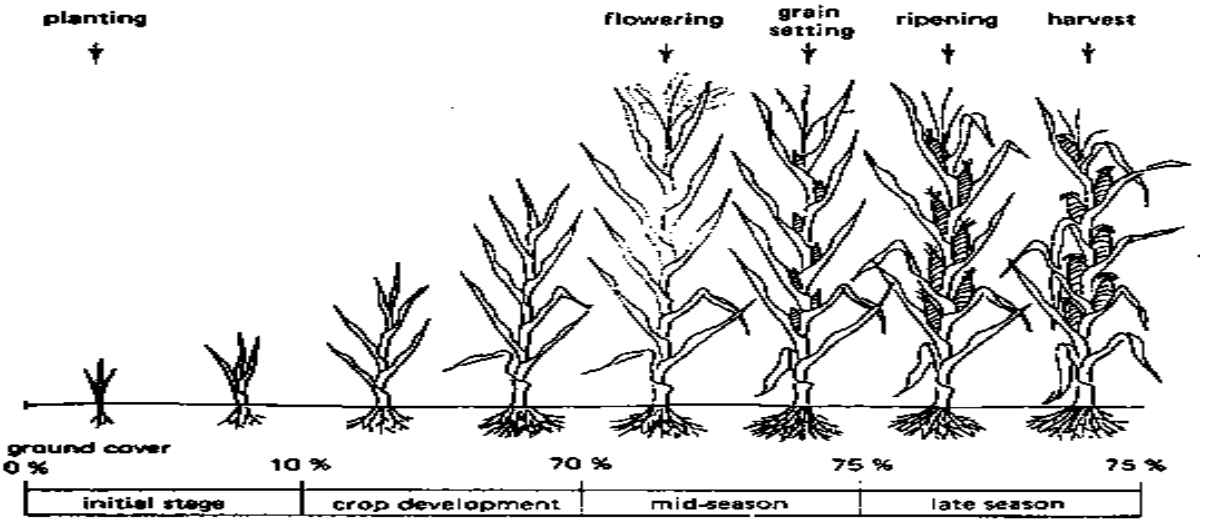
Crop Water Requirement

PLANT WATER DEMAND/REQUIREMENT

- The relationship between the reference grass crop and the crop actually grown is given by the crop factor, Kc.
- **The crop factor, Kc, mainly depends on:**
    - the type of crop
    - · the growth stage of the crop
    - · the climate



Crop ET

- ETc = Crop evapotranspiration (mm/day)
- ETo = Reference crop evapotranspiration (mm/day)
- Kc = Crop coefficient

How to Calculate Daily irrigation Requirement

(a). Daily Crop Water Requirement
(Row/Field Crop)

Crop Water Requirement, mm/day

ETc = (ETo X Kc)

ETo = Reference Evapotranspiration rate in mm/day

- Kc = Crop Factor

(b). Daily Crop Water Requirement
(Orchard)

Crop Water Requirement, mm/day

ETc = (ETo X Kc x Cp)

ETo = Reference Evapotranspiration rate in mm/day

- Kc = Crop Factor
- Cp = Canopy factor

Factors affecting Etc

1. Climatic Factors
2. Soil Water Factors
3. Irrigation Method
4. Cultural Practices

Irrigation Requirements

IRn = ETc - (Pe + Ge + Wb) + LRmm

Where:

- IRn = Net irrigation requirement (mm)
- ETc = Crop evapotranspiration (mm)
- Pe = Effective dependable rainfall (mm)
- Ge = Groundwater contribution from water table (mm)
- Wb = Water stored in the soil at the beginning of each period (mm)
- LRmm = Leaching requirement (mm)

IRRIGATION SCHEDULING

- How to Apply
  - Flood, Bed & Furrow, Sprinkler, Drip, Center pivot.
- When one should apply water.
  - Rate of water use by the crop.
  - Total available moisture.
- How Much water should be applied during irrigation.
  - The soil available moisture storage capacity.
  - The amount of available water depleted from the soil profile by crop water use.

Poor Irrigation Management

- Over and Under Irrigation.
- Reduce Crop Yield.
- Degrade Crop Quality.
- Enhance the field environment for disease/Insect/weeds epidemic.
- Increase Pumping Cost.
- Leach soluble nutrients from root zone

WHY SCHEDULING

- Each soil has different moisture holding capacity.
- Plants differ in their abilities to withdraw water from soil.
- Plants differ in their water use rate.
- Water quality (salinity) may influence water availability to plants.
- Irrigation System may have inherent characteristics to restrict frequency, rate or duration of water application.
- Certain irrigation Practices may be needed for reasons other than meeting evapo-transpiration requirements such as:
    - frost control,
    - softening of soil crust,
    - softening of clods
    - incorporation of herbicides in the soil
    - Nutrient application
- External factor Such as:
    - labour scheduling,
    - availability of water,

FACTORS EFFECTING IRRIGATION SCHEDULING

- Availability of water in the soil
- Water needs of crop
- How water is needed by the crop/plants
- Rainfall
- Output of irrigation system

Values of ETo for All Districts of Punjab

Sr. #	District	Average Daily Reference Crop Evapo-transpiration (mm/day)											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	Attock	1.8	2.8	3.8	5.9	7.8	8.5	6.7	5.8	5.2	4.1	2.8	1.8
2	Bahawalnagar	2.0	3.0	4.5	6.5	8.3	9.0	6.6	6.3	5.7	4.4	2.8	1.9
3	Bahawalpur	1.8	2.8	4.1	5.5	6.8	7.7	6.2	6.0	5.3	3.9	2.5	1.7
4	Bhakkar	1.8	2.7	4.0	6.4	8.6	9.2	7.6	6.5	5.8	4.5	2.7	1.9
5	Chakwal	1.8	2.8	3.8	5.9	7.8	8.5	6.7	5.8	5.2	4.1	2.8	1.8
6	Chiniot	1.6	2.5	3.9	5.5	7.2	7.8	6.5	5.8	5.0	3.6	2.2	1.5
7	Dera Ghazi Khan	1.7	2.4	3.7	5.2	6.8	6.9	6.3	6.0	5.1	3.8	2.3	1.6
8	Faisalabad	1.4	2.2	3.5	4.8	6.2	6.5	5.4	4.9	4.7	3.3	1.9	1.3
9	Gujranwala	1.7	2.6	4.0	6.1	7.7	8.6	7.1	6.3	5.7	4.3	2.6	1.8
10	Gujrat	1.8	2.8	3.8	5.9	7.8	8.5	6.7	5.8	5.2	4.1	2.8	1.8
11	Hafizabad	1.7	2.6	4.0	6.1	7.7	8.6	7.1	6.3	5.7	4.3	2.6	1.8
12	Jhang	1.6	2.5	3.9	5.5	7.2	7.8	6.5	5.8	5.0	3.6	2.2	1.5
13	Jhelum	1.4	2.1	3.4	4.8	5.9	6.2	4.7	4.0	4.5	4.0	2.9	1.8
14	Kasur	1.4	2.2	3.6	5.0	6.3	6.5	5.2	4.7	4.5	3.2	1.8	1.3
15	Khanewal	1.5	2.5	4.1	5.2	6.4	7.6	6.2	5.9	5.2	3.4	2.0	1.5
16	Khushab	1.7	2.5	4.0	5.6	7.2	7.6	6.1	5.3	5.1	3.8	2.3	1.7
17	Lahore	1.4	2.2	3.6	5.0	6.3	6.5	5.2	4.7	4.5	3.2	1.8	1.3
18	Layyah	1.8	2.7	4.0	6.4	8.6	9.2	7.6	6.5	5.8	4.5	2.7	1.9
19	Lodhran	1.5	2.5	4.1	5.2	6.4	7.6	6.2	5.9	5.2	3.4	2.0	1.5
20	M Bahaudin	1.7	2.5	4.0	5.6	7.2	7.6	6.1	5.3	5.1	3.8	2.3	1.7
21	Mianwali	1.4	2.0	3.3	4.6	6.2	6.5	5.6	5.0	4.6	3.1	1.8	1.2
22	Multan	1.5	2.5	4.1	5.2	6.4	7.6	6.2	5.9	5.2	3.4	2.0	1.5
23	Muzaffargarh	1.8	2.7	4.0	6.4	8.6	9.2	7.6	6.5	5.8	4.5	2.7	1.9
24	Narowal	1.2	1.9	3.1	4.4	5.4	5.8	4.4	4.3	3.8	2.7	1.6	1.1
25	Nankana Sahib	1.4	2.2	3.5	4.8	6.2	6.5	5.4	4.9	4.7	3.3	1.9	1.3
26	Okara	1.7	2.6	4.0	6.1	7.7	8.6	7.1	6.3	5.7	4.3	2.6	1.8
27	Pakpattan	1.7	2.6	4.0	6.1	7.7	8.6	7.1	6.3	5.7	4.3	2.6	1.8
28	Rahim Yar Khan	2.0	3.0	4.5	6.0	7.2	8.0	6.6	6.2	5.2	4.0	2.6	1.9
29	Rajanpur	1.7	2.4	3.7	5.2	6.8	6.9	6.3	6.0	5.1	3.8	2.3	1.6
30	Rawalpindi	1.7	1.7	3.0	4.9	6.3	7.1	6.7	4.9	5.4	4.0	2.7	1.7
31	Sahiwal	1.7	2.6	4.0	6.1	7.7	8.6	7.1	6.3	5.7	4.3	2.6	1.8
32	Sargodha	1.7	2.5	4.0	5.6	7.2	7.8	5.1	5.3	5.1	3.8	2.3	1.7
33	Sheikhupura	1.4	2.2	3.6	5.0	6.3	6.5	5.2	4.7	4.5	3.2	1.8	1.3
34	Sialkot	1.2	1.9	3.1	4.4	5.4	5.8	4.4	4.3	3.8	2.7	1.6	1.1
35	T T Singh	1.6	2.5	3.9	5.5	7.2	7.8	6.5	5.8	5.0	3.6	2.2	1.5
36	Vehari	1.7	2.6	4.0	6.1	7.7	8.6	7.1	6.3	5.7	4.3	2.6	1.8

Duration of Growth Stages of Agronomic Crops and Corresponding Kc Values

Sr.No	Crop	Date of Sowing	Duration of Initial stage	Kc initial	Duration of Development stage	Kc Development	Duration of Middle Stage	Kc Mid stage (Peak Value)	Duration of Late Stage	Kc Late stage	Total days	Date of Harvesting
1	Barley	November	15	0.3	25	0.9	50	1.15	30	1	120	April
2	Beans	June	15	0.4	25	0.7	35	1.05	20	0.95	95	Sep & Oct
3	Canola	October	25	0.35	45	0.7	70	1.15	40	1	180	Mar & April
4	Castor Beans	March	25	0.35	40	0.8	65	1.15	50	1.1	180	Sep & Oct
5	Cotton	April	30	0.5	50	0.8	60	1.25	55	0.9	195	Nov & Dec
6	Grams	October	20	0.4	30	0.9	45	1	20	1	115	Feb & Mar
7	Groundnut	March	25	0.5	35	0.8	45	1.1	25	0.85	130	July & Aug
8	Maize	Feb/July	20	0.5	30	0.85	40	1.2	20/25	0.9	115	May & Nov
9	Millets	June/July	15	0.4	25	0.7	40	1	25	0.9	105	October
10	Rapeseed	October	25	0.35	45	0.7	70	1.2	40	1	180	Mar & Apr
11	Rice	June/July	30	1.15	30	1.15	60	1.3	30	1.05	150	Nov & Dec
12	Saflower	November	25	0.5	40	0.8	65	1	30	0.8	160	April
13	Sesame	June/July	15	0.35	25	0.9	50	1.1	20	1	110	Oct & Nov
14	Sorghum	July	20	0.4	35	0.7	40	1.1	30	0.8	125	Nov & Dec
15	Soyabeans	Feb & July	20/20	0.4	25/35	0.8	50/60	1.15	15/20	0.8	110/130	June & Nov
16	Sugarcane	Feb & Sep	30/35	0.5	60/65	0.9	180/200	1.3	60/90	0.8	330/390	Dec & Jan
17	Sugar Beets	October	30	0.35	45	0.9	90	1.2	15	0.8	180	April
18	Sunflower	Jan & Feb	25	0.4	35	0.7	45	1.2	25	0.8	130	June
19	Sweet Corn	Feb & July	20	0.3	30	0.7	40	1.15	20	1.1	110	June & Nov
20	Toria	October	25	0.35	45	0.7	70	1.15	40	0.95	180	April
21	Tobacco	October	30	0.4	40	0.8	50	1.2	30	0.9	150	Mar & April
22	Wheat	November	15	0.4	25	0.8	50	1.2	30	0.7	120	April

Duration of Growth Stages of Vegetable Crops and Corresponding Kc Values

Sr.No	Crop	Date of Sowing	Initial stage		Development stage		Middle Stage		Late Stage		Total days	Date of Harvesting
			Duration	Kc	Duration	Kc	Duration	Kc	Duration	Kc		
1	Ash gourd	Oct & Feb	15	0.6	25	0.9	50	1	30	1	120	March
2	Bitter gourd	Mar & Jun	30	0.6	40	0.9	50	1	30	1	150	Sep & Oct
3	Beans green	Oct	15	0.4	25	0.7	25	0.95	10	0.95	75	Jan
4	Beans dry	Mar	15	0.4	25	0.8	35	1.15	20	0.7	95	July
5	Bringle	Apr	30	0.6	50	0.9	60	1.05	40	0.9	180	Nov & Dec
6	Cabbage	Oct	30	0.4	40	0.9	65	1.05	30	1	165	Feb & Mar
7	Capsicum/ Sw. pepper	Mar	25	0.5	35	0.8	45	1.05	25	0.9	130	July & Aug
8	Carrot	Oct	15	0.7	25	0.9	40	1.05	20	0.95	100	January
9	Cauliflower	Aug	15	0.7	25	0.9	40	1.05	20	0.95	100	December
10	Chillies	Feb	30	0.3	40	0.5	70	0.75	30	1	170	August
11	Cucumber	Feb /Mar	15	0.6	20	0.9	30	1	15	0.9	80	May/Jun
12	Egg Plant	Nov	20	0.6	30	0.8	55	1.05	25	0.9	130	April
13	Garlic	Sep/ Oct	30	0.7	40	0.9	70	1	30	0.7	170	March/April
14	Ladyfinger	Feb / Mar	15	0.7	20	0.8	40	1	15	0.9	90	May/June
		Jun	15	0.7	20	0.8	40	1	15	0.9	90	September
15	Lettuce	Feb & Sep	25	0.7	35	0.8	30	1	10	0.95	100	Dec & Jan
16	Muskmelon	Mar	20	0.5	25	0.75	40	1.05	15	0.75	100	July/August
17	Onion dry	Oct	15	0.5	25	0.75	70	1.05	30	0.75	140	April
18	Onion green	Oct	15	0.5	25	0.75	60	1	--	--	100	February
19	Peas Green	Sep/ Oct	20	0.5	25	0.85	35	1.15	--	--	80	Dec/Jan
20	Peas seed	Sep/ Oct	20	0.5	25	0.85	35	1.15	20	0.3	100	Jan/Feb
21	Potato (Autumn)	Sep/ Oct	25	0.5	30	0.85	35	1.15	30	0.75	120	Dec/Jan
	Potato (spring)	Jan/ Feb										Apr/May
	Potato (Summer)	Mar/ April										Aug/Sep
22	Pumpkin	Feb	20	0.6	30	0.9	30	1	20	0.8	100	
23	Radish	July to Nov	10	0.7	15	0.8	20	0.9	5	0.85	50	Sep to Jan
24	Spinach	Mar to June	20	0.7	30	0.85	40	1	10	0.95	100	July to Oct
25	Squash	Feb & June	25	0.5	35	0.75	25	0.95	15	0.75	100	June & Oct
26	Tomato	Sep/ Oct	30	0.6	40	0.9	40	1.15	25	0.8	135	Feb/March
27	Turnip	Sep to Nov	10	0.5	20	0.85	25	1.1	5	0.95	60	Nov to Jan
28	Water Melon	Feb/ Mar	15	0.4	30	0.7	30	1	25	0.75	100	June/July
		Jun/ Jul										Oct/Nov

S.No	Month	Eto	Kc	Cf	WR	Eto (90% efficiency of System
		mm/day			mm/day	mm/day
1	Jan	3.2	0.60	0.30	0.58	0.64
2	Feb	3.8	0.60	0.40	0.91	1.01
3	Mar	4.9	0.85	0.60	2.50	2.78
4	Apr	6.3	0.85	0.80	4.28	4.76
5	May	7.1	0.85	1.00	6.03	6.71
6	June	6.5	0.85	1.00	5.52	6.14
7	July	5.2	0.85	1.00	4.42	4.91
8	August	4.8	0.85	1.00	4.08	4.53
9	Sep	5.1	0.85	1.00	4.33	4.82
10	Oct	5.0	0.75	1.00	3.75	4.17
11	Nov	3.9	0.75	1.00	2.92	3.25
12	Dec	3.2	0.75	1.00	2.40	2.67
					Average	3.86

PHYSICAL PROPERTIES OF SOILS

Soil Texture	Field Capacity (Fc)	Permanent Wilting Point (PWP)	Available Moisture (AW)=Water Holding Capacity=Fc-PWP		AW% by volume =Asg x % by weight	
	% by volume cm/ m	*% by volume cm/ m*	*% by volume cm/m*	*% by volume inch/foot*	mm/m	inch/foot
Sandy	15	7	8	1.00	82.5	0.99
	(10-20) Range	(3-10)	(7-10)	0.8-1.2		
loam	21	9	12	1.40	120.0	1.44
	(15-27)	(6-12)	(9-15)	1.1-1.80		
Loam	31	14	17	2.00	168.0	2.02
	(25-36)	(11-17)	(14-19)	1.7-2.3		
Clay loam	36	18	19	2.30	189.0	2.27
	(31-42)	(15-20)	(17-22)	2.0-2.6		
Silty clay	40	20	21	2.5	208.0	2.50
	(35-46)	(17-22)	(18-23)	2.2-2.8		
Clay	44	21	23	2.7	225.0	2.70
	(39-49)	(19-24)	(20-25)	2.4-3.0		

Source: Principles of Farm Irrigation System Design by Larry G. James 1988

Available Soil Water Holding Capacity (AW)

Soil Texture	Available Moisture (AW)/WHC mm/m		Inch/Foot
	Range	Average	
1. Very coarse texture-very coarse sand	33-62	**42**	**0.50**
2. Coarse texture-coarse, fine and loamy sands	62-104	**83**	**1.00**
3.Moderately coarse textured-sandy loams	104-145	**125**	**1.50**
4.Medium texture-very fine sandy loam, loam, silt loam	125-192	**167**	**2.00**
5.Moderately fine texure-clay loams, silty-clay loam, sandy clay loam	145-208	**183**	**2.20**
6.Fine texture-sandy clay, silty clay, clay	133-208	**192**	**2.30**
7.Peat, muck	167-250	**208**	**2.50**
Note: 1 mm/m = 0.012 inch/foot			

Source: Sprinkle and Trickle Irrigation by Jack Keller

Average Rooting Depth (Rd)

CATEGORY	CROP	mm	Foot
Shallow root depth-<500 mm	**Cabbage**	**400**	**2**
	Cauliflower	**400**	**2**
	Garlic	**400**	**2**
	Ginger	**500**	**2**
	Onion	**400**	**2**
	Rice	**300**	**1**
	Spinach	**400**	**2**
	Turmeric	**500**	**2**
Medium root Depth -500 to 1000 mm	**Banana**	**700**	**3**
	Bitter gourd	**600**	**2**
	Carrot	**500**	**2**

	Chickpea	**600**	**2**
	Chilli	**700**	**3**
	Coriander	**600**	**2**
	Groundnut	**600**	**2**
	Lentil	**600**	**2**
	Mustard	**600**	**2**
	Papaya	**600**	**2**
	Pointed gourd	**900**	**4**
	Potato	**500**	**2**
	Radish	**500**	**2**
	Sesbania	**600**	**2**
	Soybean	**700**	**3**
	Tomato	**1000**	**4**
	Turnip	**500**	**2**

Average Rooting Depth (Rd)

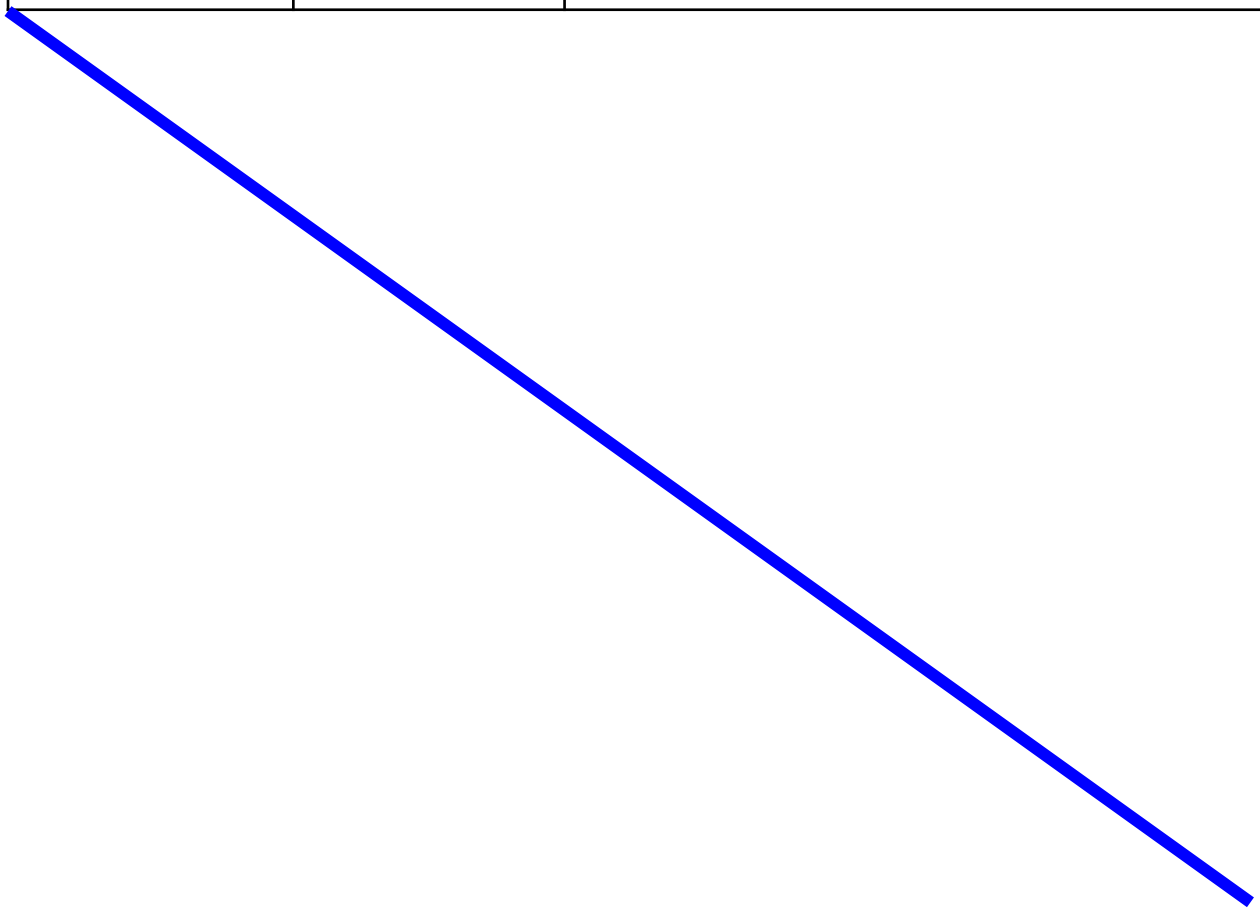
CATEGORY	CROP	mm	Foot
Deep root -1000 mm and above	**Bottle gourd**	**1200**	**5**
	Citrus	**1100**	**4**
	Cotton	**1200**	**5**
	Cucumber	**1200**	**5**
	Egg plant (Brinjal)	**1000**	**4**
	Fruit Trees	**1500**	**6**
	Grapes	**1200**	**5**
	Lady's finger (Okra)	**1000**	**4**
	Maize	**1300**	**5**
	Pumpkin	**1200**	**5**
	Sugarcane	**1500**	**6**
	Sweet potato	**1200**	**5**

	Watermelon	**1200**	**5**
	Wheat	**1200**	**5**

Maximum Allowable Depletion (MAD)%

CROP TYPE	CROP	MAD (%)
CEREALS	Wheat	50
	Maize	50
	Rice	80-100
OIL SEEDS	Mustard	50
	Groundnut	50
	Soybean	50
GOURDS	Pumpkin	50
	Watermelon	50
	Bittle gourd	50
	Cucumber	50
	Bottle gourd	50
ROOTAND TUBER CROPS	Radish	50
	Potato	70
	Sweet potato	50
	Carrot	50
VEGETABLES	Tomato	65
	Egg plant	65
	Cauliflower	65
	Spinach	65
SPICES	Chilli	60
	Coriander	65
	Garlic	70
	Garlic	50
	Onion	70
	Turmeric	50
FRUIT	Banana	65

	Papaya	50
SUGAR CROPS	Sugarcane	70 50



Flood Irrigation

Sprinkler Irrigation

Drip Irrigation

HOW MUCH DEPTH OF WATER T BE APPLIED (MM) FOR FULL IRRIGATION

Maximum Irrigation Depth to be applied for FULL IRRIGATION

Id = TAW x MAD(%)
Id = Maximum net depth of water to be applied per irrigation, mm (in.)
This is the same as RAW
AW = (FC) – (PWP) or figures of AW are available
TAW = AW x Rd
MAD = Management Allowable Deficit of the soil
For example if Aw= 125 mm/m, Rd=1.2 m, MAD= 50% then

TAW = 125 x 1.2 = 150 mm

Id = 150 x 50/100 = 75 mm= RAW

Maximum Irrigation Interval

$$Ii = \frac{Id}{\text{Peak Daily Crop Water Requirement}}$$

Where

Ii = Irrigation interval or frequency (days)

Id = Net depth of water application per irrigation to meet Water Requirement

ETc = Daily crop water requirement

For example if Peak ETc is 9.77 mm/day, then irrigation interval = **75/9.77 = about 8 days**

Exercise-1

For the following data of ETo, given in mm/day.

Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec

4.3 4.1 4.2 3.9 3.3 2.9 3.2 4.2 5.5 6.2 4.9 4.3

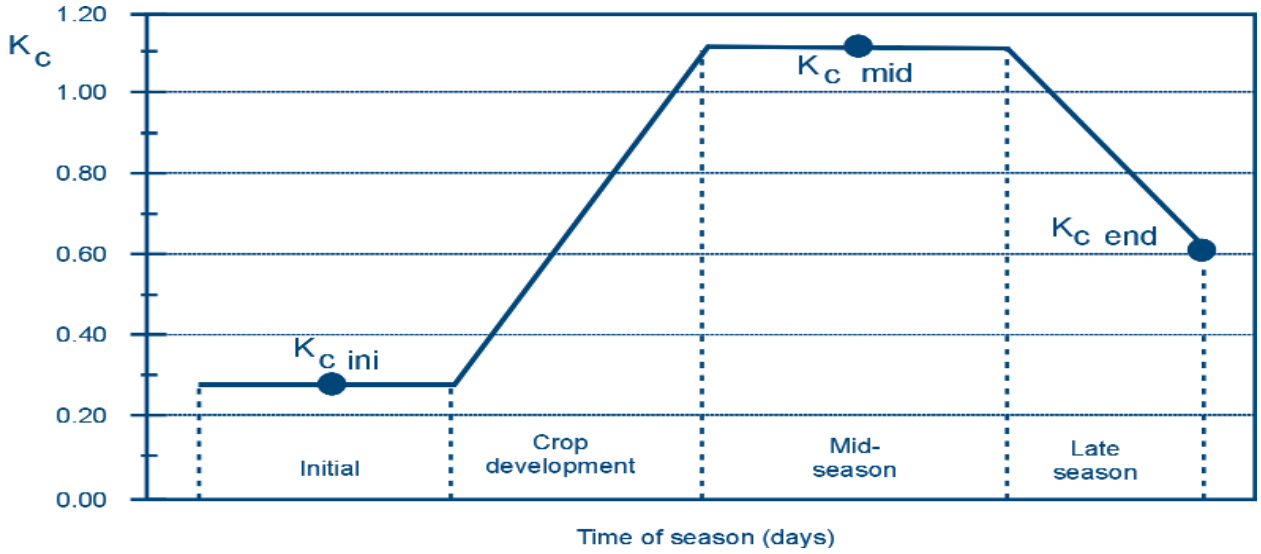
Kc ini = 0.59, Kc mid = 1.20, Kc end = 0.35

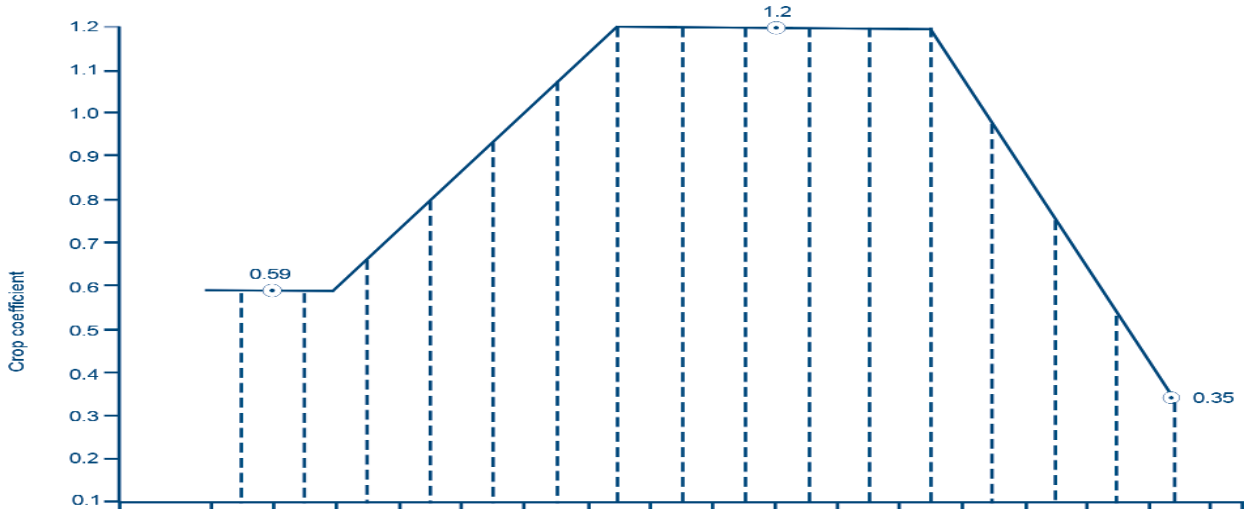
Estimate the crop evapotranspiration for a maize crop planted on 15 October on the project site. The soils are heavy textured.

The first step is to establish the length of the growth stages:

- Based on local experience, the duration of the initial stage is expected to be 20 days for a maize crop planted on 15 October, because of the favorable weather conditions. The development stage, also from local experience, will be 45 days and the mid-season stage will be 50 days. The late season stage is expected to last 39 days.
- Therefore the crop will finish around the 15th of March.
- *The Kc curve for maize can now be drawn, for initial planning purposes, where Kc ini , Kc mid, and Kc end are 0.59, 1.2 and 0.35 respectively, and the four lengths of growth stages are 20, 45, 50 and 39 days.*

- *Using the ETo figures and the Kc values, the crop evapotranspiration ETc for maize can be calculated. For a decade within one month, the daily ETo within the month is multiplied with the corresponding Kc to derive the ETc.*
- *For the first full decade in October ETc = 6.2 x 0.59 = 3.7 mm/day.*
- *For a decade that falls in two months, the weighted average of daily ETo from each month is multiplied by the corresponding Kc. For example, the ETc of decade 2 (end of October and early November) is calculated as follows:*
- *ETo in October = 6.2 mm/day and ETo in November = 4.9 mm/day.*
- *The planting date being 15 October means that decade 2 has 5 days in October and 5 days in November. The weighted ETo would be: (5/10) x 6.2+ (5/10) x 4.9 = 5.6 mm/day. This proportional ETo would then be multiplied by the corresponding Kc.*





Decade	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
	October		November		December		January				February			March		
K_c	0.59	0.59	0.66	0.79	0.92	1.06	1.20	1.20	1.20	1.20	1.20	1.20	0.98	0.75	0.54	0.35
ET_o	6.18	5.56	4.93	4.62	4.31	4.31	4.29	4.26	4.26	4.17	4.08	4.08	4.08	4.15	4.21	4.21
ET_c	3.65	3.28	3.25	3.89	4.25	4.57	5.17	5.15	5.11	5.11	5.00	4.90	4.00	3.11	2.27	1.47

Exercise-2

Maiz has to be grown on July 21st at Agriculture Farm IUB, District Bahawalpur.

Estimate the crop water requirement (mm/day) for whole of the growing period (at 10 day interval).