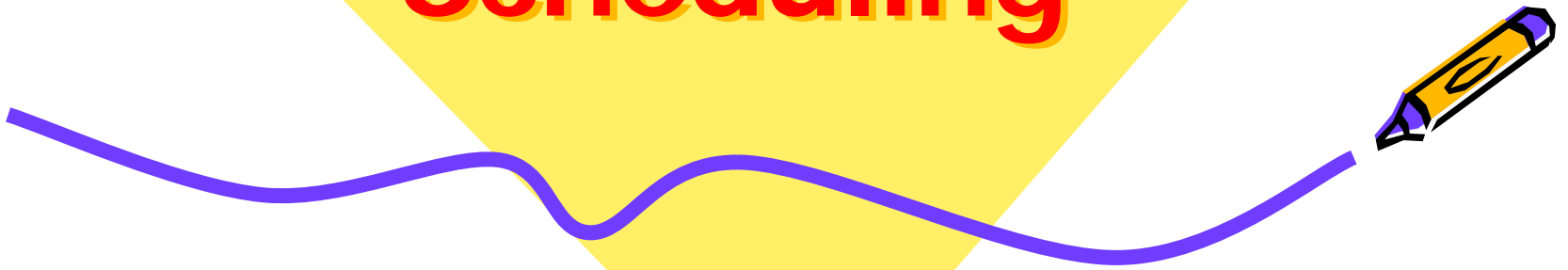




# Water Balance Irrigation Scheduling



Richard L. Snyder, LAWR, University of California, Davis

# CIMIS Stations



California Irrigation Management Information System (CIMIS)  
**REFERENCE EVAPOTRANSPIRATION**

STATE OF CALIFORNIA  
 THOMAS M. ARNOLD, GOVERNOR  
 DEPARTMENT OF WATER RESOURCES  
 LARRY M. LUTHE, DIRECTOR  
 2007 Water Assessment Report

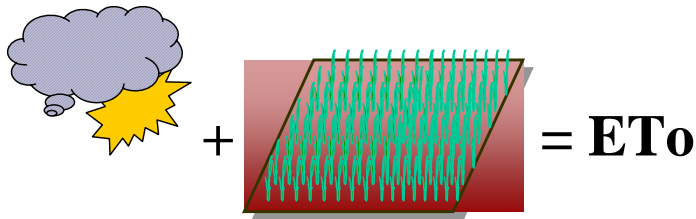
Developed as a cooperative project between the  
 Department of Land and Water Resources  
 and the Department of Water  
 California Department of Water Resources  
 California Department of Water Resources  
 May Prepared by David W. Jones 1999  
 Data Analyzed by Richard L. Ripstein, Richard L. Ripstein, Richard L. Ripstein, Richard L. Ripstein  
 Background Data from Water and USGS Stations

# CIMIS

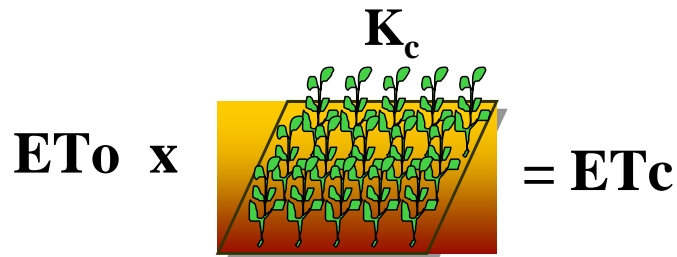
1. Provides ETo information to California
2. Started July 1982
3. Transfer July 1985 to DWR
4. Currently 120-130 stations
5. Calculate ETo with modified Penman Eq.
6. Before CIMIS < 0.5% used ET
7. Currently, about 30-35% of farmers use ET
8. Currently, more than 50% of area uses ET



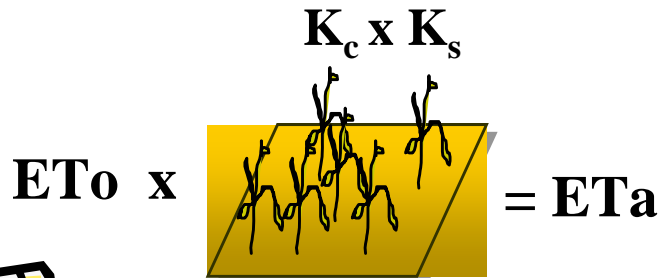
# Estimating Crop ET ( $ET_a$ )



$ET_0$  from weather



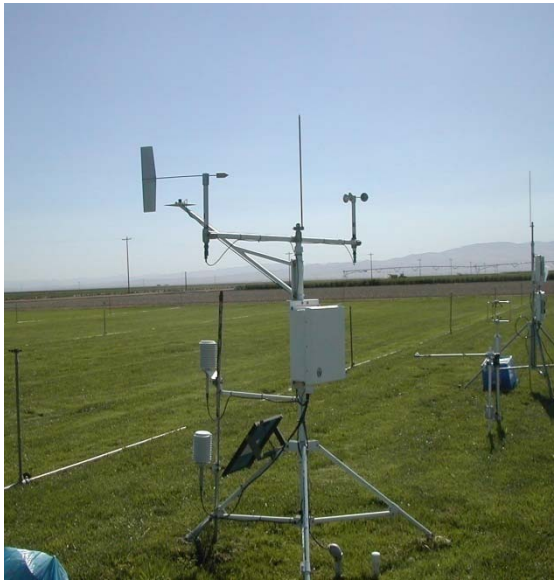
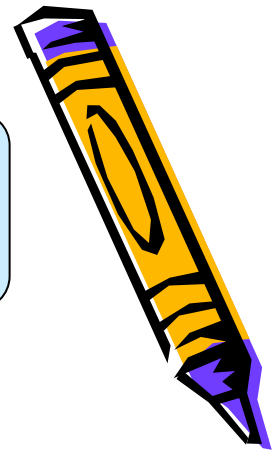
$ET_c = ET_0 \times K_c$



$ET_a = ET_c \times K_s$



# ETo Stations (over grass)





# Crop Coefficient

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

$ET_c$  - measured

$ET_o$  - estimated

$ET_0$  - accounts for weather

$K_c$  - accounts for crop

surface wetness

light absorption

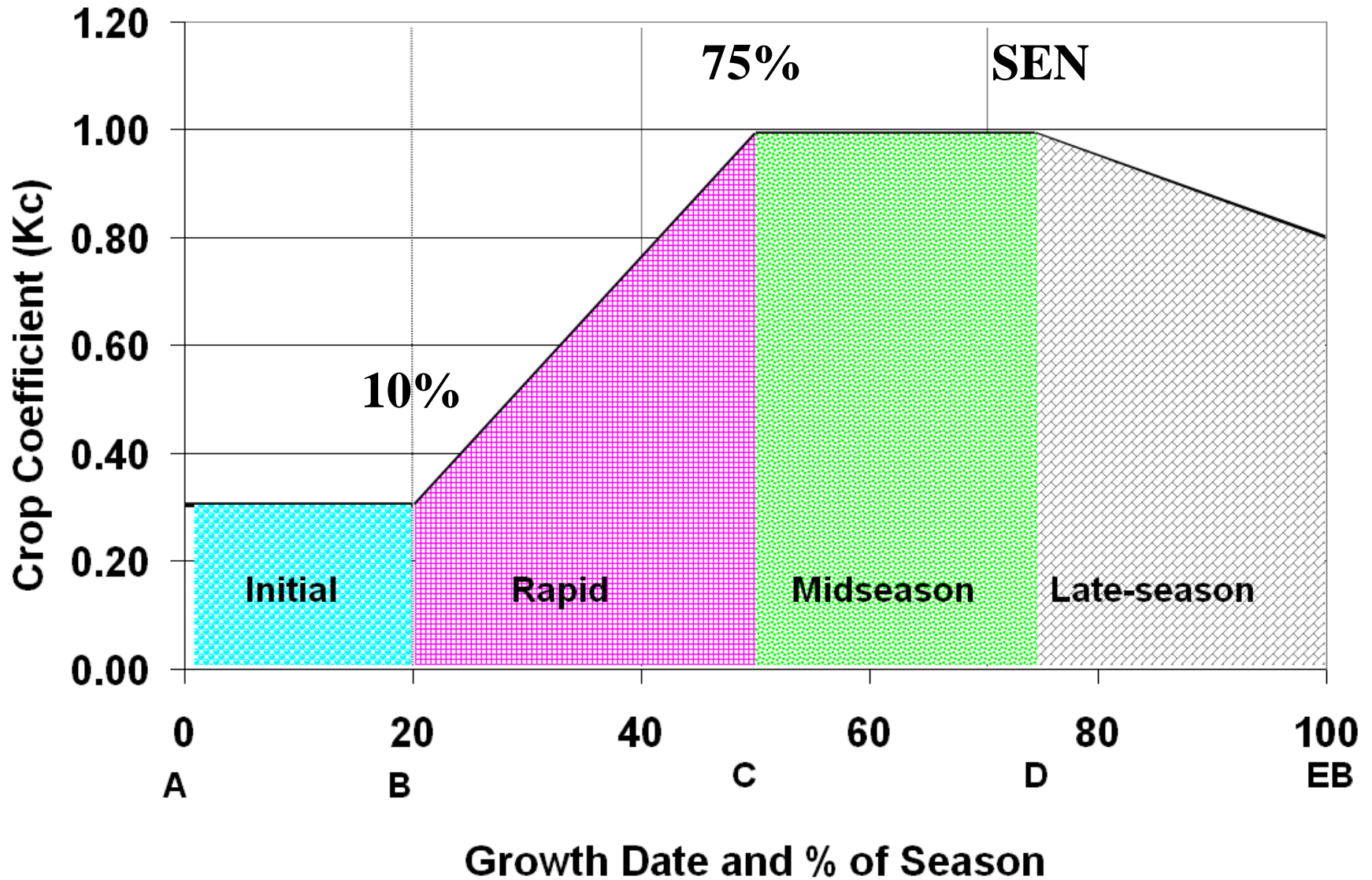
canopy roughness

physiology

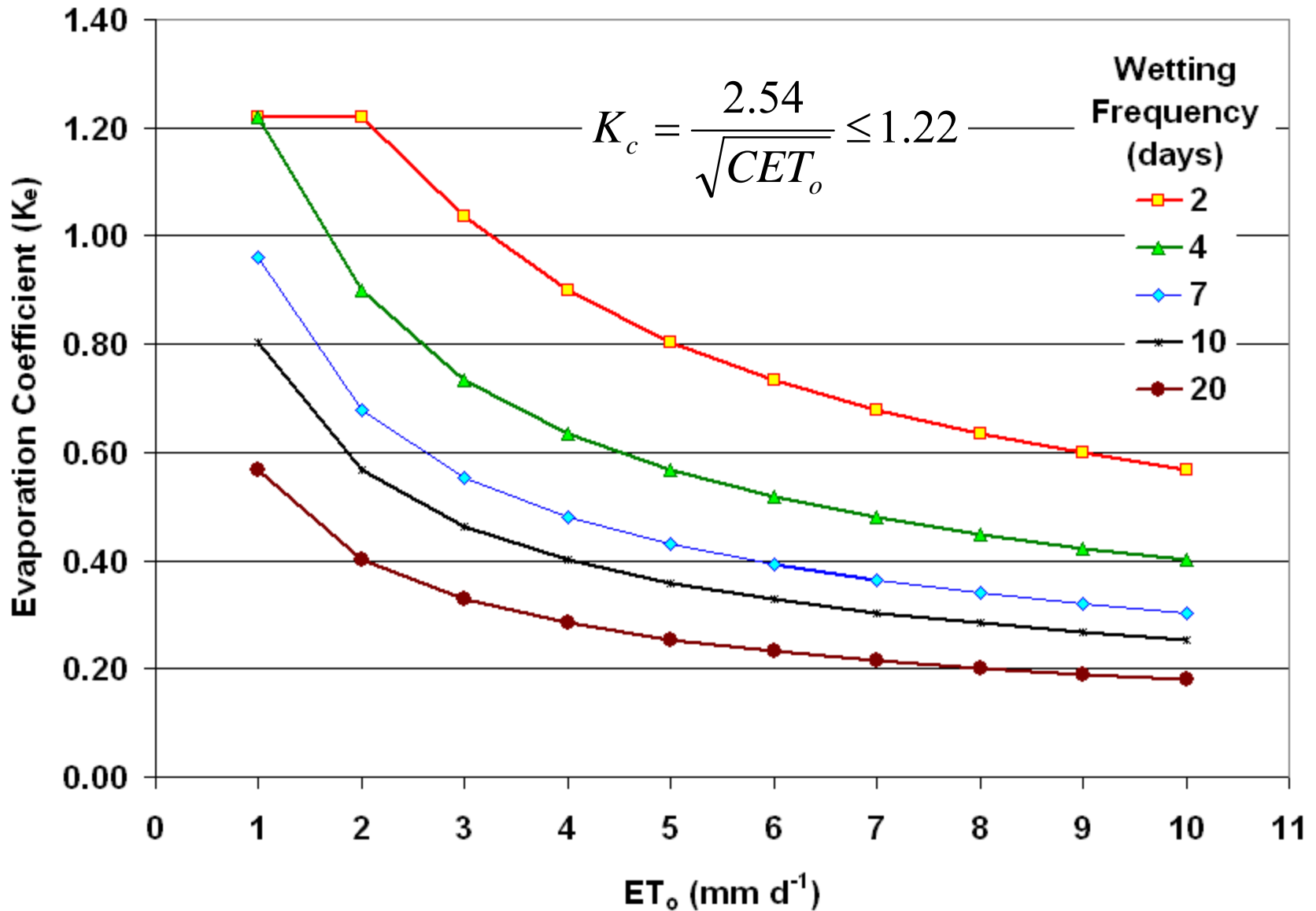
age



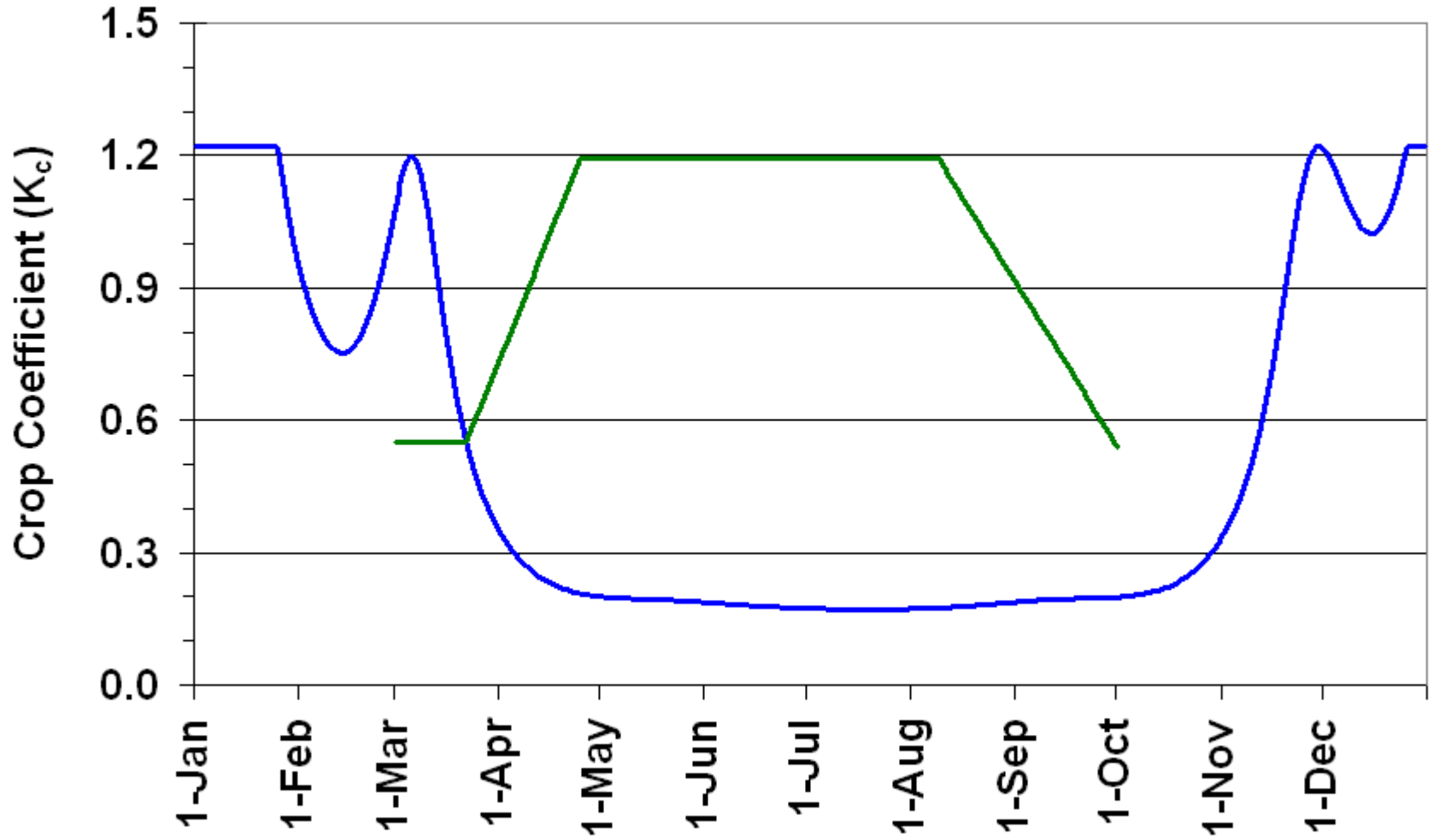
# Field & Row Crops



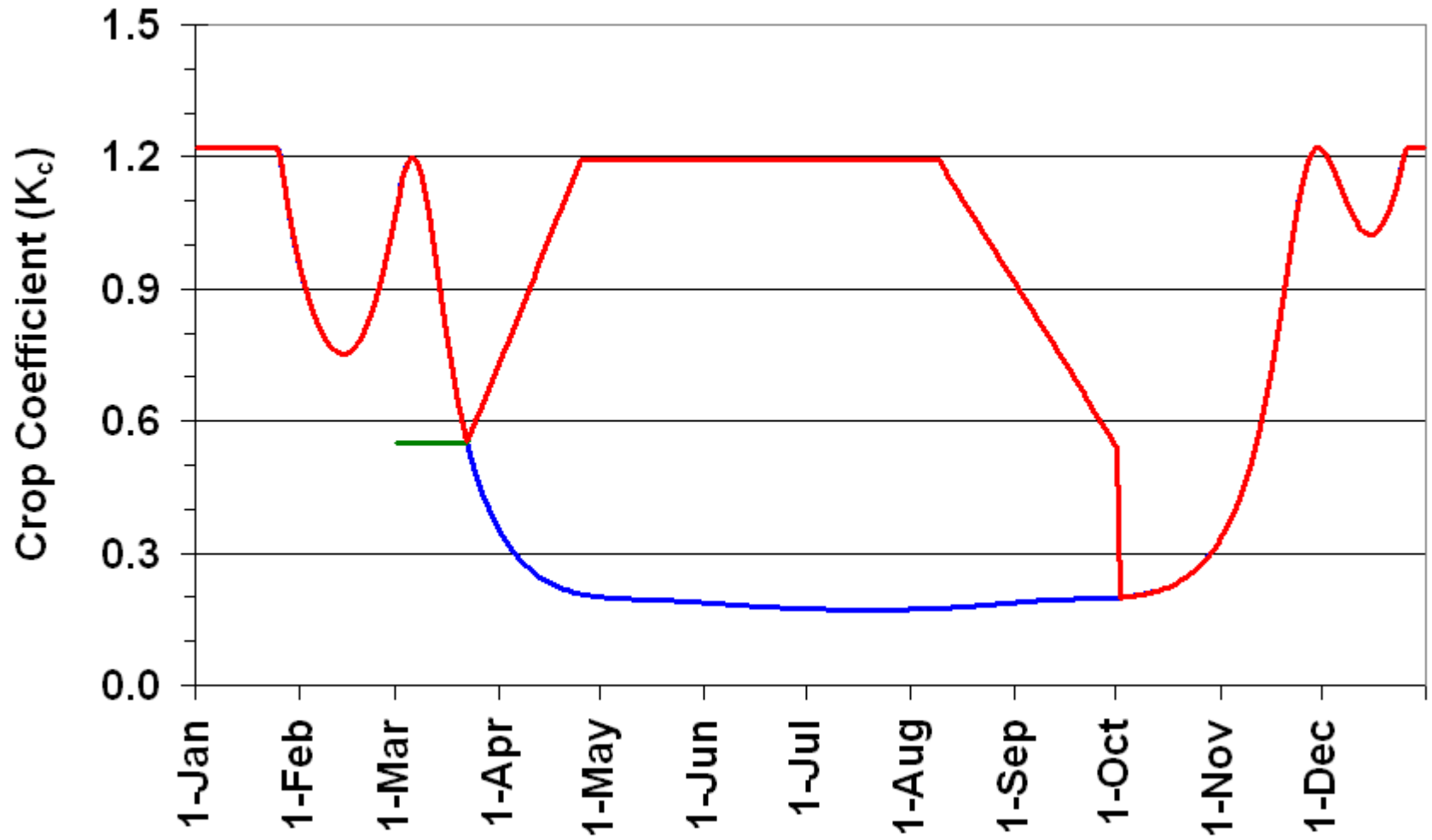
# Evaporation Coefficient ( $K_e$ )



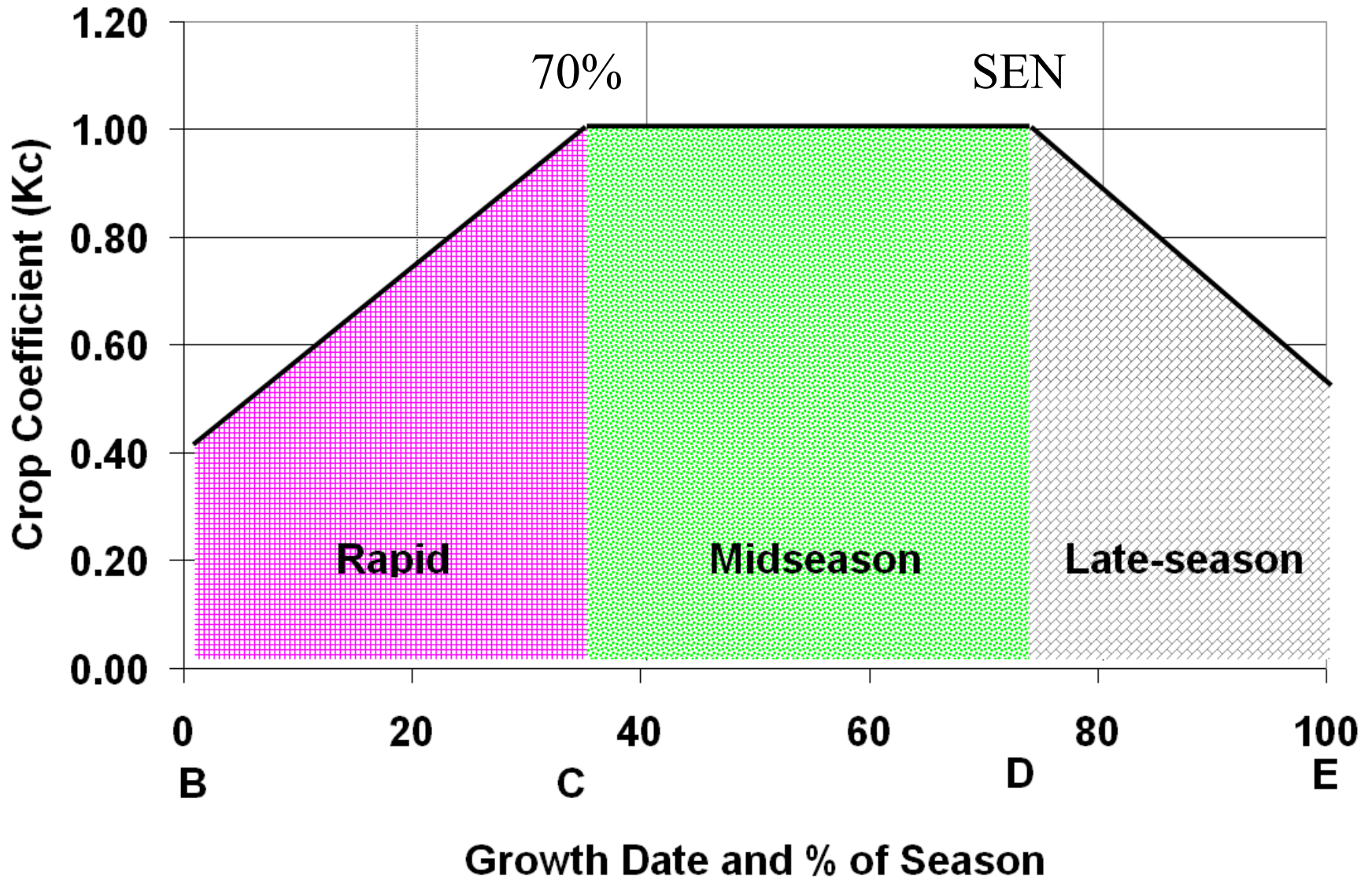
# In-season $K_c$ and $K_e$



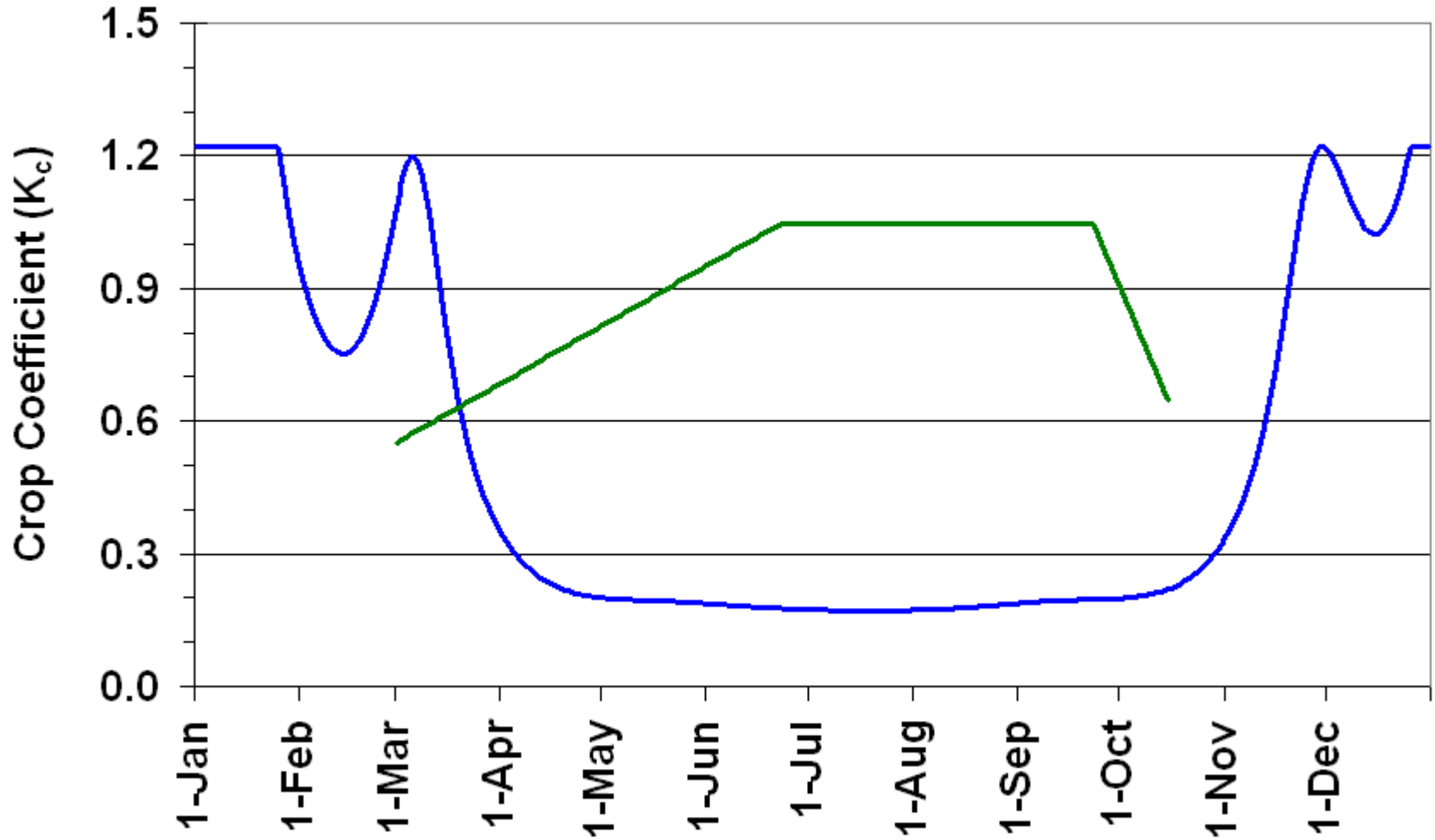
# Adjusted for Rainfall



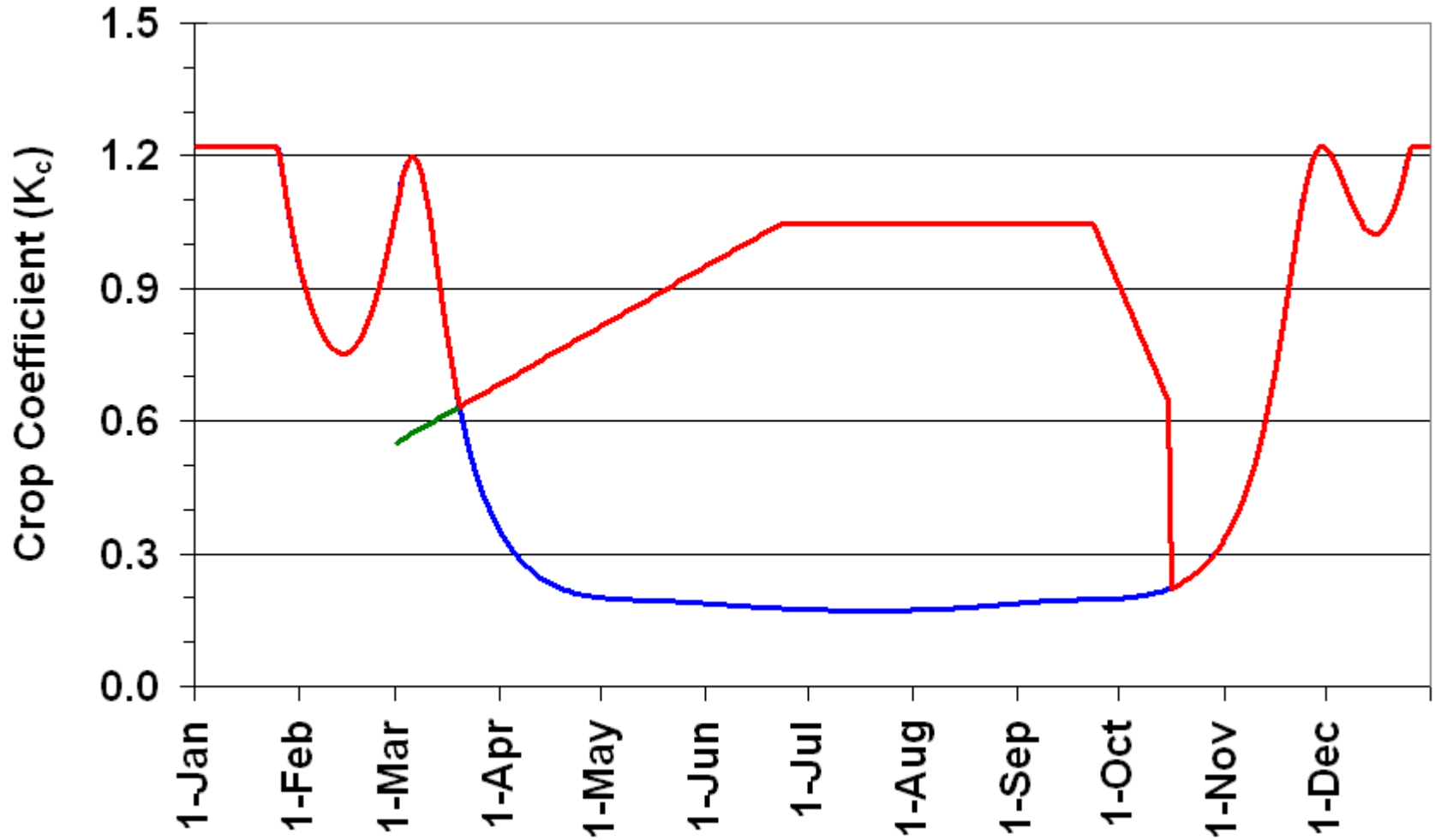
# Orchard & Vine Crops



# Deciduous Orchard $K_c$ and $K_e$

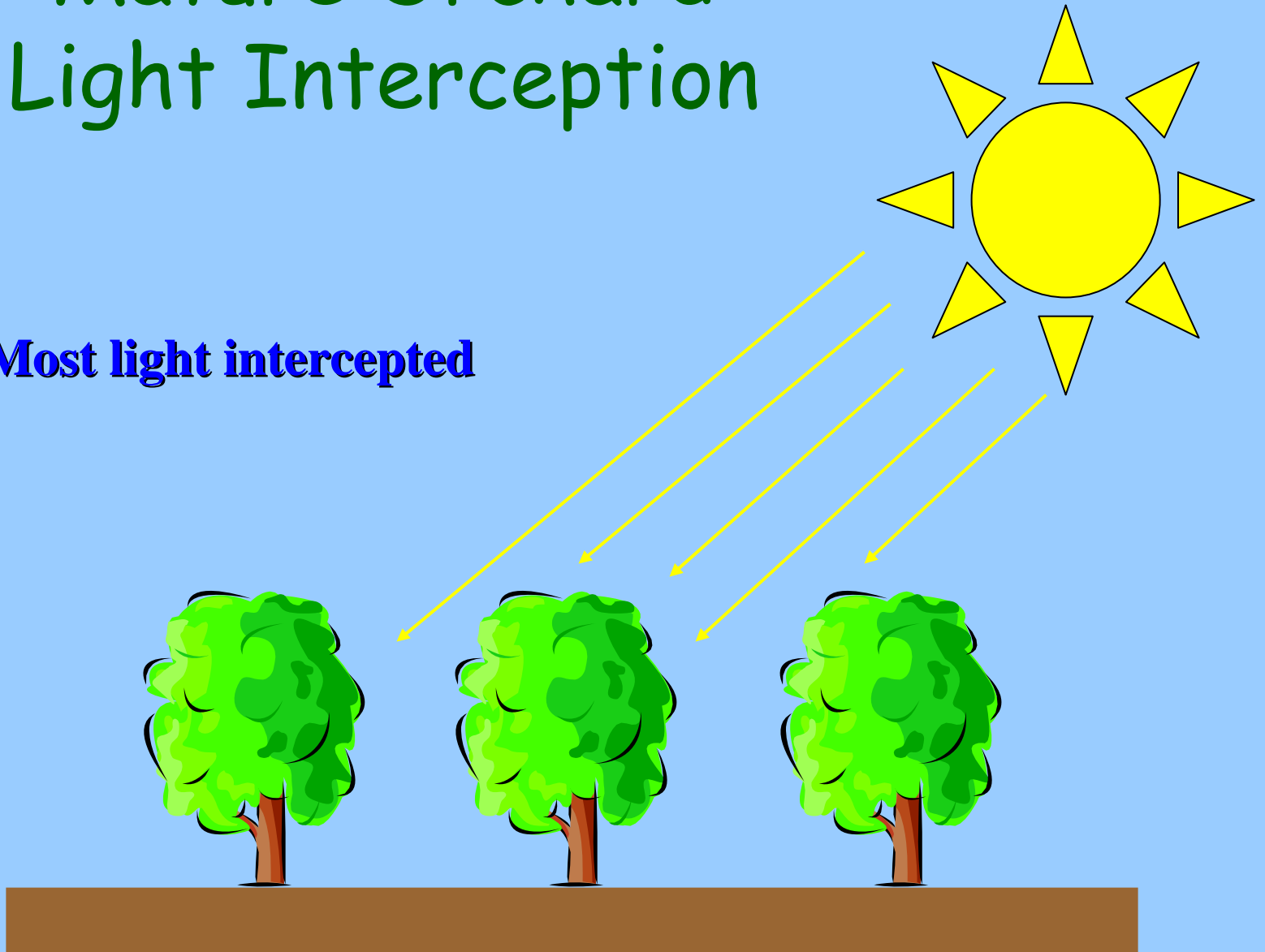


# Deciduous Orchard Rainfall Adjustment



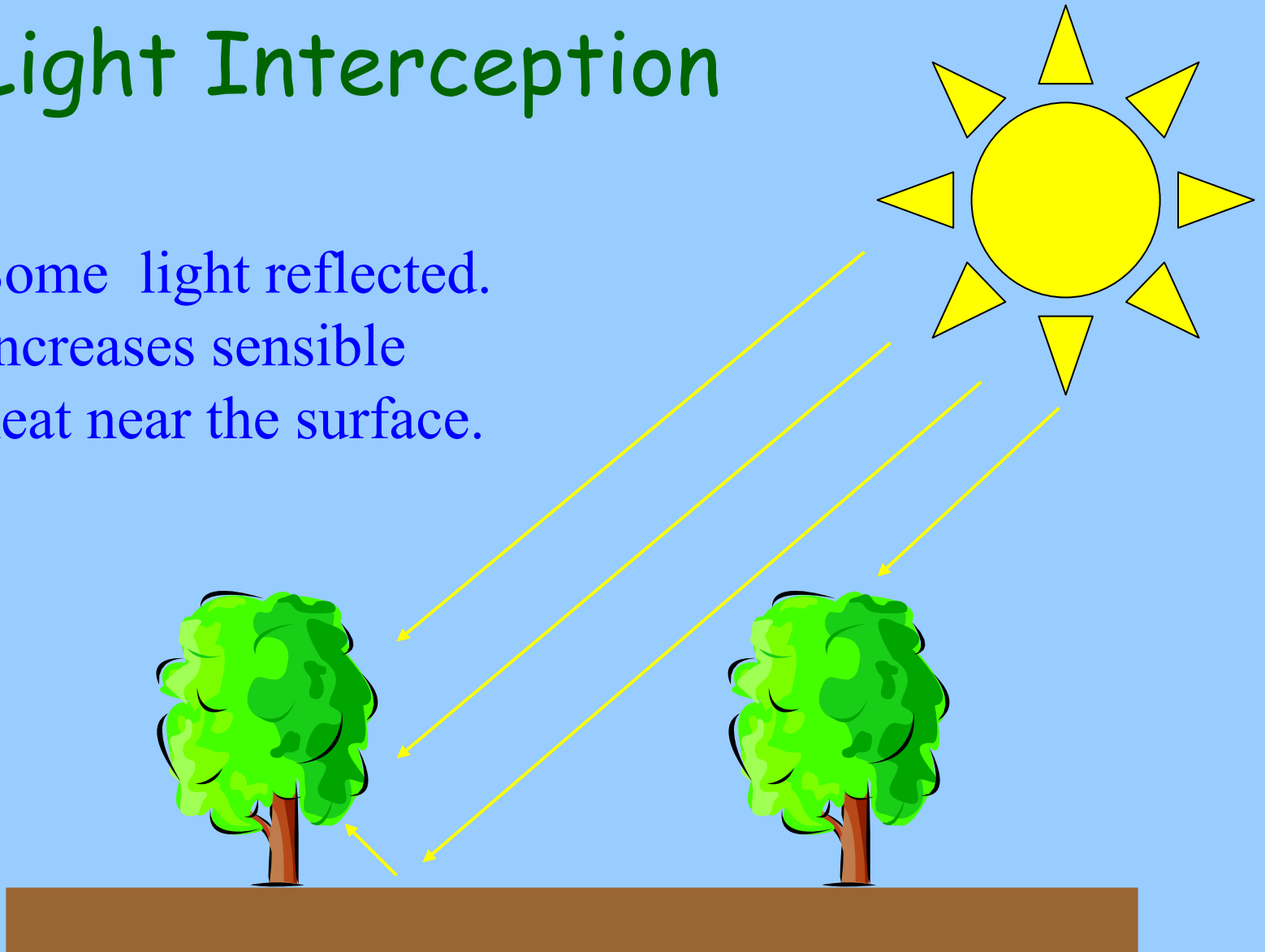
# Mature Orchard Light Interception

**Most light intercepted**

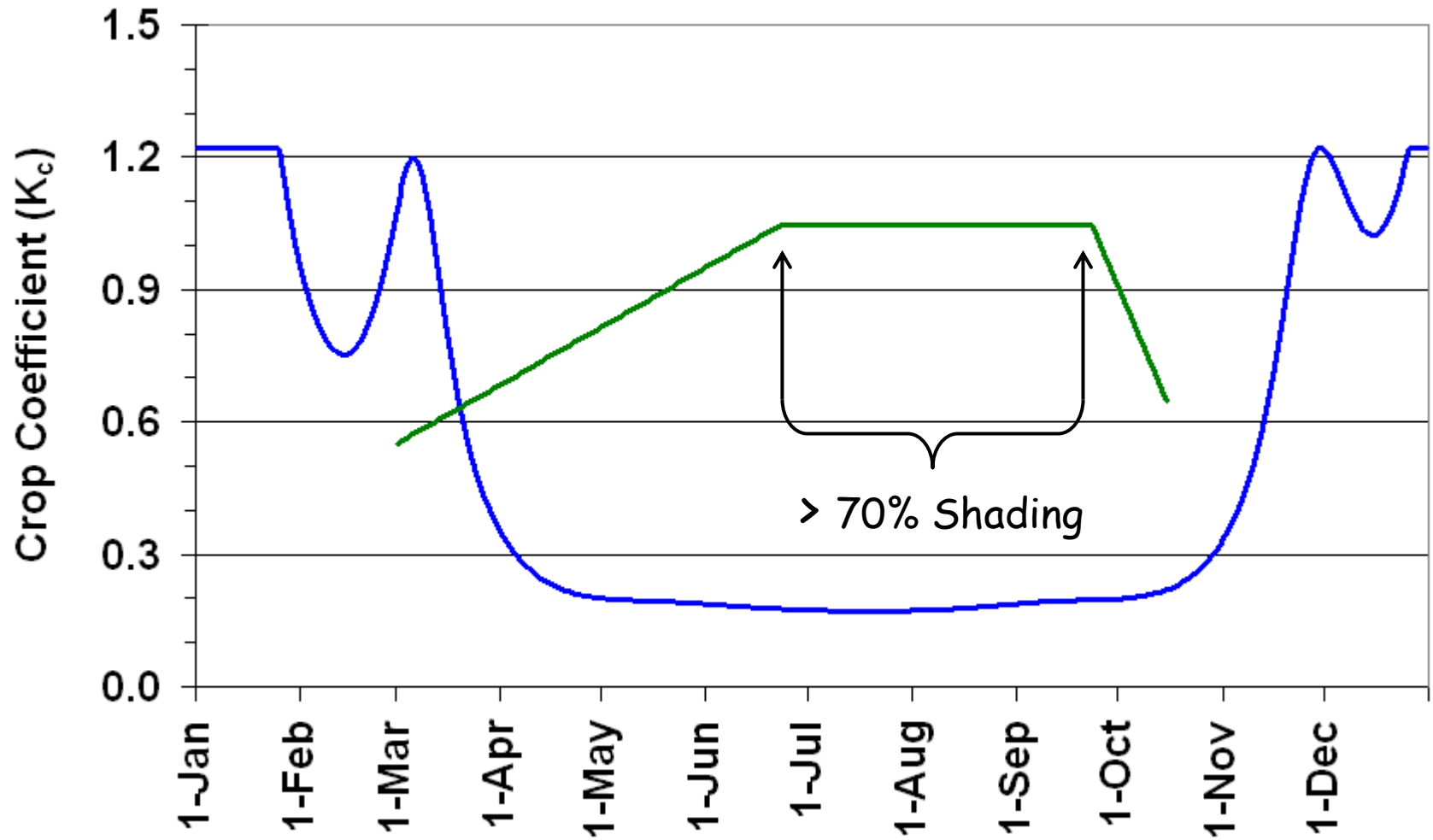


# Immature Orchard Light Interception

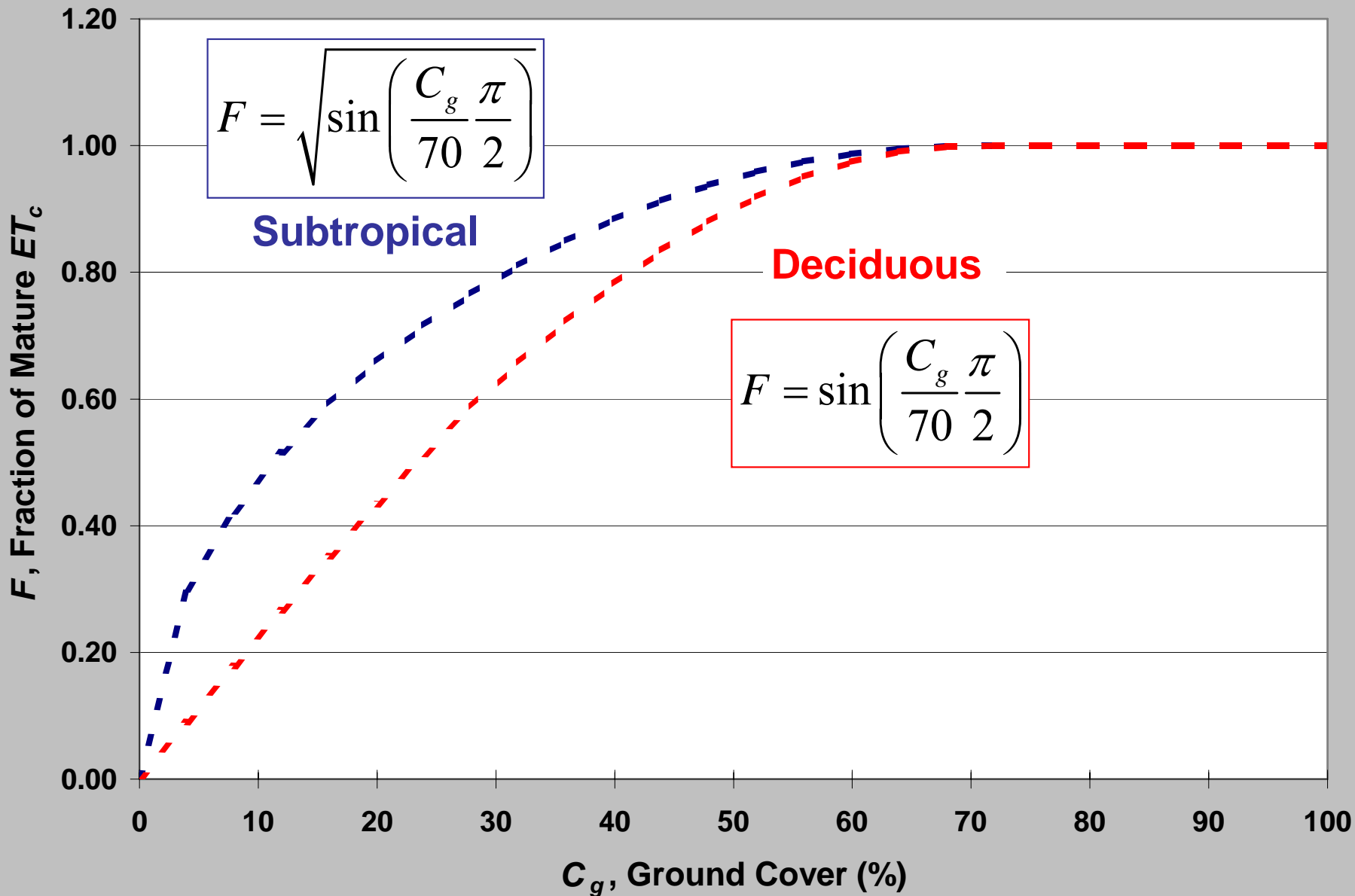
Some light reflected.  
Increases sensible  
heat near the surface.



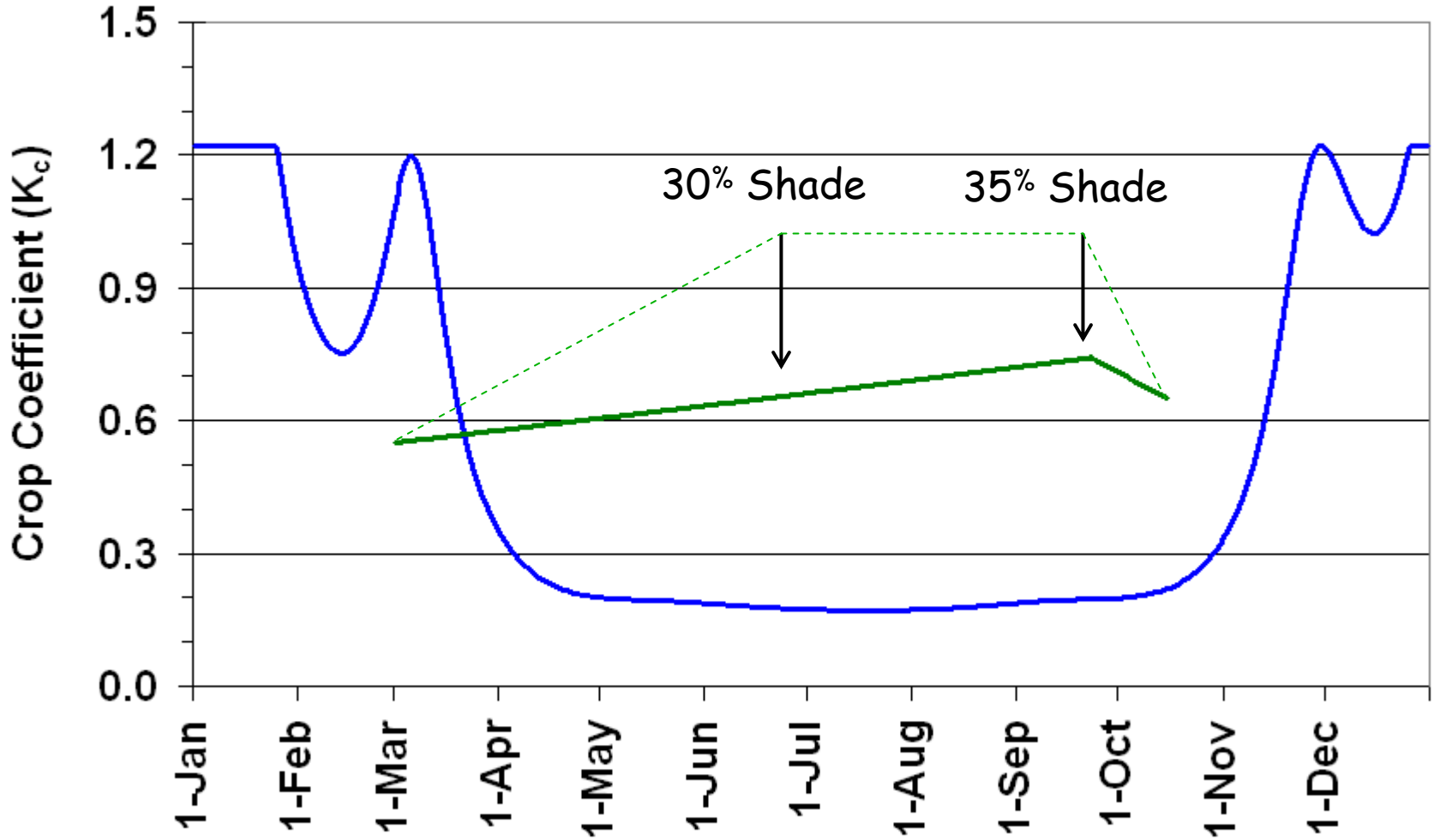
# Mature Deciduous Orchard



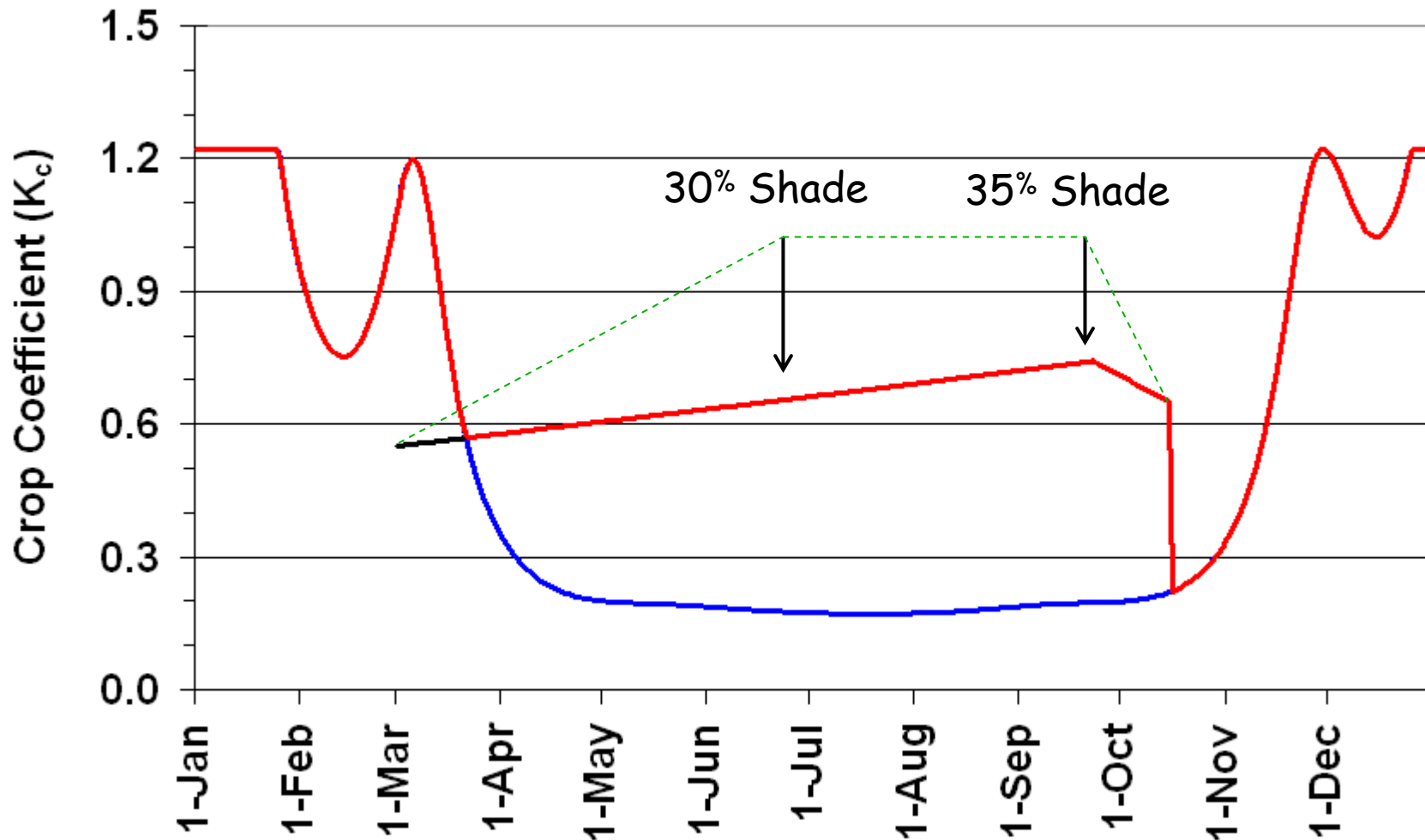
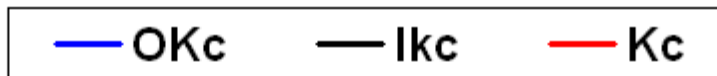
# Correction for Immaturity



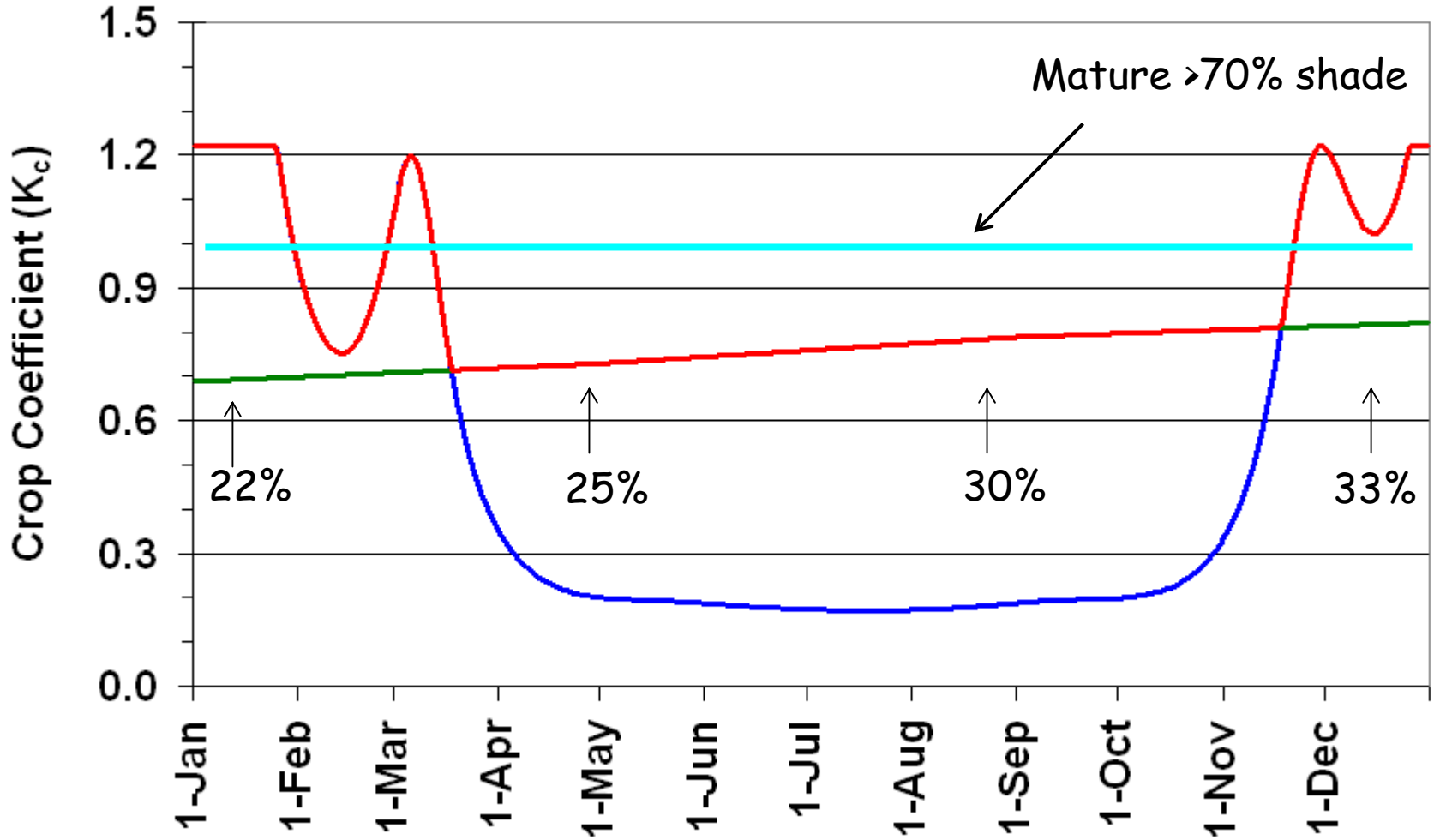
# Immature Deciduous Orchard



# Immature Deciduous Orchard Kc



# Immature Citrus Kc Adjustment



# Water Balance



$$\Delta W = I + P + C - R - D - ET_a$$

$\Delta W$ -change in water content

$I$  - irrigation application

$P$ - precipitation (& fog)

$C$ - capillary (water table)

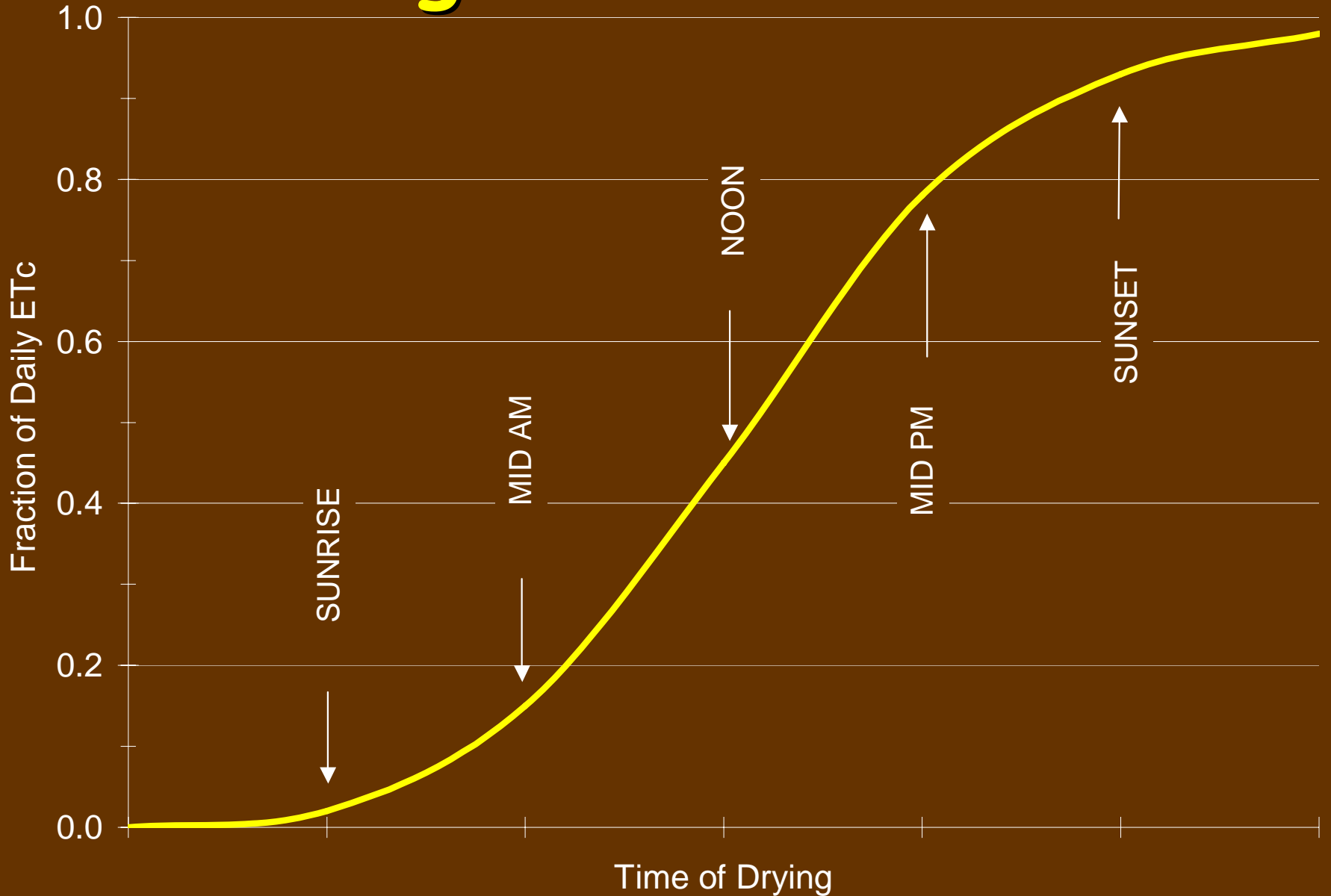
$R$ - runoff

$D$ - deep percolation

$ET_a$ -actual evapotranspiration

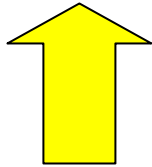


# Fog Contribution



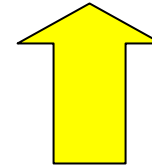
# Water Table Contribution

$ET_c$



No Water Table

$ET_c$



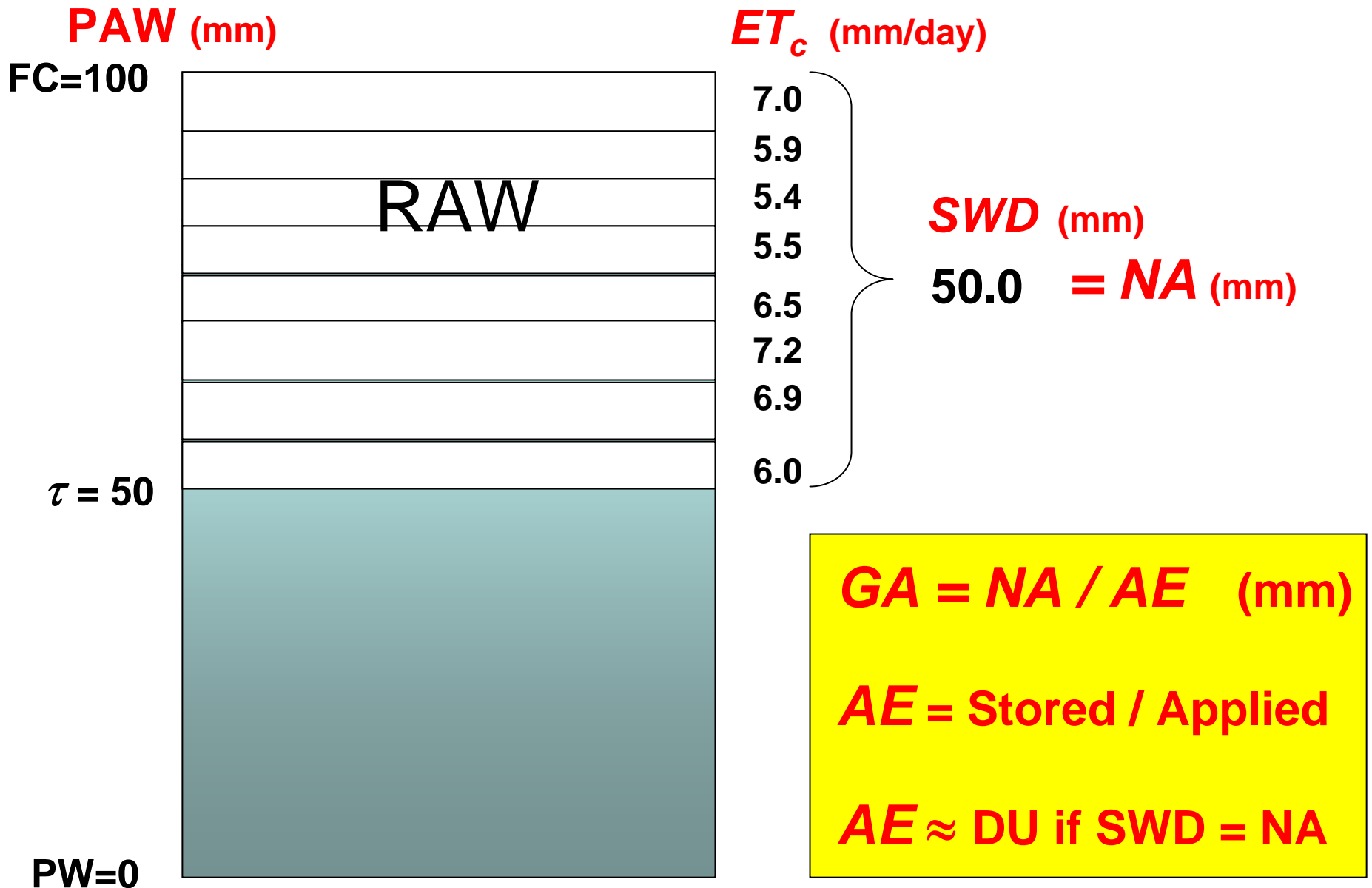
With Water Table

# High Frequency System Evaluations

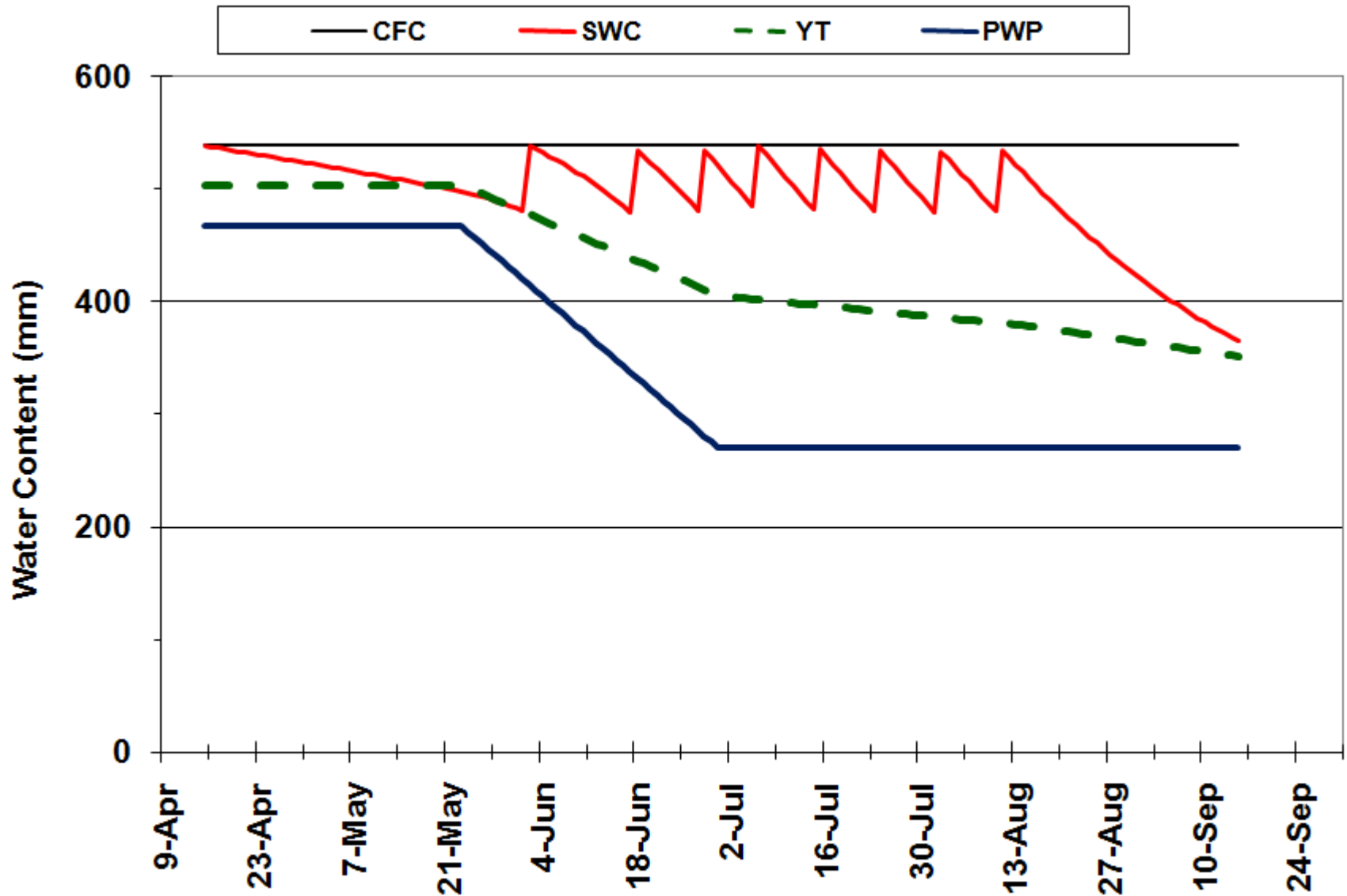
SIT E	DU	Published Flow Rate	Mean Flow Rate	Range Flow Rate
	%	(lph)	(lph)	(lph)
1	81	1.9	1.5	0.8-2.3
2	38	45.4	34.1	10.6-75.7
3	57	3.8	3.4	1.9-8.7
4	96	40.5	36.7	36.3-37.1
5	75	22.7	20.8	14.0-21.6

CVRCD Mobile Lab team in Coachella Valley

# Basic Irrigation Scheduling



# Tomatoes (AR=10 mm/hr; AE=75%)



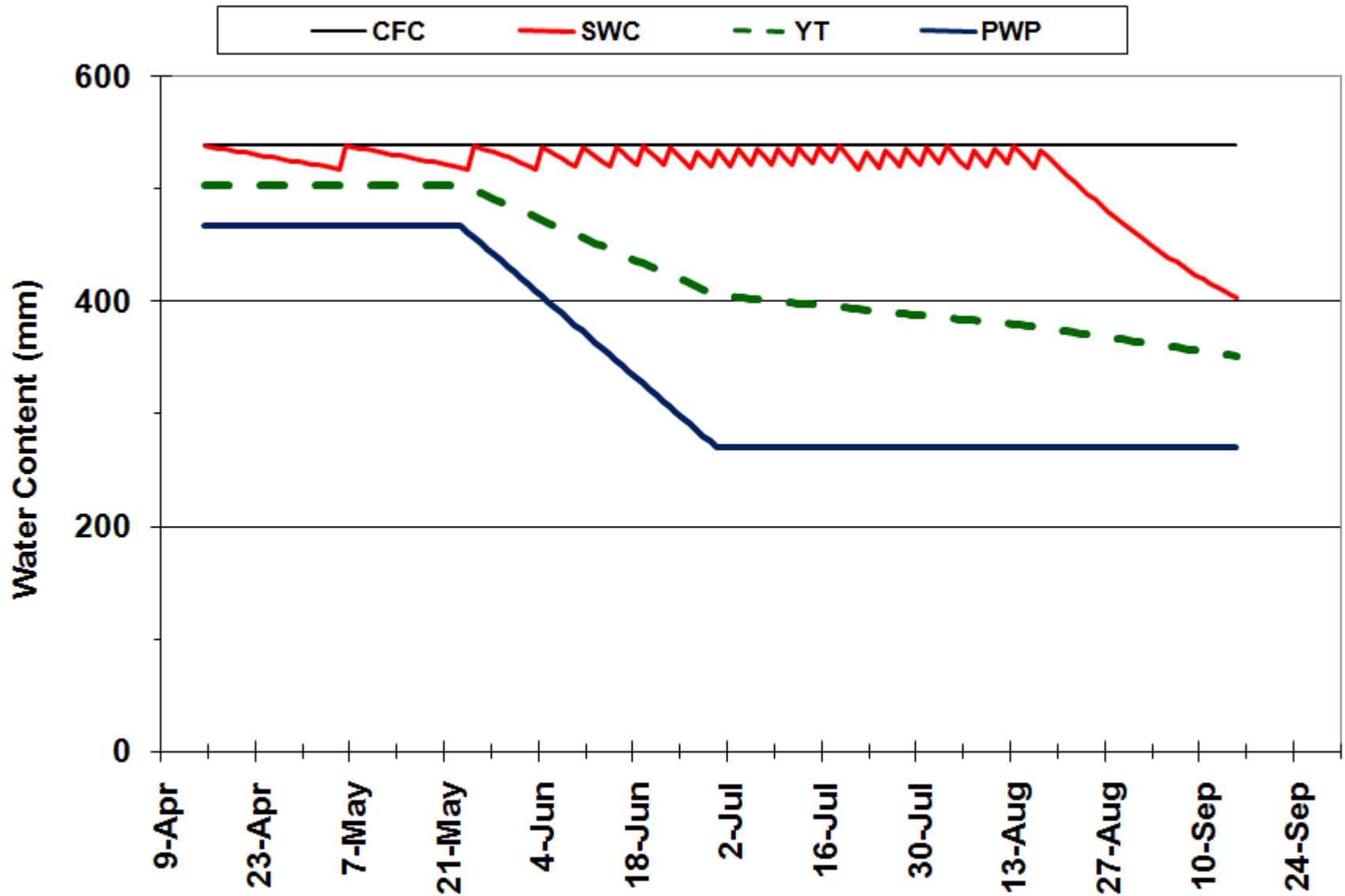
Year: 2002  
crop: Tomato

Growth

Date	Date	Kc
A	15-Apr-02	0.19
B	23-May-02	0.19
C	30-Jun-02	1.05
D	15-Aug-02	1.05
E	15-Sep-02	0.65

Number	Date	NA mm	GA mm	AE %	Runtime	
					Hours	Minutes
1	02-Jun-02	60	80	75	8	0
2	18-Jun-02	60	80	75	8	0
3	28-Jun-02	60	80	75	8	0
4	06-Jul-02	60	80	75	8	0
5	15-Jul-02	60	80	75	8	0
6	24-Jul-02	60	80	75	8	0
7	02-Aug-02	60	80	75	8	0
8	11-Aug-02	60	80	75	8	0

# Tomatoes (AR=1.0 mm/hr; AE=90%)



Year: 2002  
crop: Tomato

Growth

Date	Date	Kc
A	15-Apr-02	0.19
B	23-May-02	0.19
C	30-Jun-02	1.05
D	15-Aug-02	1.05
E	15-Sep-02	0.65

Number	Date	NA mm	GA mm	AE %	Runtime	
					Hours	Minutes
1	06-May-02	21.6	24.0	90	24	0
2	25-May-02	21.6	24.0	90	24	0
3	04-Jun-02	21.6	24.0	90	24	0
4	10-Jun-02	21.6	24.0	90	24	0
5	15-Jun-02	21.6	24.0	90	24	0
6	19-Jun-02	21.6	24.0	90	24	0
7	23-Jun-02	21.6	24.0	90	24	0
8	27-Jun-02	21.6	24.0	90	24	0
9	30-Jun-02	21.6	24.0	90	24	0
10	03-Jul-02	21.6	24.0	90	24	0
11	06-Jul-02	21.6	24.0	90	24	0
12	09-Jul-02	21.6	24.0	90	24	0
13	12-Jul-02	21.6	24.0	90	24	0
14	15-Jul-02	21.6	24.0	90	24	0
15	18-Jul-02	21.6	24.0	90	24	0
16	22-Jul-02	21.6	24.0	90	24	0
17	25-Jul-02	21.6	24.0	90	24	0
18	28-Jul-02	21.6	24.0	90	24	0
19	31-Jul-02	21.6	24.0	90	24	0
20	03-Aug-02	21.6	24.0	90	24	0
21	07-Aug-02	21.6	24.0	90	24	0
22	10-Aug-02	21.6	24.0	90	24	0
23	13-Aug-02	21.6	24.0	90	24	0
24	17-Aug-02	21.6	24.0	90	24	0



Table Grapes



Pasture



Rice



Peach Orchard



Bare Soil



Citrus



**The End**

**Thanks**

*R.L. Snyder*

*<http://biomet.ucdavis.edu>*

Copyright © Regents of the University of California 2003

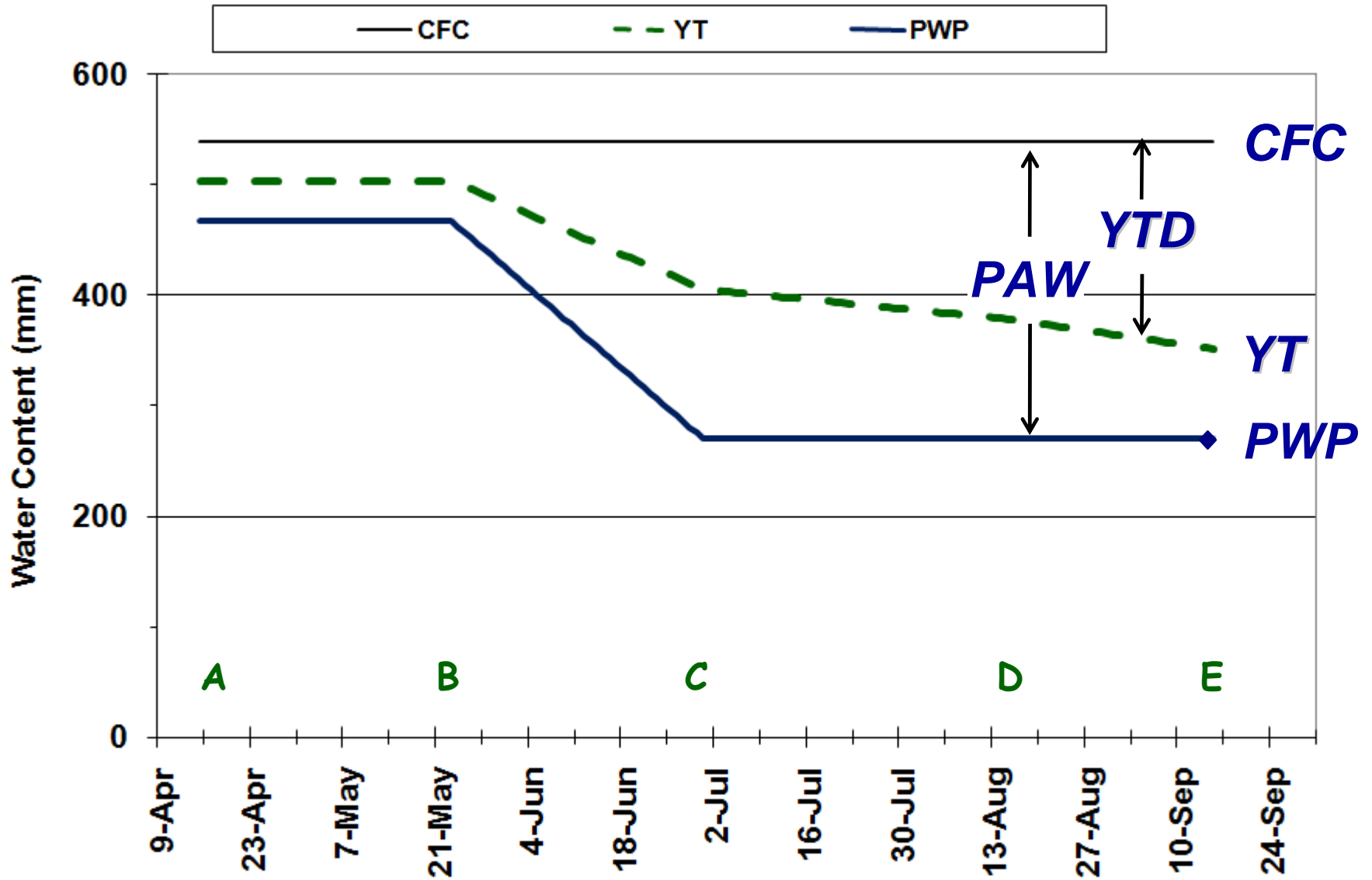
# Soil and Crop Characteristics



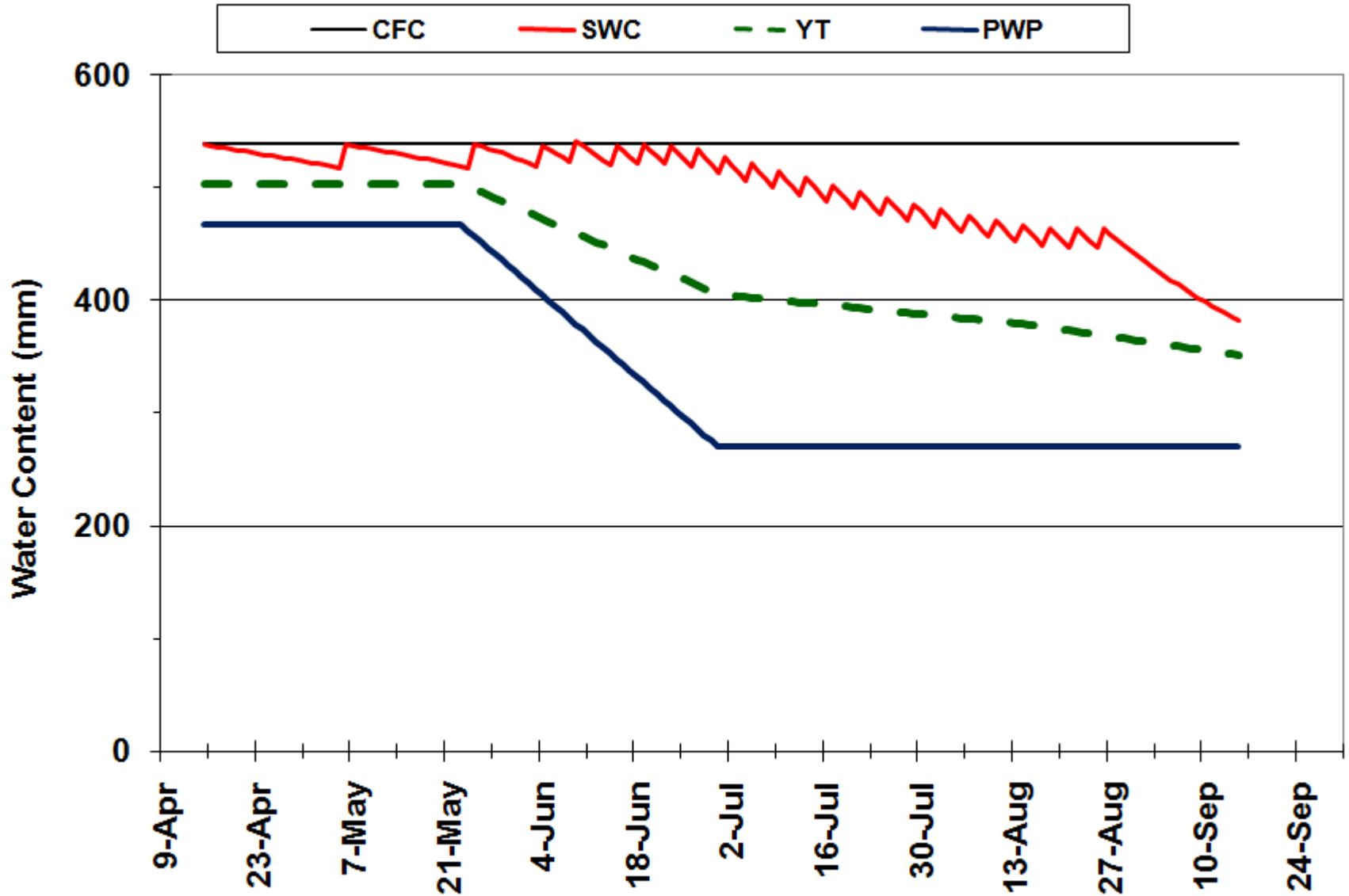
Date	Growth Date	Rooting Depth	Total Water Holding Capacity	Available Water Holding Capacity	Cum Field Capacity CFC	Plant Available Water PAW	Allowable Depletion	Yield Threshold YTD
		m	m/m	m/m	mm	mm	%	mm
15-Apr-02	A	0.4	0.36	0.16	540	72	50	36
23-May-02	B	0.4	0.36	0.16	540	72	50	36
30-Jun-02	C	1.5	0.36	0.18	540	270	50	135
15-Aug-02	D	1.5	0.36	0.18	540	270	60	162
15-Sep-02	E	1.5	0.36	0.18	540	270	70	189



# SW Content



# Tomatoes (AR=1.0 mm/hr; DU=90%)

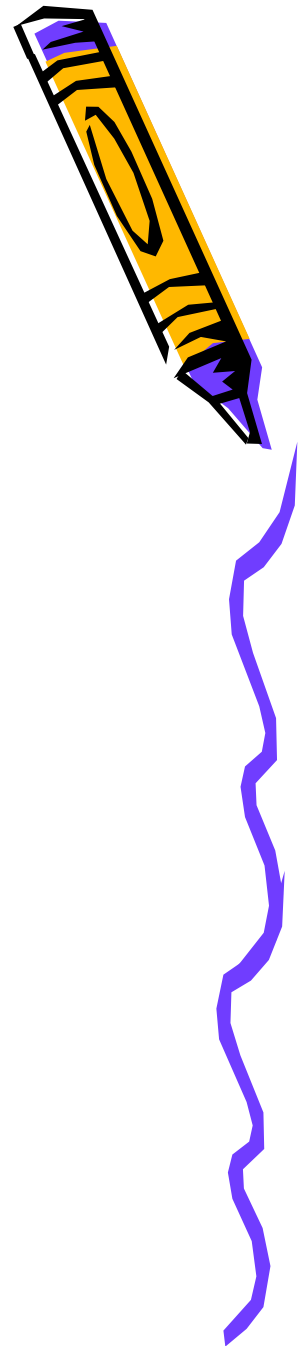


Year: 2002  
crop: Tomato

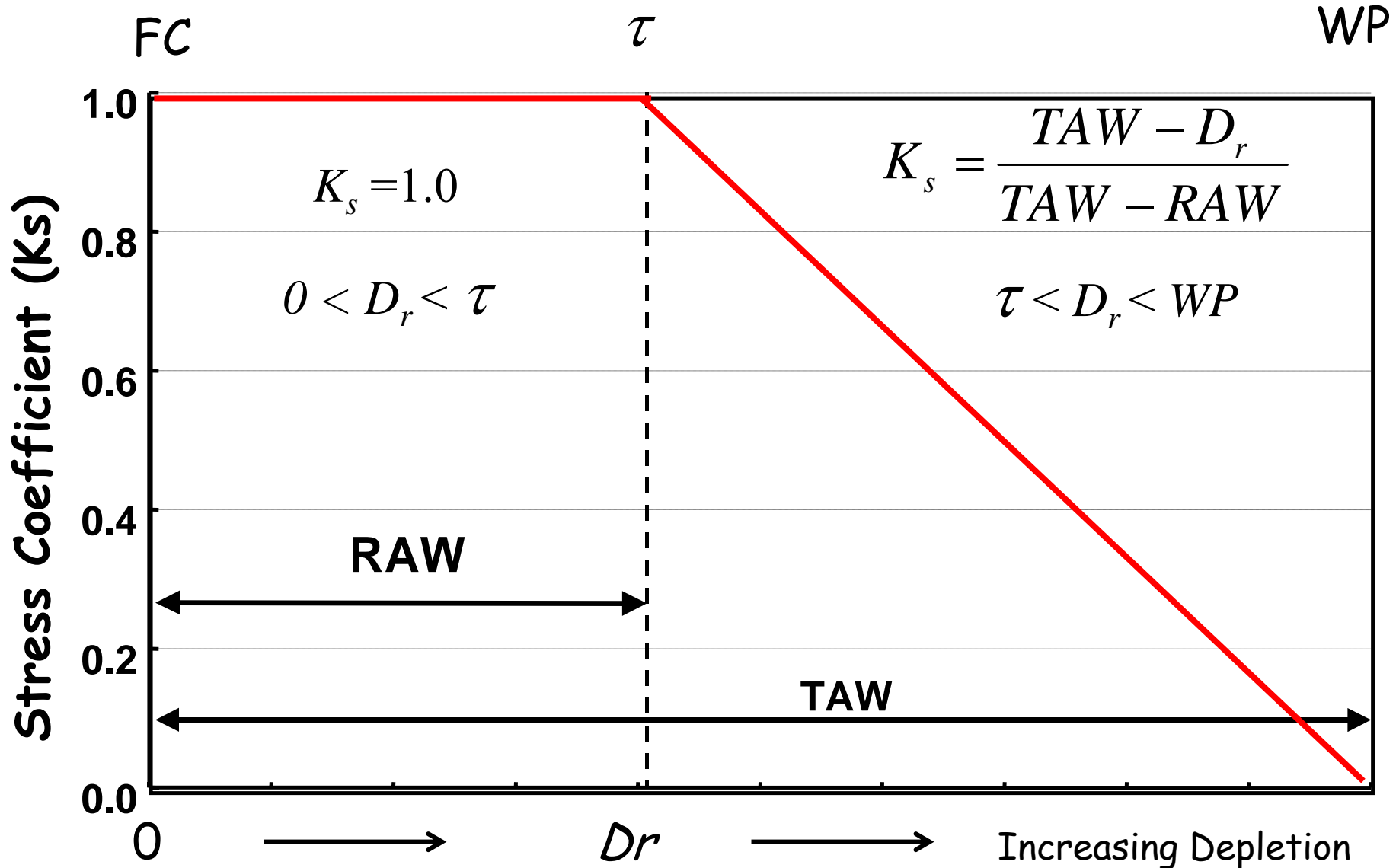
Growth

	Date	Date	Kc
A	15-Apr-02		0.19
B	23-May-02		0.19
C	30-Jun-02		1.05
D	15-Aug-02		1.05
E	15-Sep-02		0.65

Number	Date	NA mm	GA mm	AE %	Runtime	
					Hours	Minutes
1	06-May-02	21.6	24.0	90	24	0
2	25-May-02	21.6	24.0	90	24	0
3	04-Jun-02	21.6	24.0	90	24	0
4	09-Jun-02	21.6	24.0	90	24	0
5	15-Jun-02	21.6	24.0	90	24	0
6	19-Jun-02	21.6	24.0	90	24	0
7	23-Jun-02	21.6	24.0	90	24	0
8	27-Jun-02	21.6	24.0	90	24	0
9	01-Jul-02	21.6	24.0	90	24	0
10	05-Jul-02	21.6	24.0	90	24	0
11	09-Jul-02	21.6	24.0	90	24	0
12	13-Jul-02	21.6	24.0	90	24	0
13	17-Jul-02	21.6	24.0	90	24	0
14	21-Jul-02	21.6	24.0	90	24	0
15	25-Jul-02	21.6	24.0	90	24	0
16	29-Jul-02	21.6	24.0	90	24	0
17	02-Aug-02	21.6	24.0	90	24	0
18	06-Aug-02	21.6	24.0	90	24	0
19	10-Aug-02	21.6	24.0	90	24	0
20	14-Aug-02	21.6	24.0	90	24	0
21	18-Aug-02	21.6	24.0	90	24	0
22	22-Aug-02	21.6	24.0	90	24	0
23	26-Aug-02	21.6	24.0	90	24	0



# Stress Coefficient ( $K_s$ )



# EFFECTIVE RAINFALL

***P*** – precipitation

***Q*** – runoff

***SWD*** – soil water depletion

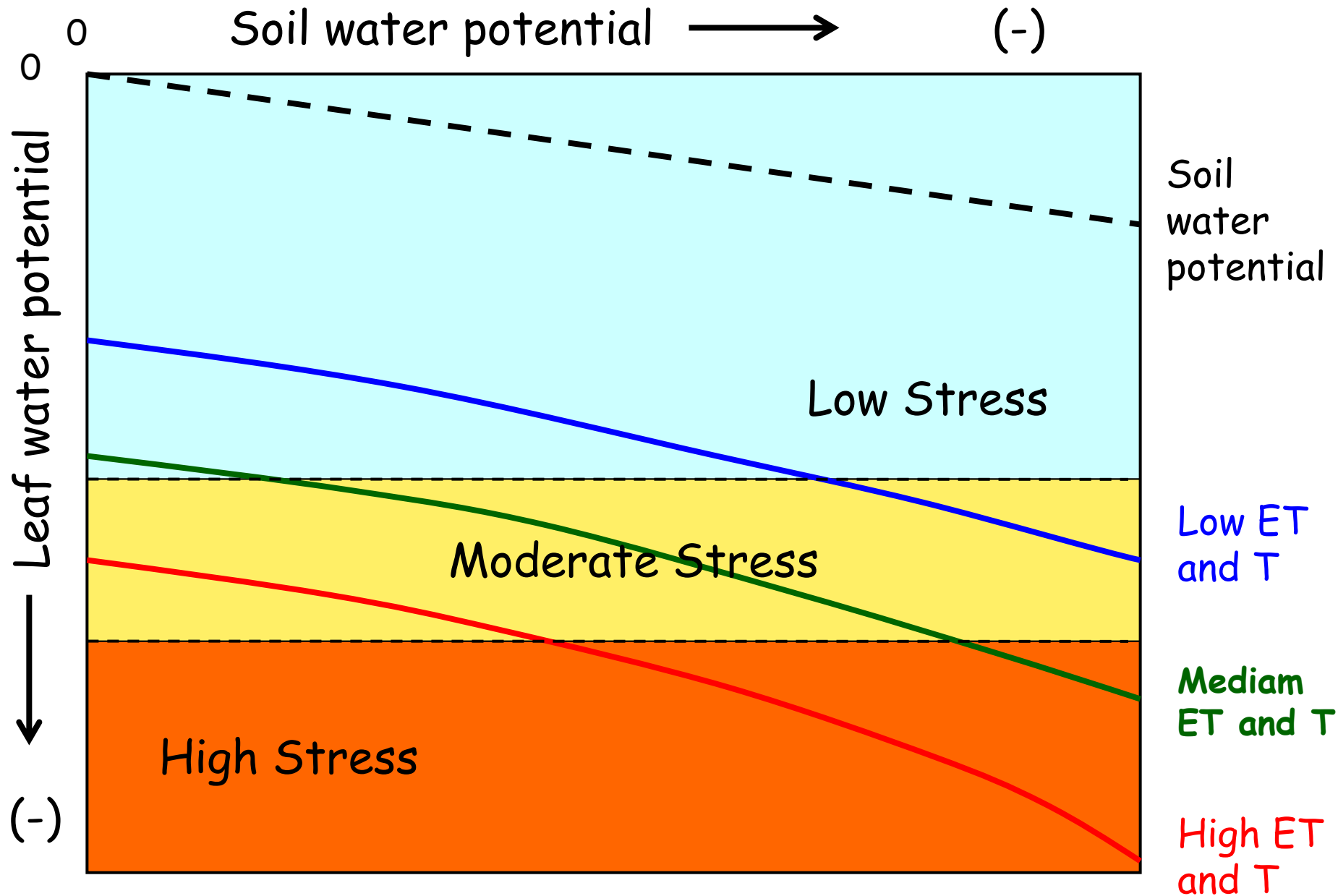
***R*** – effective rainfall

If  $P - Q < SWD$ , then  $R = P - Q$

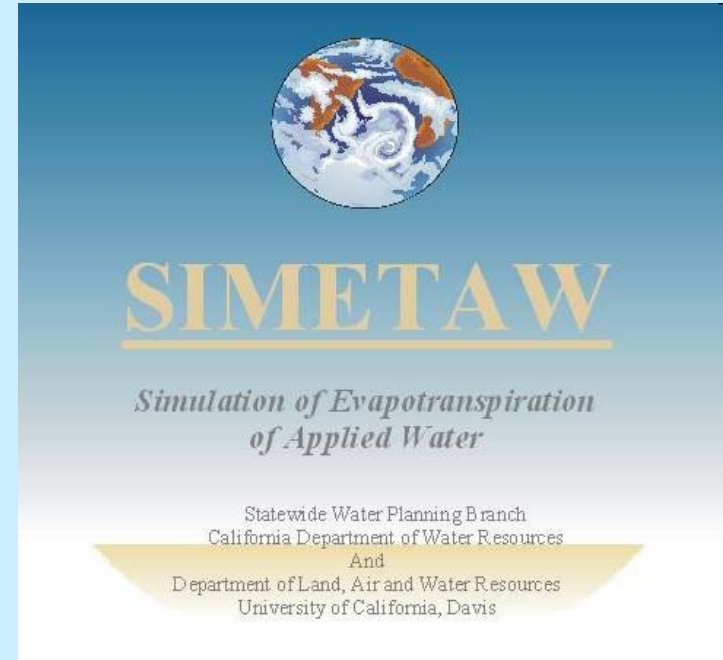
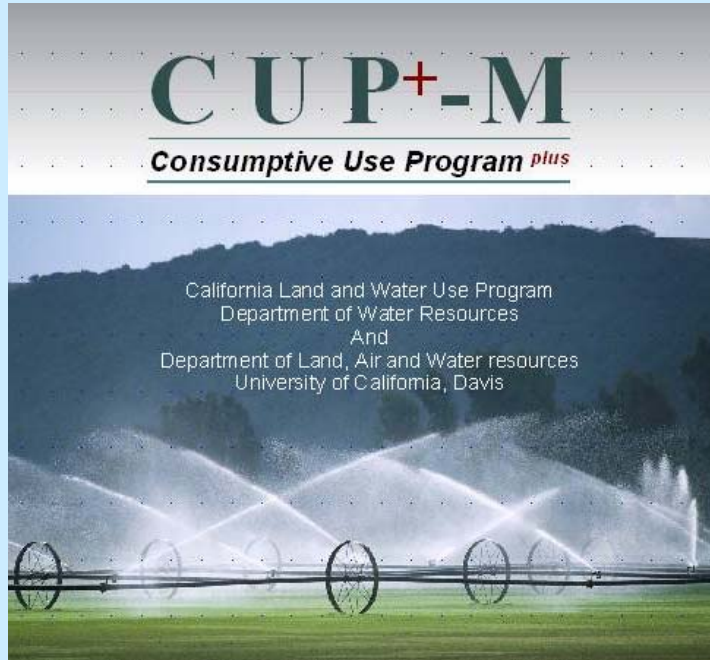
If  $P - Q \geq SWD$ , then  $R = SWD$



# Leaf Water Potential



# Water Resources Planning Programs



[http://www.water.ca.gov/  
landwateruse/models.cfm](http://www.water.ca.gov/landwateruse/models.cfm)

# Evapotranspiration Calculation



<http://biomet.ucdavis.edu>  
**Evapotranspiration**

Program

Documents

PMmon.xls

PMmonDoc.doc

PMday.xls

PMdayDoc.doc

PMhr.xls

PMhrDoc.doc



# Irrigation Scheduling



1. BISM - Basic Irrigation Scheduling
2. LIMP - Landscape Irrigation Management Program

## Programs

BISM.xls

LIMP.xls

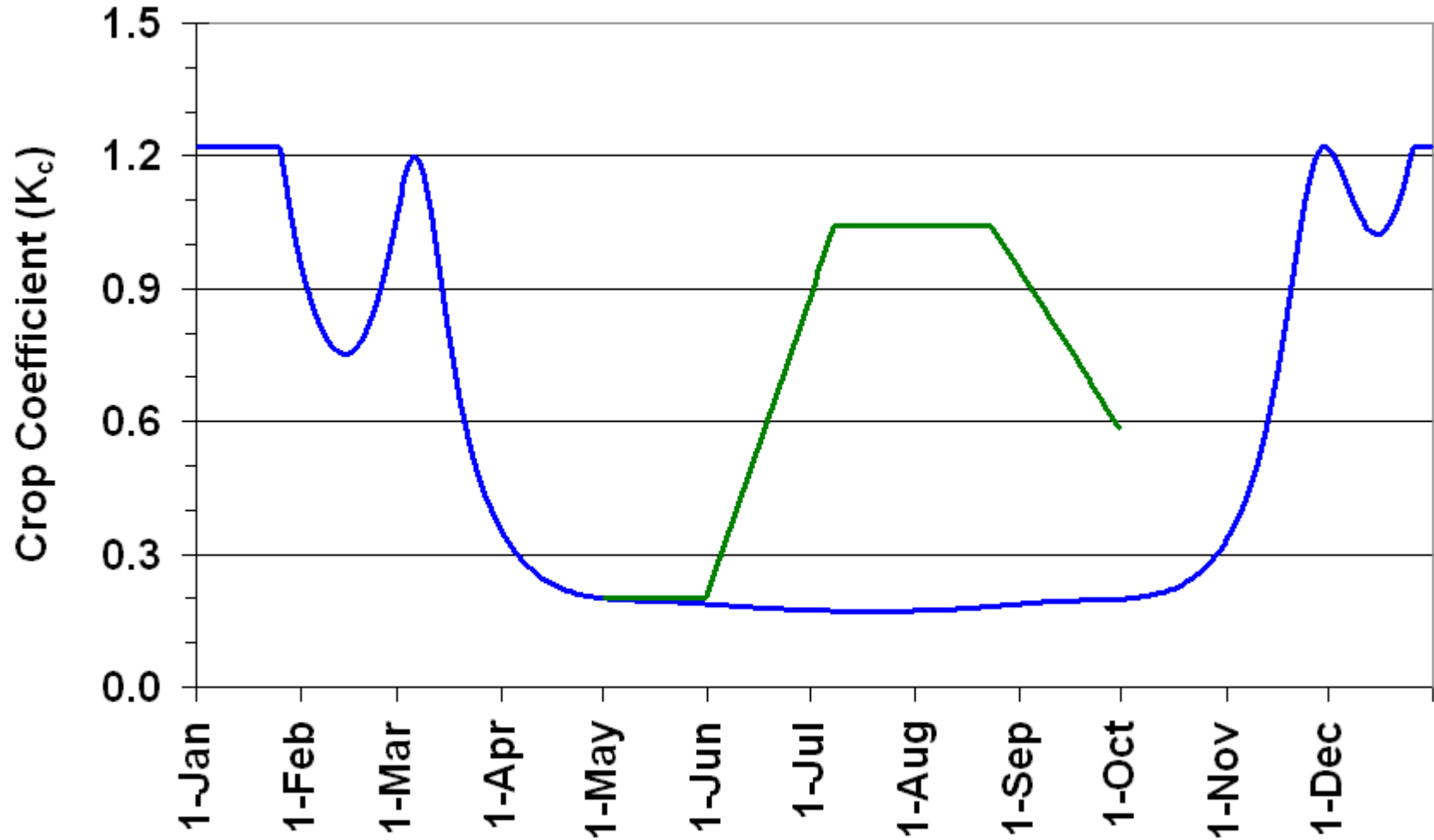
## Documents

BIS.doc

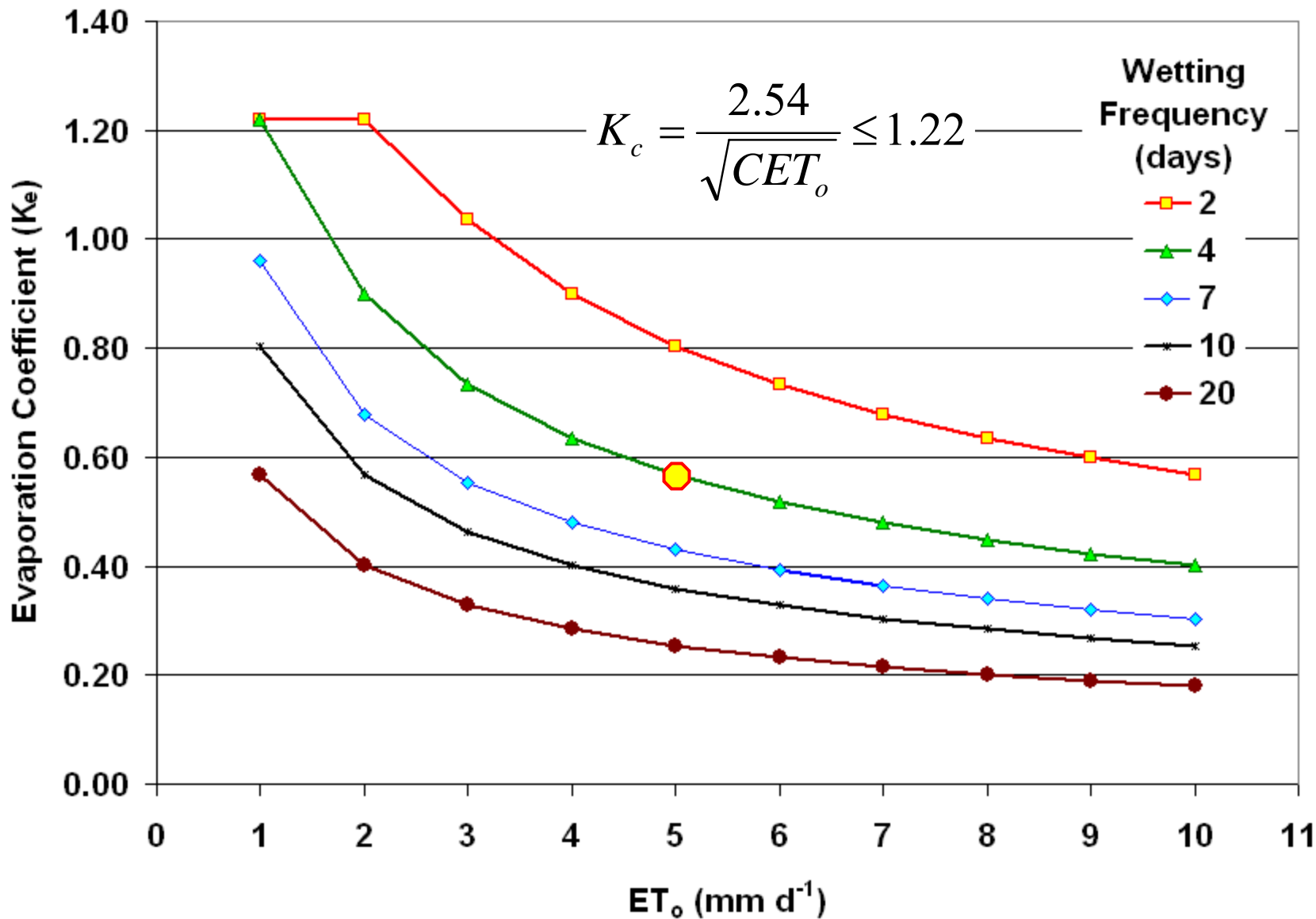
LIMP.doc



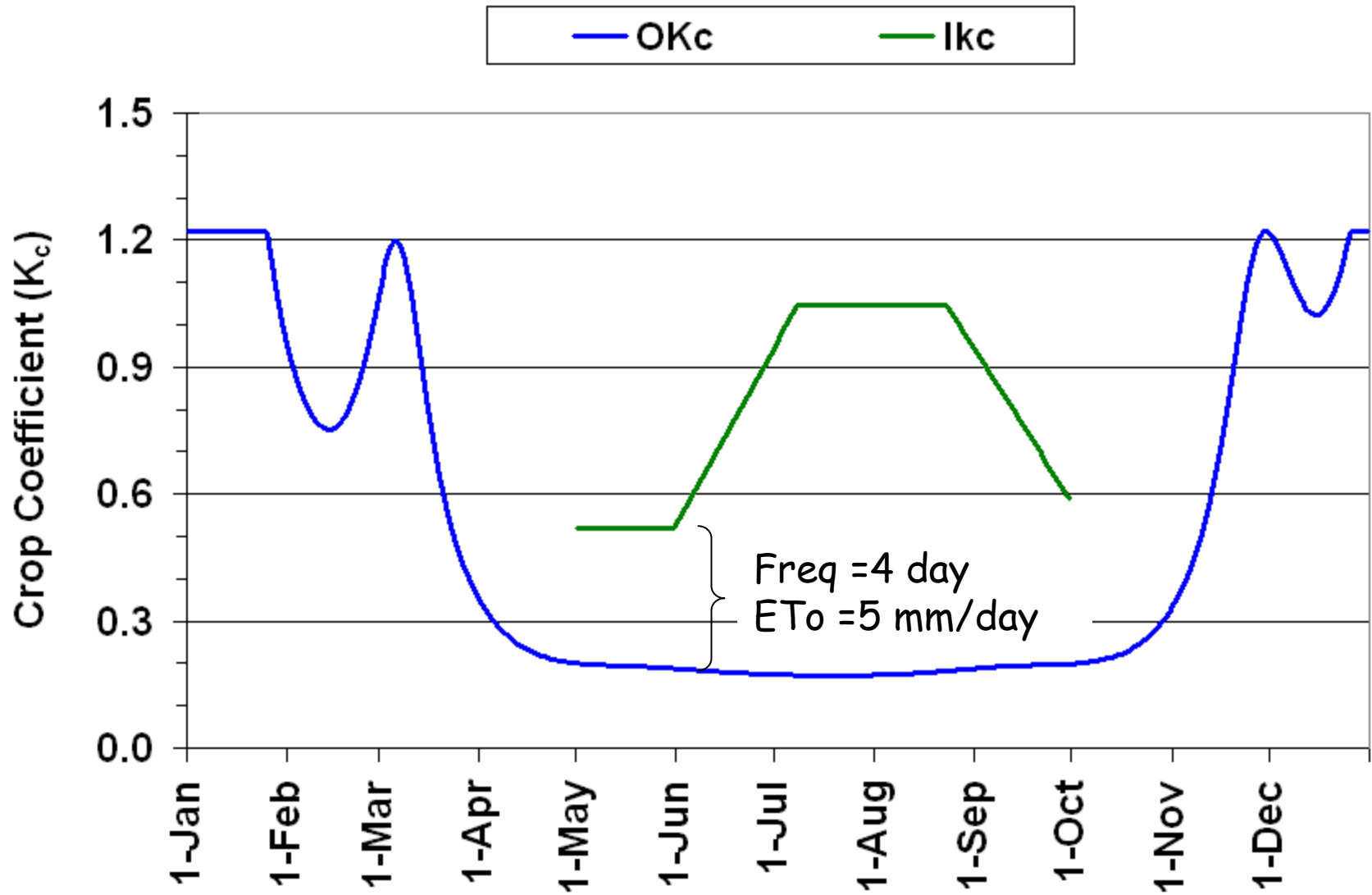
# Initial Growth Irrigation



# Initial Growth ( $K_c$ )



# Initial Growth Adjustment



# Kc Adjusted for Initial Growth Irrigation

