat released when the earth surface is cooling and interpreted it as available energy for ET_c and would continuously predict appreciable ET_c rates.

Crop coefficient (K_c) measured by MLs under validation of PACCC

The coriander growing periods were divided into initial, developing, middle and late growing stages (Fig. 8). The initial stage was from seedling until 10% of plant growth (0 to 15 DAS). The developing stage was from 10% of the growing period to flowering stage (15 to 50 DAS). The middle period began with the flowering stage and ran to the yielding stage (50 to 75 DAS). The final late stage ran from the yielding period to the harvest period (75 DAS and onwards). During the initial, middle and late growth stages, the K_c of coriander were determined as 0.66, 1.26 and 0.98 respectively. Similar results were found by Ghamarnia *et al.,* (2013). They determined the actual seasonal ET_c as 647mm and K_c as 0.66, 1.19, 1.36, 0.98 for the initial, developing, middle and final stages of coriander crop respectively

Crop coefficient (K_c) measured by FWB under field testing of PACCC

The seasonal variation of coriander K_c by FWB under field testing of PACCC is shown in Fig. 9.The average K_c of coriander crop during the initial, mid and late stages was found as 0.67, 1.28 and 0.96 respectively..

The coriander crop ET_c measured by all three methods on common days are depicted in Table 2. It can be seen that PACCC slightly underestimated ET_c as compared to MLs and FWB method throughout the crop period. The reason might be the accumulated humidity during the closing period of PACCC. However, the maximum difference between the coriander ET_c measured by MLs and PACCC was only 0.74 mm/day while the maximum difference between the coriander ET_c measured by FWB and PACCC was only 0.4 mm/day. Initially, no significant variation was found in coriander crop ET_c measured by MLs and FWB due to lower vegetation canopy in field but after 15 DAS, FWB slightly overestimated ET_c throughout the crop period as compared to ET_C measured by MLs. The reason might be the uptakes of residual soil moisture in deeper soil profiles.

CONCLUSIONS

The developed PACCC is portable as well as more convenient, cost effective and reasonably accurate as compared to the lysimeter to measure the actual ET_c and K_c. The corianders ET_c measured by MLs inside and outside the PACCC were found reasonably comparable indicating no effects of changes in micro-climate for short span of time on the plant growth processes. The average K_c measured by MLs under validation of PACCC were found as 0.66, 1.26 and 0.98 and measured by FWB under field testing of PACCC were found as 0.67, 1.28 and 0.96 during the initial, mid and late stages, respectively. The actual crop evapotranspiration can be taken as 1.185 times the ET_c measured by PACCC.

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Authors Contribution: **D. Kumar**: Conceptualization, Methodology, Analysis, Writing-original draft and Review; **P.H. Rank**: Reviewing and Editing.

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