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Estimation of evapotranspiration under polyhouse and open field conditions in capsicum

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ABSTRACT

A field experiment was conducted at Agricultural Engineering College and Research Institute, Kumulur, Tamil Nadu, to estimate crop evapotranspiration and crop coefficient of capsicum under polyhouse and open field conditions for two consecutive seasons during 2019. Microclimatic parameters like maximum and minimum temperature (ºC), relative humidity (%) and light intensity (lux) were recorded during the study. EM 50 soil moisture sensors were used to observe the soil moisture status for the entire crop growth period. The actual crop evapotranspiration was worked out using the standard soil water balance equation. The crop coefficient for capsicum was estimated for different crop growth stages. During the winter season, crop coefficients for initial, developmental, middle and end stages were 0.49, 0.76, 0.98 and 0.88, respectively, for the crop grown inside polyhouse, and the same were 0.59, 0.77, 1.02, 0.90, respectively, for the crop grown outside condition. The water use efficiency of capsicum under drip irrigation was calculated as 56 Kg/ha.mm during the summer season and 66.7 kg/ha.mm during the winter season. Similarly, the water use efficiency of 11.7 kg/ha.mm and 17.6 kg/ha.mm during summer and winter seasons, respectively, in open field conditions.

Keywords: *Capsicum annuum* L., Crop coefficient, Evapotranspiration, Water use efficiency, Polyhouse.

INTRODUCTION

India is one of the largest producer of capsicum crop after china, Mexico and Indonesia. Controlled environment with proper irrigation facility ensure good growth of capsicum under protected cultivation. Meager studies are available to determine crop water requirement of capsicum under protected environment. Depth of irrigation of 0.5 cm gave higher yield of capsicum grown inside greenhouse compared to 0.25 cm depth of irrigation (Kumar *et al.,* 11).

A yield of 4300 was obtained at 1.0 ET_c compared to the yield of 3800 kg/ha obtained at 0.75 ET_c in capsicum crop (variety Indra) with the seasonal water consumption of around 420 mm (Raju *et al.,* 15). For getting good yield and quality of the produce, the study of micro climatic parameters inside polyhouse is necessary. Crop variety, season of sowing and method of cultivation affected microclimatic parameters inside greenhouse there by crop water uptake (Harmanto *et al.,* 9). Proper application of fertilizers will increase the yield and quality of capsicum. Different application rates of nitrogen and potassium fertilizers influenced yield of sweet pepper under naturally ventilated greenhouse. The application of 25% increased nitrogen fertilizers increased the yield considerably (Nijamudeen *et al.*, 13). Soil moisture sensors are very much useful to estimate in-situ volumetric soil moisture content. Three types of soil moisture sensors were installed at different depth in corn field and the importance of soil moisture sensors were validated to determine the irrigation scheduling (Aguilar *et al.*, 1) used.

Soil moisture based irrigation resulted in more stable soil moisture condition in the root zone thus reduced the number of unnecessary irrigation events in vegetable cultivation (Dukes *et al.*, 7).

To determine water requirement of capsicum the potential and actual evapotranspiration needs to be calculated. Penman Monteith method is the most consistent method to calculate potential evapotranspiration and crop coefficient (Kashyap and Panda, 10). Drip irrigation levels with 100% irrigation requirement throughout the crop period consumed 415 mm of water in capsicum crop Singh (16). The crop evapotranspiration ($mmday^{-1}$) value of green chilli was 2.2, 3.1, 3.2, 1.4 in polyhouse and 2.6, 3.5, 3.6, 1.6 in open field condition for the initial, developmental, middle and end season stages respectively (Aiswarya *et al.*, 3). The distribution and concentration of applied fertilizers depend on the distribution of moisture content from the emitter in sweet pepper (*Capsicum annuum* L.) (Nijamudeen *et al.*, 14). Based on crop physiological parameters the crop coefficient will be varying from plant to plant. Crop coefficient values need be derived to calculate

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irrigation requirement of all the crops. Crop coefficient values of rose under greenhouse was developed based on soil water balance method ranged from 0.48 to 0.96 in open field condition and 0.59 to 1.01 in polyhouse condition (Singh *et al.*, 17).

Capsicum requires good growing environment to produce better quality of crops (Thuy and Kenj, 19). As the open field condition does not encourage the better production of capsicum crop, the ultimate better choice is to raise the crop under polyhouse. Polyhouse is being utilized to grow flowers, vegetables, and fruits throughout the year as it protects the crops from wind, precipitation and solar radiation, dry humidity etc. It creates a favorable microclimate for the crop that results in higher yield and good quality Capsicum fruits. The cultivation of capsicum crop is meagre in Trichy district, Tamil Nadu, India as the climate is not suitable for its cultivation. Hence a study was carried out to raise capsicum under polyhouse equipped with foggers and soil moisture sensors as well as in open field condition. As the demand of water has been increasing day by day, the available water should be used judicially especially for crop cultivation. Hence, the estimation of exact quantity of water required for the crop is very much necessary. Estimation of crop water requirement based on meteorological parameter alone would not be accurate in all the places as the soil conditions are different. Hence, there should be a combined approach by considering weather parameters, soil moisture status, crop growth stages to estimate crop coefficient for the given crop. Since there is no published K_c value of Capsicum for semi-arid region, hence the study was conducted to estimate crop coefficient of drip irrigated Capsicum under poly house and open field condition in Kumulur, Trichy, Tamil Nadu, India.

MATERIALS AND METHODS

The experimental site is geographically situated at 10.93°N latitude and 78.84°E longitudes at an altitude of 57 m above mean sea level. Field experiment was conducted at Central Farm of Agricultural Engineering College and Research Institute, Tamil Nadu Agricultural University, Kumulur, Tamil Nadu during 2019 to estimate the crop evapotranspiration of drip irrigated Capsicum under open field and polyhouse conditions for summer and winter seasons. Capsicum crop was raised with the crop geometry of 60 cm × 45 cm under polyhouse equipped with foggers. The average maximum and minimum temperatures in polyhouse and open field were 37.3°C, 26.9°C and 35°C, 25°C. In the open field, the average maximum relative humidity was 62% and minimum relative humidity was 41%. The average maximum and minimum relative humidity was observed as 80% and 65%, respectively in polyhouse (Table 1). Capsicum requires day time temperature ranges from 25°C to 30°C (Thuy and Kenj, 19). Whenever the temperature exceeds inside polyhouse, foggers were operated to maintain the temperature and relative humidity.

The physical properties of soil like particle size distribution, textural class, bulk density, and chemical properties like soil pH, electrical conductivity, available nitrogen, phosphorus, potassium, calcium and magnesium were estimated. The texture of the soil was found as sandy loam consists of sand, silt and clay percentage as 68.4, 20.3, and 10.5, respectively by international pipette method. The soil pH was 7.9 and electrical conductivity was 0.35 dS/m assessed by pH meter and EC meter. The soil physical and chemical properties are given in Table 2.

The soil was well pulverized and raised beds were prepared. The laterals were laid with the on-line drippers of 4 lph capacity at an interval of 0.45 m. For the estimation of uniformity distribution of 4 lph emitter, the variation discharge formula (Christiansen, 6) was used and the value obtained was 93%. The microclimatic parameters like maximum temperature (ºC), minimum temperature (ºC), relative humidity (%) and light intensity (lux) in polyhouse and open field were observed daily by using thermometer, hygrometer and lux meter.

Table 1. Climatic parameters during study period.

Climatic parameters	Polyhouse	Open field
Average maximum temperature	37.3°C	35°C
Average minimum temperature	26.9°C	25°C
Average relative humidity	80%	65%
Average light intensity	26309.7 lux	50155.8 lux

Table 2. Soil physical and chemical properties.

Soil properties	Values
Sand	68.4%
Silt	20.3%
Clay	10.5%
Textural class	Sandy loam
Bulk density	1.32 $g.cm^{-3}$
Soil pH	7.9
Electrical conductivity	0.35 dS/m
Availalble Nitrogen	156 $kg.ha^{-1}$
Available Phosphorus	21 $kg.ha^{-1}$
Available potassium	115 $kg.ha^{-1}$
Available calcium	24 $g.kg^{-1}$
Available magnesium	45.6 $g.kg^{-1}$

Capsicum variety NS 292 and Indra were taken for trials. Seedlings were transplanted with the spacing of 0.60 m0.45 m. The Bell pepper seedlings were raised during summer and winter seasons. The reference evapotranspiration (ET_o) was calculated by the standard method of FAO Penman–Monteith method (Allen, 4) from the meteorological data. Three EM 50 soil moisture sensors probe were installed at the crop effective root zone depth (20-30 cm depth) and connected to the data logger at different places. Soil moisture in the crop root zone was observed continuously at every five minutes interval by EM 50 soil moisture sensor and the data were recorded automatically in the data logger. Calculation of the time of operation of drip irrigation system is essential to derive the amount of irrigation water to be given for proper irrigation scheduling. The time of operation of drip irrigation system was calculated by multiplying crop spacing, percentage wetted area, crop coefficient and dividing by dripper discharge. The amount of water depleted by the crop was arrived in terms of the volumetric moisture content from the EM 50 soil moisture sensor. The actual crop evapotranspiration was estimated by soil water balance method formula (Singh, 17)

$$ET_c = P + I - R - D \pm \Delta W$$

Where,

ET_c = Crop evapotranspiration (mm), P= Precipitation (mm), I=Irrigation water depth (mm), R = Surface runoff (mm), D= Amount of water drained from the root zone (mm), ΔW= Change in soil water storage (mm). For providing the exact amount of water to the crops, the surface runoff and amount of water drained from root zone was assumed as zero. The precipitation was taken as zero inside the polyhouse. Hence, the change in soil moisture content was taken as the actual crop evapotranspiration of Capsicum. The FAO Penman Monteith equation is given as,

$$ET_o = \frac{0.408\Delta(R_n - G) + \gamma \frac{900}{T_{mean} + 273} u_2 (e_s - e_a)}{\Delta + \gamma(1 + 0.34u_2)}$$

Where, ET_0 = reference evapotranspiration (mm day^{-1}), R_n = net radiation at the surface of the plant (MJ m^{-2} day^{-1}), G = heat flux density of soil (MJ m^{-2} day^{-1}), T_{mean} = mean daily air temperature at the height of 2m (°C), U_2 = wind speed at the height of 2m (m s^{-1}), e_s = saturation vapor pressure (kPa), e_a = actual vapor pressure (kPa), e_s- e_a = saturation vapor pressure deficit (kPa), Δ = slope vapor pressure curve (kPa °C^{-1}), γ = psychrometric constant (kPa °C^{-1}).

Crop coefficient is very important parameter which decides the efficient irrigation water management as it considers the physiological parameter of crop growth. The crop coefficient of Capsicum crop was estimated by the following equation (Allen, 4)

$$K_c = \frac{ET_c}{ET_o}$$

Where,

K_c = Crop coefficient; ET_c = Crop evapotranspiration (mm) and ET_o = Reference crop evapotranspiration (mm)

The moisture distribution pattern was also studied in sandy loam soil of the experimental field under drip irrigation. Soil samples were collected from the depth of 10 cm, 20 cm and 30 cm to the horizontal distance of 0-15 cm, 15-30 cm and 30-45 cm away from the emitter respectively. Growth and yield parameters of Capsicum were observed in both polyhouse and open field conditions for both summer and winter seasons. The yield per plant was recorded at each harvest and the total yield in both polyhouse and open field conditions were calculated. The water use efficiency was calculated by dividing the yield (Kg.ha^{-1}) with the water used (mm) in the season.

RESULTS AND DISCUSSION

Minimum and maximum temperature was found more inside polyhouse when compared to open field condition. Around 2 to 3°C increased temperature was observed inside polyhouse throughout the year (Fig. 1). Maximum temperature was recorded during summer season i.e. April to May compared to winter season October to December in both inside and outside polyhouse. The lowest temperature was recorded during December and January inside and outside polyhouse, respectively.

The relative humidity was found maximum inside polyhouse when compared to open field (Fig. 2). This was due to confined environment of polyhouse with crops. 2 to 12% difference of relative humidity was observed throughout the year.

Light intensity was found minimum inside polyhouse. Around 24 to 63% increase in light intensity was recorded in open field condition throughout the year (Fig. 3). Similar, result was reported by Aikman (2) that Irradiation between canopy was uniform under low light intensity which was favourable for maximum photosynthesis activity. Similar study was reported by MintuJob (12) that air

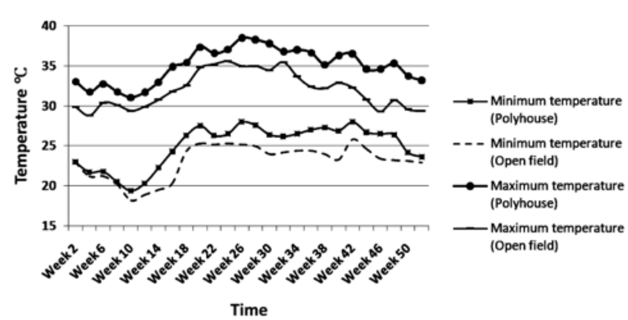

Fig. 1. Comparison of maximum and minimum temperature in polyhouse and open field.

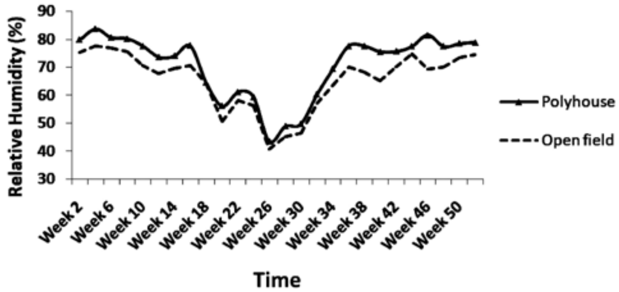

Fig. 2. Comparison of relative humidity in polyhouse and open field.

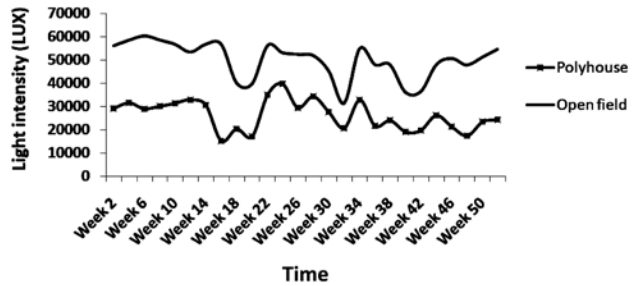

Fig. 3. Comparison of light intensity in polyhouse and open field.

temperature inside the polyhouse was maximum than the open field condition from December to March and air temperature in open field condition was maximum after March. He also reported that relative humidity was less during December to March both in open field and under greenhouse and the light intensity was less around 30-50% inside greenhouse.

Soil moisture distribution of drip irrigated soil mainly depends on the soil properties, dripper discharge, irrigation time and crop water uptake. The moisture content of the soil samples was estimated by gravimetric method. The soil samples were collected after two hours of irrigation. It was found that, the moisture content at 10 cm depth ranged from 23.8 % to 27.6% at 20 cm depth the moisture content varied from 23.5% to 26.5% and at 30 cm depth it varied from 26.8% to 22.4% for the horizontal distance of 0-15 cm, 15-30 cm and 30-45 cm away from the emitter respectively (Table 3). The moisture content was found maximum near the emitter and as the radial distance increased, the moisture content decreased. Arunadevi and Selvaraj (5) tested soil moisture distribution in different drip layouts like single row drip irrigation, paired row drip irrigation and micro tube irrigation, found that the moisture content decreased as depth and distance increased from the emitting point.

Open field condition had higher reference evapotranspiration compared to polyhouse condition for both the crop seasons. Reference crop evapotranspiration (ET_0) was estimated using ET_0 calculator from the observed micro-climatic parameters inside polyhouse for the entire crop growth period.

Table 3. Soil moisture distribution at different depth of soil.

Depth (cm)	Moisture distribution (vol%)		
	Radial distance from dripper		
	0-15 cm	15-30 cm	30-45 cm
10 cm	27.62	26.12	23.78
20 cm	26.51	24.87	23.50
30 cm	26.81	25.39	22.43

The per day values of ET_0 in polyhouse for initial, development, middle, end stage during summer season and winter season were more or less similar. The ET_o value reached higher during middle stages of the crop for the both season, it was because of the maximum length of the growing season of the crop. The average reference crop evapotranspiration value in open field and polyhouse during two seasons is given in Table 4.

The crop evapotranspiration (ET_c) was estimated by using soil water balance method. The crop evapotranspiration (ET_c) was found less inside polyhouse when compared to open field condition because, the micro climatic parameters were maintained by operating foggers inside whenever the temperature increased. The summer season showed higher crop water requirement than the winter crop season. Higher ET_c value was found during middle stage of the crop growth season as it had more number of crop growing days for both the season as well as both atmospheric conditions. During initial stage less crop evapotranspiration value was found as the crop canopy was lesser during that time. Higher crop evapotranspiration was recorded during summer season due to maximum temperature. The average crop evapotranspiration (ET_c) is given in Table 5.

The crop coefficient of Capsicum was developed from the value of reference evapotranspiration and

Table 4. Average reference crop evapotranspiration (ET_o) during two seasons.

Crop growth stages	ET_o (mm/day) (Summer season)		ET_o (mm/day) (Winter season)	
	Open field	Polyhouse	Open field	Polyhouse
Initial	5.5	4.6	4.7	4.6
Development	5.7	5.4	5.2	4.8
Middle	7.0	6.3	6.3	6.0
Terminal	5.8	5.0	5.1	4.2

crop evapotranspiration. During summer season, crop coefficient value for initial, developmental, middle and end stages were recorded higher compared to winter season. It was due to maximum crop evapotranspiration rate during summer season. The crop coefficient values were found maximum for the outside cultivation condition compared to polyhouse because of the higher evapotranspiration rate of Capsicum grown in outside condition. The average crop coefficient for different crop growth stages is given in Table 6.

Similar study was reported by Tahashildar *et al.* (18) that the crop evapotranspiration (ET_c) for *capsicum annumm* L. in the Himalayan region was ranging from 1.11 mm day^{-1} to 3.12 mm day^{-1} and the developed crop co-efficient were for initial stage (0.33), mid stage (0.64) and end stage (0.30). Fernandandez *et al.* (8) reported that the crop coefficient value for the initial stage was 0.2 at 15 days after transplanting, mid stage was 1.4 and end stage was 0.9 for *capsicum annuum* L.

The yield was obtained maximum in polyhouse (12.6 t/ha and 14 t/ha for summer and winter season, respectively) compared to open field condition (7 t/ha and 9.3 t/ha for summer and winter season, respectively). The water use efficiency of capsicum under drip irrigation was calculated as 56 kg/ha.mm during summer season and 66.7 kg/ha.mm during winter season and the same was 11.7 kg/ha.mm and 17.6 kg/ha.mm during summer and winter season, respectively in open field condition (Table 7). The crop coefficient for capsicum and water use efficiency was arrived inside and outside polyhouse conditions for efficient irrigation management for the semi-arid region.

Polyhouse is the promising technology for quality crop production. As the polyhouse produces the conducive micro climate inside, the crop production is high with high quality produce. The capsicum crop evapotranspiration and crop coefficient were estimated for the semi-arid condition in sandy loam soil. The region which has the similar climatic condition and soil can utilize the value of crop coefficient for different stages of crop growth for efficient irrigation management which will lead to conserve water and better yield and water use efficiency.

AUTHORS' CONTRIBUTION

Conceptualization of research (AK); Designing of the experiments (AK); Contribution of experimental materials (AAD); Execution of field/lab experiments and data collection (AK); Analysis of data and interpretation (AK & AAD); Preparation of the manuscript (MS).

Table 5. Average crop evapotranspiration (ET_c) during two seasons.

Crop growth stages	ET_c (mm/day) (Summer season)		ET_c (mm/day) (Winter season)	
	Open field	Polyhouse	Open field	Polyhouse
Initial	3.3	2.5	2.8	2.3
Development	4.8	4.5	3.9	3.6
Middle	7.2	6.5	6.4	5.7
Terminal	5.4	4.5	4.6	3.6

Table 6. Crop coefficient (K_c) of capsicum during two seasons.

Crop growth stages	Crop coefficient (K_c) (Summer season)		Crop coefficient (K_c) (Winter season)	
	Open field	Polyhouse	Open field	Polyhouse
Initial	0.60	0.54	0.59	0.49
Development	0.85	0.83	0.77	0.76
Middle	1.03	1.00	1.02	0.98
Terminal	0.94	0.89	0.90	0.88

Table 7. Comparison of yield and water use efficiency in polyhouse and open field condition.

Particulars	Yield (t/ha)				Water use efficiency (kg/ha.mm)			
	Summer season		Winter season		Summer season		Winter season	
	Polyhouse	Open field	Polyhouse	Open field	Polyhouse	Open field	Polyhouse	Open field
Values	12.6	7	14	9.3	56	11.7	66.7	17.6
Min	*12.3*	*6.4*	*13.5*	*8.7*	*56*	*10.7*	*64.3*	*16.5*
Max	*12.9*	*7.8*	*14.5*	*9.7*	*57.3*	*13*	*69*	*18.4*
Mean	*12.6*	*7*	*14*	*9.3*	*56*	*11.7*	*66.7*	*17.6*
SD	*0.3*	*0.72*	*0.5*	*0.53*	*1.3*	*1.2*	*2.4*	*1*
CV (%)	*2.4*	*10.3*	*3.6*	*5.7*	*2.3*	*10.3*	*3.6*	*5.7*

SD : Standard Deviation; CV: Coefficient of variation (%)

DECLARATION

The authors declare no conflict of interest.

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