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Estimation of evapotranspiration and crop co-efficient of carrot (*Daucus carota*) for water management using weighing lysimeter

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ABSTRACT

An experiment was carried out during 2006 and 2007 to find out the crop evapotranspiration (ET_c) rate of carrot (*Daucus carota*) using weighing type lysimeter at Udhagamandalam. Reference crop evapotranspiration (ET_0) for the growing period was worked out by FAO Penman–Monteith (FAO 56–PM) equation using daily meteorological data. This ET_0 along with observed ET_c from lysimeter was used to determine the crop co-efficient (K_c) at 3 stages, namely growing stage, mid-stage and late-stage based on the rate of crop evapo-transpiration and crop co-efficient. The average crop co-efficient values for 3 stages were found to be 0.70, 1.1 and 0.77; and those of crop evapo-tranpiration were 2.62, 3.53 and 3.01 mm/day; all in respective order. Due to climatic advantage, the crop is grown three times during the year (first season-from second week of April to end of August, second season-from mid August to end of December, third season from mid December to mid-April) with weekly average water requirement of 22.0 mm. From the analysis of average weekly rainfall for 48 years (1960–2007) and water requirement of the crop, supplemental irrigation of 7.3 m^3/ha/day for the first three to four weeks in the first season and 26.5 m^3/ha/day during the third season are required to avoid the risk of crop failure, whereas in the second season, the available rainfall serves the crop water requirement.

Key words: Carrot, Crop co-efficient, Evapotranspiration, Lysimeter

Crop evapotranspiration (ET_c) is used to determine the water requirement of the crop. Measurement of ET_c being difficult, the same is commonly estimated using the meteorological data. A common procedure for estimating ET_c is to first estimate reference crop evapotranspiration (ET_c) from weather data and then to apply empirical crop co-efficient (K_c), ie the ratio of crop evapotranspiration (ET_c) to reference crop evapotranspiration (ET_c). Different methods have been attempted by many scientists to estimate the ET_c for different crops in different climatic conditions. (Kumar *et al*. 2002, Irmak *et al.* 2003). For estimating ET_0; Penman-Monteith (PM) method is most preferred as it suits a wide variety of climatic conditions (Kashyap and Panda 2001). The FAO adopted this method as a global standard (Allen *et al.* 1998). Sikka *et al.* (2001) also approved this method of computing ET_0 because of its better performance in hills like Nilgiris.

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Although crop co-efficient values for different crops grown under different climatic conditions as suggested by Doorenbos and Pruitt (1977) are used where locally measured data are not available; Allen *et al.* (1998) have suggested that these values need to be derived empirically for each crop based on the local conditions.

In Nilgiri, the major annual crops, viz potato (*Solanum tuberosum)*, cabbage *(Brassica oleracea)*, carrot *(Daucus carota)* etc. are commonly grown both under rainfed and irrigated condition. The yield varies and suffers due to uneven rainfall distribution and improper irrigation scheduling. Carrot is one of the major crops. Hence, study on evapotranspiration rate of this crop is of immense importance for irrigation scheduling and management. The water requirement of crops varies during growing period mainly due to variation in crop canopy (Gerson *et al.* 2001). Since, crop co-efficients using lysimetric data for the Nilgiris region of Southern India are not available, hence an attempt has been made to determine the rate of ET_c and crop co-efficient of carrot crop in the Nilgiris, differentiate the different crop growth stages based on the crop co-efficient and compare the ET_c with the weekly average available rainfall for planning of supplemental irrigation.

MATERIALS AND METHODS

The experiment was conducted in a weighing type lysimeter at the research farm of CSWCRTI, Research Centre, Udhagamandalam, Tamil Nadu, India situated at altitude of 11°242 N, longitude of 76°412 E and elevation of 2 218 m above mean sea level. The area receives an average annual rainfall of 1228 mm from both south-west (June–August) and north–east monsoon (September–November) with occasional rain in the remaining period. The mean monthly maximum and minimum temperatures are 22.1°C and 8.5°C occurring in April and January, respectively.

In this experiment, a weighing type lysimeter with the tank size of 1.2 m×1.2 m×1 m (length×breadth×depth) supported by a weighing bridge with sensitivity of 200 g (0.14 mm of water depth) was installed in the experimental area adjacent to the meteorological observatory. Details about the design dimensions of lysimeter are referred from Bhardwaj (1983). Suitable arrangements were made to measure the deep percolation loss, surface runoff and change in soil moisture content. 'Karoda' carrot was sown in and around the lysimeter during mid-August (on 16 August 2006 and 13 August 2007 in the first and second year, respectively) to maintain similar micro-climatic conditions following the recommended agronomic practices. All the cultural operations including harvesting of carrot were carried out at the same time in the tank as well as the surrounding field. Carrot was grown under rainfed condition with supplemental irrigation.

Regular recording of rainfall, changes in weight of lysimeter tank, measurement of runoff and deep percolation losses from the tank were made on daily basis at 0830 hr (ISI) for computing daily ET_c following a simple water budgeting technique. The surface run-off was measured through the holes made into the side wall of the tank at surface level and connected to the measuring container by flexible pipe.

The daily meteorological data such as temperature (maximum and minimum), relative humidity, wind velocity and sunshine hours were collected from the meteorological observatory located within the Research Farm and suitable adjustments were made according to the FAO Penman-Monteith recommendations. FAO Penman-Monteith (FAO 56–PM) equation (Allen *et al.* 1998) was used to find out reference crop evapotranspiration (ET_0) using daily average meteorological data; and the crop co-efficient (K_c) was calculated using the relationship

$$ET_c = K_c \times ET_0$$

RESULTS AND DISCUSSION

Crop co-efficient

The average crop co-efficient (K_c) values obtained from crop evapotranspiration and reference ET using Penman-Monteith equation for different growth stages is presented in Fig 1. Based on the change in crop co-efficient, as is evident from the figure, the entire cropping period is divided into three distinct stages. During the initial stage (for about one month from the sowing till full canopy development), K_c value goes on increasing from 0.49 to 1.0 with an average of 0.70. In the mid stage (for nearly two months in between initial and late stages), crop co-efficient attained a nearly constant value with an average of 1.1, whereas in the late stage (for nearly one and half months till harvesting) at a declining rate with an average value of 0.77.

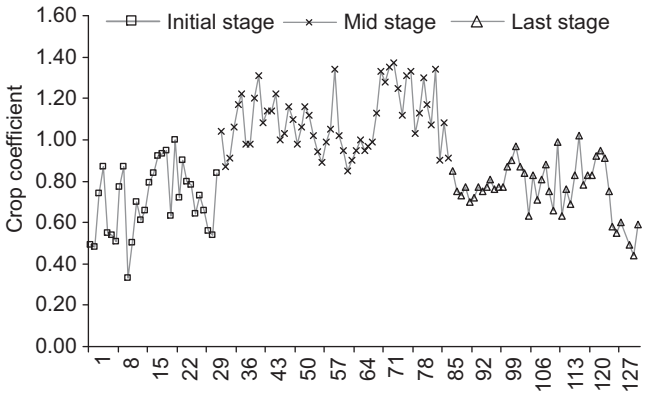

Fig 1 Crop co-efficient at different stages of crop growth

Crop evapotranspiration

The crop evapotranspiration (ET_c) was measured as the change in mass of the lysimeter divided by the evaporating area of the lysimeter converted to depth of water (mm). The daily crop evapotranspiration of carrot varied from a minimum of 1.93 mm/day to a maximum of 3.4 mm/day during the initial stage with an average value of 2.62. Similarly, in the mid-stage, the daily crop-evapotranspiration went up to a maximum of 4.49 mm/day with average value of 3.53 (Table 1). It was observed that the ET_c increased over time due to canopy development as observed in the initial stage; attained a nearly constant rate in the mid-stage and declined in the late stage. In the late stage, the crop evapotranspiration rate varied from a minimum of 2.22 mm/day to a maximum of 3.78 mm/day with an average of 3.01.

In general, an increasing trend of crop evapotranspiration in the mid-stages can be attributed to more crop water demand owing to full canopy development in addition to evaporative demand. However, in the late stage, though there is not much variation in the atmospheric demand, the transpiration rate decreases due to decrease in physiological activity of plants. Thus this type of variation in crop co-efficient and crop evapotranspiration is mainly due to plant water requirement patronized by trend in canopy development.

Weekly water requirement and crop planning

The weekly evapotranspiration for the crop varies from a minimum of 18.0 mm at the end of the late stage (just before harvesting) to a maximum of 26.8 mm during the mid-stage

Table 1 Crop evapotranspiration at different growing stages

Initial stage		Mid stage		Late stage	
DAS	ET_c	DAS	ET_c	DAS	ET_c
1	2.13	32	3.55	87	3.4
2	2.26	33	2.57	88	3.75
3	2.21	34	2.78	89	3.26
4	2.62	35	3.06	90	3.47
5	2.48	36	3.08	91	3.06
6	2.53	37	3.31	92	3.26
7	2.43	38	3.42	93	3.68
8	2.46	39	2.92	94	3.47
9	2.78	40	3.94	95	3.47
10	2.24	41	3.32	96	3.47
11	2.70	42	3.24	97	3.78
12	2.78	43	3.64	98	3.47
13	2.78	44	3.82	99	3.61
14	3.13	45	3.89	100	3.06
15	3.04	46	3.4	101	3.19
16	2.88	47	3.23	102	3.06
17	2.58	48	3.51	103	3.47
18	2.43	49	3.13	104	3.19
19	2.89	50	3.47	105	2.29
20	1.93	51	3.82	106	3.26
21	3.08	52	3.82	107	2.68
22	2.94	53	3.58	108	2.78
23	2.65	54	3.78	109	2.78
24	2.43	55	3.47	110	2.58
25	2.78	56	3.11	111	2.43
26	2.67	57	3.28	112	3.13
27	3.40	58	4.01	113	2.57
28	3.06	59	4.49	114	2.99
29	2.08	60	3.61	115	2.78
30	2.08	61	2.99	116	2.58
31	2.97	62	3.13	117	2.46
Average	2.62	63	3.13	118	2.92
		64	3.42	119	3.61
		65	3.17	120	3.13
		66	3.03	121	3.13
		67	3.06	122	2.94
		68	3.47	123	2.97
		69	3.6	124	2.85
		70	3.83	125	2.71
		71	3.74	126	2.36
		72	3.55	127	2.72
		73	3.82	128	2.22
		74	3.6	129	2.31
		75	3.89	130	2.64
		76	3.89	Average	3.01
		77	3.78		
		78	3.89		
		79	4.03		
		80	3.83		
		81	3.89		
		82	3.68		
		83	4.02		
		84	3.47		
		85	3.83		
		86	4.03		
		Average	3.53		

DAS, Days after sowing

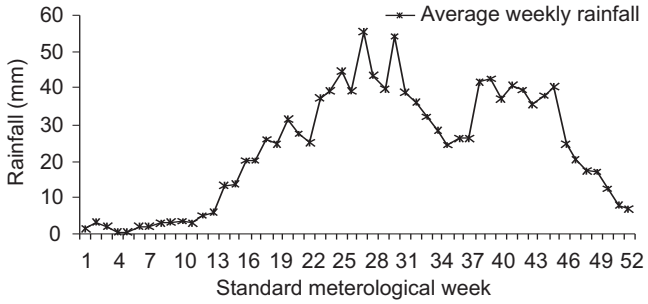

Fig 2 Weekly average rainfall (1960–2007)

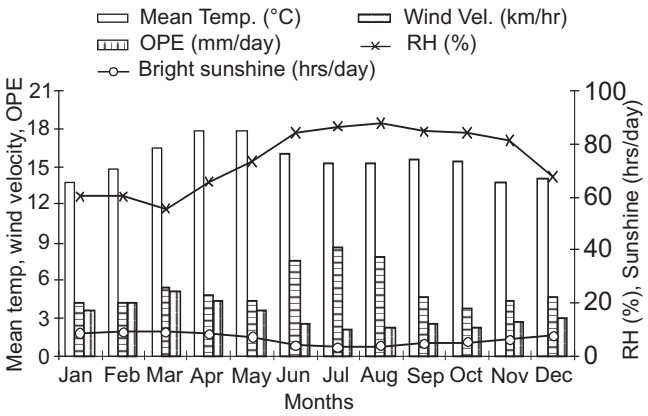

Fig 3 Monthly variation in climatic parameters (1960–2007)

of the crop growth period with an average of 22 mm in the entire growing period. Due to the climatic advantage, the crop is grown three times during a year depending on the rainfall and supplemental irrigation. Therefore, analysis of the average weekly rainfall for 48 years (1960–2007) were made to compare the rainfall availability (Fig 2) and water requirement of the crop assuming similar trend in crop evapotranspiration due to little variation of the climatic parameters throughout the year (Fig 3). In the first season the crop is sown during the second week of April and harvested in the end of August. As such, due to some pre-monsoon rainfall and south-west monsoon, the available rain water is sufficient for taking the crop except in the first three to four weeks, when the available weekly average rainfall is little less than the requirement to meet the crop evapotranspiration. To avoid the risk, supplemental irrigation of 7.3 m^3/ha/day is required; which can be made available from subsurface collection well of 3 m×3 m with 0.8 m depth of water. In the second season, the normal cropping time is from mid-August to end of December receiving a part of the south-west and entire north-east rainfall thus serving the crop water requirement. In the third season, the crop is grown from mid-December to mid-April with an available average weekly rainfall of about 3.5 mm, thereby, creating an average weekly deficit of 18.5 mm. So the crop during this period can be grown by developing water resources in the form of sub-surface collection wells or pumping water from the nearby streams. The estimated water requirement for

supplemental irrigation is 26.5 $m^{3/}$ha/day and a subsurface collection well of 3 m×3 m with 2.9 m depth of water will be sufficient for assured irrigation.

The crop period of carrot is divided into three distinct stages as growing stage, mid stage and late stage based on the change in Kc and the average values were found to be 0.70, 1.1 and 0.77 all in respective order. Therefore the water requirement in different stages can be estimated from the reference evapotranspiration using the meteorological data and these crop co-efficient values in the absence of data on crop evapotranspiration.

REFERENCES

Allen R G, Pereira L S, Raes D and Smith M. 1998. Crop Evapotranspiration-Guidelines for Computing Crop Water Requirements. *FAO Irrigation and Drainage Paper* **56**: FAO, Rome, Italy.

Bhardwaj S P. 1983. Lysimeters and evapotranspiration, *Bulletin No. T–17/D–14*, CSWCRTI, Dehradun.

Doorenbos J and Pruitt W O. 1977. Crop water requirement. *Irrigation and Drainage Paper No.***24** (revised), FAO, Rome, Italy.

Gerson A M, Flavio B A, Emilio S and Mamor F. 2001.The influence of crop canopy on evapotranspiration and crop coefficient of beans (*Phaseolus vulgaris* L.). *Agricultural Water Management* **49**(3): 211–24.

Irmak S, Allen R G and Whitty E B. 2003. Daily grass and alfalfa-reference evapotranspiration estimates and alfa-to-grass evapotranspiration ratios in Florida. *Journal of Irrigation & Drainage Engineering* **129**(5): 360–70.

Kashyap P S and Panda R K.2001.Evaluation of evapotranspiration estimation methods and development of crop-coefficients for potato crop in a sub-humid region. *Agricultural Water Management* **50**(1): 9–25

Kumar M, Raghuwanshi N S, Singh R, Wallender W W and Pruitt W O. 2002. Estimating evapotranspiration using artificial neural network. *Journal of Irrigation & Drainage Engineering* **128**(4): 224–33.

Sikka A K, Madhu M and Tripathi K P. 2001. Comparison of different methods of estimating evapotranspiration in the Nilgiris, South India. *Indian Journal of Soil Conservation* **29**(3): 213–19.