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IRRIGATION ENGINEERING

[BTAI 2201]

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WATER REQUIREMENTS OF CROPS

Consumptive Use: It is the quantity of water lost in evaporation from the soil and water surface, transpiration by the vegetations grown on the soil and that used in metabolic activity. Water used in metabolic activity is very less (usually less than 1% of evapotranspiration). Thus, in usual sense, the term consumptive use is taken as evapotranspiration, *ET_{crop}*.

Water Requirement: It is the water needed for raising a crop in a given period starting from seedling to harvest. It includes consumptive use and other unavoidable losses and also the water required for special operations like land preparation, transplanting and leaching.

Evapotranspiration: It is the total amount of water lost by the evaporation from the soil and water surface and transpiration by the vegetations. It depends on the crop types, its coverage amount and management and cultural practice of the crop.



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Methods to Estimate Crop Water Requirement

Most important component of water requirement of crop is its evapotranspiration.

There are several methods used to determine the crop evapotranspiration. Broadly they can be classified as:

- Direct measurements and
- Estimation method.

The direct measurement method comprises the followings:

- Lysimeter experiment
- Field experimental plots
- Soil moisture depletion studies and
- Water balance method

Estimation of evapotranspiration can be achieved by:

- Aerodynamic method
- Energy balance method
- Combination method and
- Empirical method



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Lysimeter Method

Lysimeter studies involve the growing of crop in large containers (lysimeters) and measuring their water loss & gains. Mainly there are 2 types of lysimeters.

Weighing type

Drainage

Weighing type

Weighing type lysimeters give more accurate results compared to drainage type. To get more accurate & short period results, weighing type lysimeter can be used.

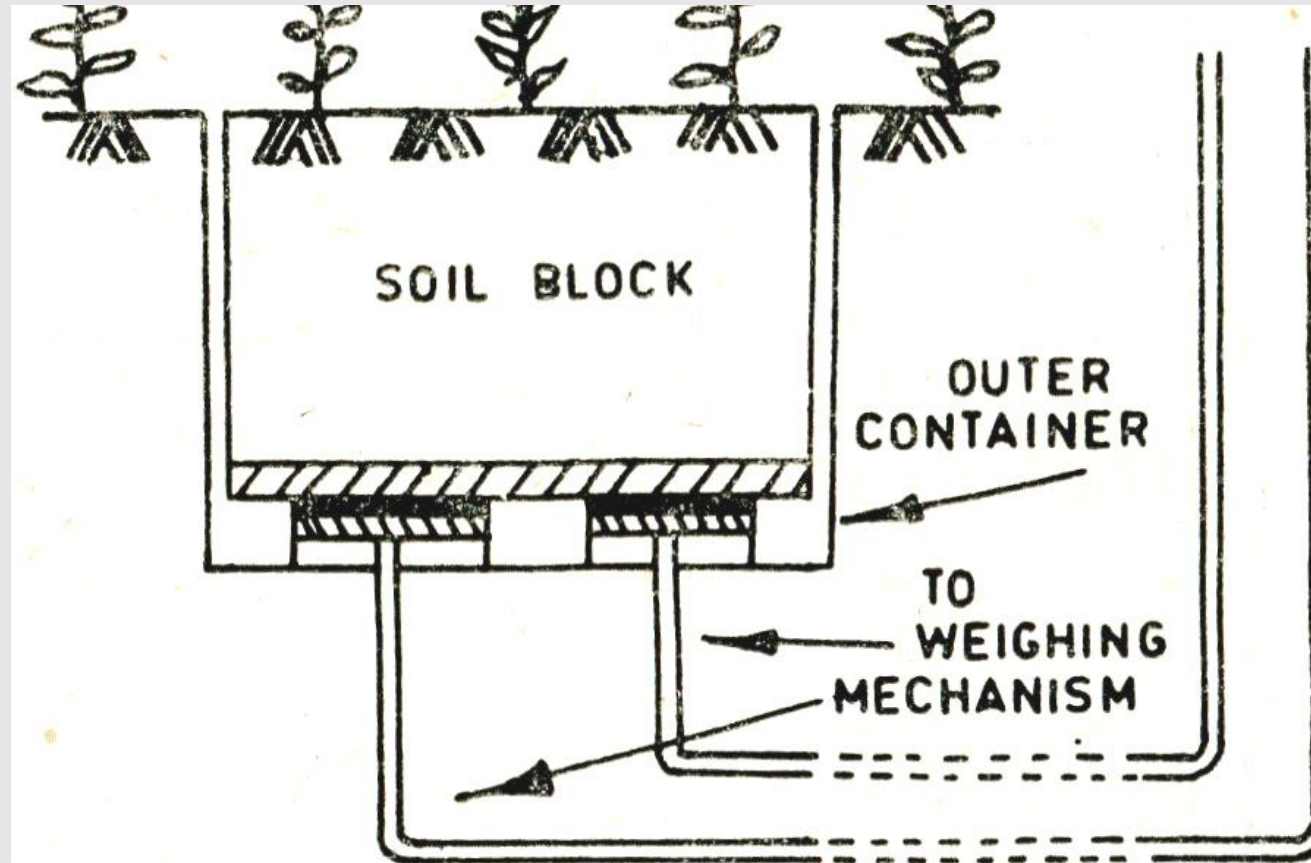
Soil & crop conditions of the lysimeters should be close to natural condition.



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Weighing Type Lysimeter





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In weighing type lysimeter, water balances parameters like water added, water retained by the soil & water lost through all sources-evaporation, transpiration and deep percolation are measured.

The techniques yield measurement of total water loss & is useful as an indicator of field water loss.

The precautions needed in this case is that the tank must be permanently buried in the ground and surrounded by a large area of crop with same height as crop.

Water table is maintained as specific depth in the tank by connecting it to a supply tank provided with float mechanism which has an arrangement for receiving excess water that tends to build up in the tank. Water is applied in measured amount to the lysimeter as irrigation is applied to the crops in the fields where lysimeter is set up.

Water received either from reservoir or precipitation excluding outflow, constitutes water used by the crops.



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Soil Moisture Depletion Studies

In this method, soil moisture within the crop effective root zone before & just after irrigation & also within each irrigation cycle is measured. SMC from different profile layers within the crop effective root zone are measured & then these values are used to compute total SMC in the entire crop root zone.

Water use from crop root zone is given as:

$$u = \sum_{i=1}^n \frac{(M_{1i} - M_{2i})}{100} \cdot A_i \cdot D_i + ER - DP$$

where, u = water use from crop root zone for successive sampling periods or within one irrigation cycle, mm; n = number of soil profile layers in crop effective root zone D ; M_{1i} = SMC, % at the time of 1st sampling in the i^{th} layer;

M_{2i} = SMC, % at the time of the second sampling in the i^{th} layer;
 A_i = apparent specific gravity of i^{th} layer and D_i = depth of the i^{th} layer, mm,

ER = effective rainfall, mm & DP = percolation from effective root zone, mm.



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Field Experimental Plots

$$WR = IR + ER + \sum_{i=1}^n \frac{(M_{bi} - M_{ei})}{100} \cdot A_i \cdot D_i$$

where, WR = seasonal water requirement, mm; IR = total irrigation water supplied, mm; ER = seasonal effective rainfall, mm; M_{bi} and M_{ei} = soil moisture percentage at the beginning and end of the season in the i^{th} layer of the soil, respectively and other terms of equation are as discussed above.



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Q1. Profile soil moisture content of a potato field in 60 cm effective root zone depth are measured as follows:

Profile layer, cm	Soil moisture content, %	Apparent Specific gravity, gm/cc	
	Beginning of irrigation cycle	End of irrigation cycle	
0-15	18	10	1.60
15-30	20	11	1.58
30-45	25	15	1.59
45-60	25	15	1.60

If effective rainfall within the irrigation cycle is 10 mm, & percolation from the effective root zone of the crop is 10 mm, estimate the water use from the crop root zone within the irrigation cycle.



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Q2. A field is sown with ground nut. The profile soil moisture content of the field at sowing and at harvest time are measured and presented in table as below.

Profile layer, cm	Soil moisture content, %		Apparent Specific gravity, gm/cc
	At sowing	At harvest	
0-15	20	10	1.62
15-30	22	11	1.60
30-45	25	13	1.59
45-60	25	15	1.60

If the crop is supplied with 10 cm irrigation, effective rainfall in the crop growing season is 12 cm and there is no percolation loss from the crop effective root zone in the entire season, then estimate the seasonal water requirement of the crop.



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Water Balance Method:

The water balance model of a crop field (generally non-paddy) under unsaturated phase is expressed (**B. Panigrahi, 2001**) as:

$$S_{w,i} = S_{w,i-1} + R_i + I_{s,i} - ET_{crop_i} - SR_i - S_i - D_i$$

where, R = rainfall; I_s = supplemental irrigation, ET_{crop_i} = evapotranspiration of the crop; SR = runoff from the crop field; D = percolation loss in the crop field, S = seepage loss from the crop field and S_{wi} and S_{wi-1} = SMC on i th and $(i-1)$ th day, respectively. The term i of the above equation refer to the day which may be taken as 1 day.



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Water Balance in Paddy Field (B. Panigrahi, 2001)

$$D_{p,i} = D_{p,i-1} + R_i + I_{s,i} - ET_{crop_i} - SR_i - S_i - D_i$$

where, D_{pi} and D_{pi-1} are the ponding depths occurred at the end of day i and $i-1$, respectively.

Other terms of the equation are described as above.



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Estimation of Evapotranspiration:

$$ET_{crop} = K_s \cdot K_c \cdot ET_o$$

where, ET_{crop} = crop evapotranspiration or simply evapotranspiration; K_c = crop coefficient, K_s = Crop stress factor (1 for adequate SMC) and ET_o = reference crop evapotranspiration or potential evapotranspiration.

$$K_c = \text{FAO 24}$$

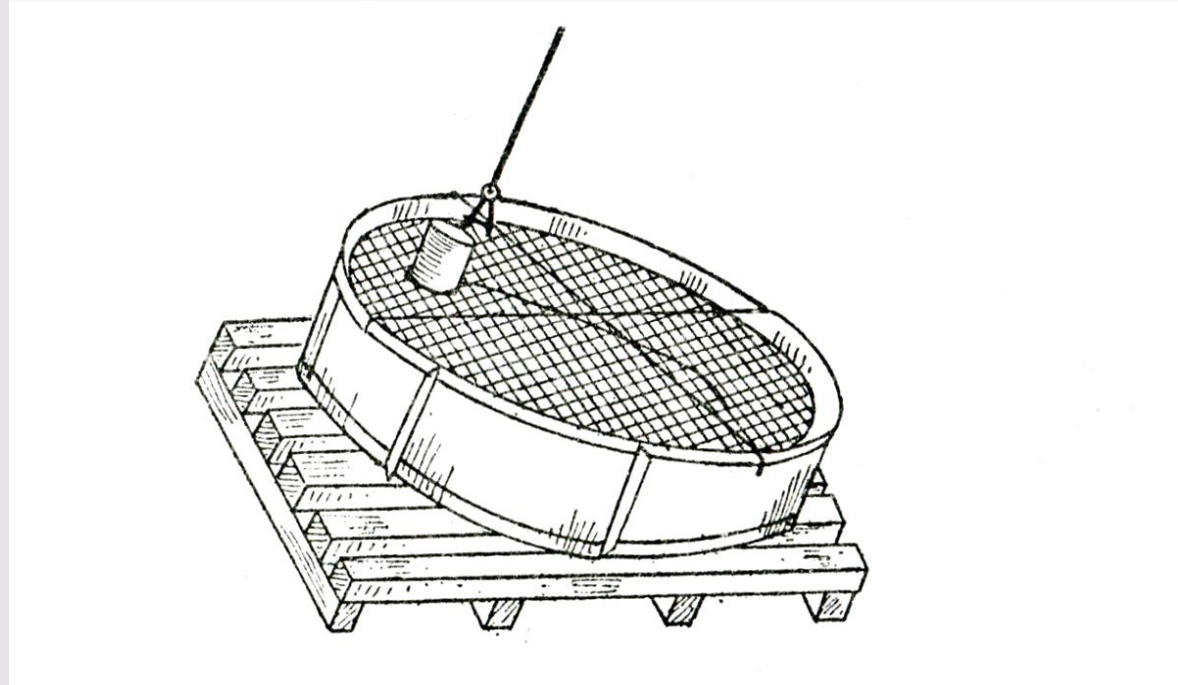
$$K_s = \text{FAO 56}$$



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Estimation of ETo by **Pan Evaporation Method**





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Estimation of E_{To} by Pan Evaporation Method

$$E_{To} = E_{pan} K_p$$

Where, E_{pan} = Pan Evaporation & K_p = Pan coefficient

Sample Calculation: Calculate the reference crop evapotranspiration value (E_{To}) as measured by class A open galvanized pan in a given site under the following conditions with data measured as:

Water level in the pan on previous day at 7 A.M. is 18.5 cm & that measured after 24 hours at the same time is 20.5 cm. There is 7.0 cm rainfall in between 24 hours. Assume $K_p = 0.75$



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Solution:

There is 7 cm rainfall within the two consecutive day's readings of water measurement.

Water level readings on previous day = 18.5 cm

Water level reading on day after 24 hours = 20.5 cm

Hence, the value of $E_{pan} = 18.5 + 7.0 - 20.5 = 5$ mm/day.

$$K_p = 0.75$$

Hence, $ET_o = E_{pan} K_p$

$$= 5 \times 0.75 = 3.85 \text{ mm/day.}$$



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Crop Coefficient (K_c) for Estimating Actual Evapotranspiration:

The values of K_c for a particular crop at a location should be determined experimentally. If the values of K_c for particular crop and place are not available then the K_c (FAO 24/FAO 56) may be used.

Values of KC during initial and maturity stage of crop are less and so ETo is less.

During Crop development and Mid season stage KC is high and so ETo is high.



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Trend of Kc values of crops

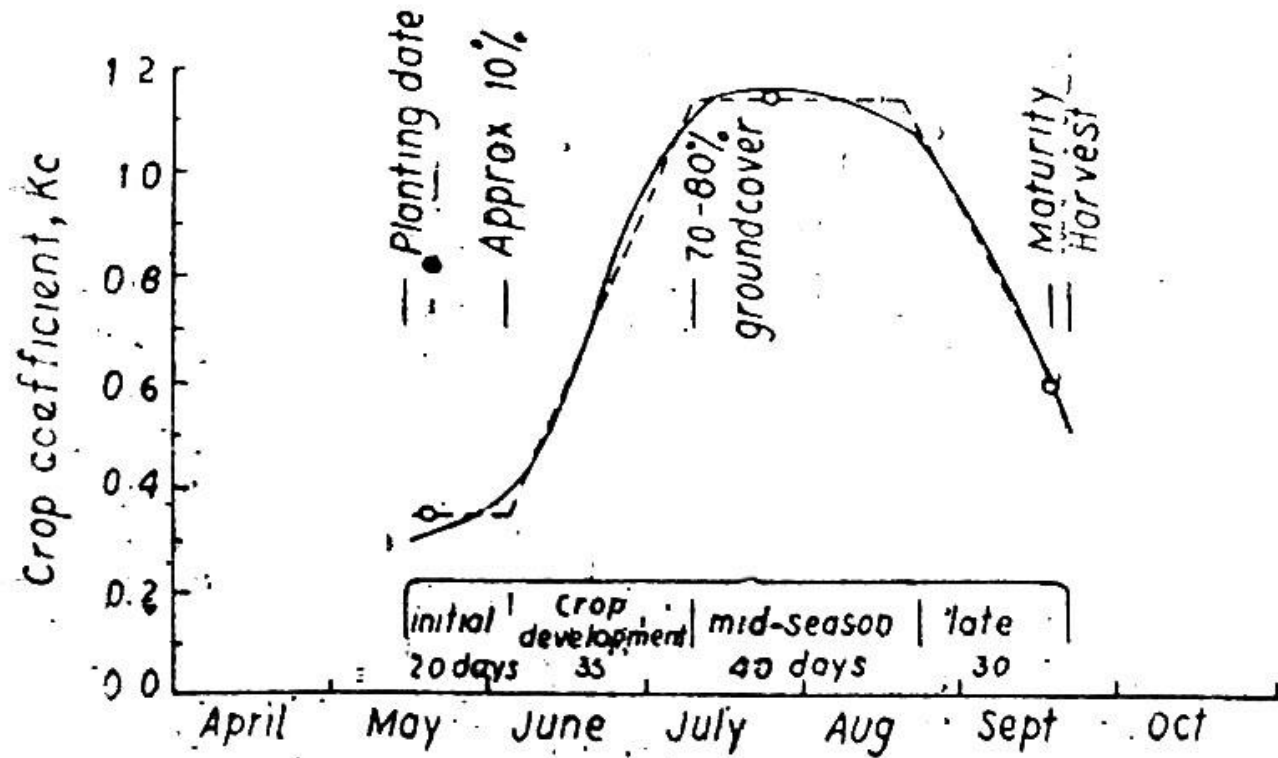


Fig. 9.4 Example of crop coefficient curve.



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