

# Irrigation Scheduling

## Determining Run Times

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Doing More With Less  
Stockton, CA  
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# Learning Objectives

- How to calculate a schedule
  - Irrigation system factors
  - Why is soil important in scheduling?
  - Climate
  - Landscape factors

# Irrigation Objectives

- Provide water to plants
  - only when it is needed
  - only the amount that will be used
  - only where it can be used



# Developing An Irrigation Schedule

- Things you need to know
  - Distribution uniformity
  - Precipitation rate
  - Soil texture
  - Landscape and plant coefficients
  - Climate (Water Use Rates)

# Developing An Irrigation Schedule

- Things you need to know
  - Distribution uniformity
  - Precipitation rate
    - How fast water is applied

# Precipitation Rate

- Calculating PR
  - Average of all ( $Avg_T$ ), mL
  - Catch can throat area (C), sq.in
    - This is 16.6 sq. in. for the ones used
  - Valve on duration (T), minutes
    - Let's set this at 4 minutes

mL
36
29
18
19
26
33
16
22
38
22
14
21
<hr/> Avg <sub>T</sub> = 24.5

$$PR = \frac{Avg_T}{C \times T} \times 3.66 = \frac{24.5}{16.6 \times 4} \times 3.66 = 1.35 \text{ in/hr}$$

# Developing An Irrigation Schedule

- Things you need to know
  - Distribution uniformity
  - Precipitation rate
  - Soil texture
    - Plant available water

SoilWeb app

<http://casoilresource.lawr.ucdavis.edu/gmap/>

# Soil Texture

	Soil Texture	Infiltration Rate (in/hr)	Plant Avail Water (cm/cm)*	Irrig to Wet to Depth (in)**
Coarse	sand / fine sand	1.5	0.05	0.3
	loamy sand	1	0.07	0.42
Moderately Coarse	sandy loam	0.8	0.11	0.66
Medium	loam	0.4	0.16	0.96
	silty loam	0.25	0.2	1.2
	silt	0.3	0.2	1.2
Moderately Fine	sandy clay loam	0.1	0.15	0.9
	clay loam	0.07	0.16	0.96
	silty clay loam	0.05	0.18	1.08
Fine	sandy clay	0.08	0.12	0.72
	silty clay	0.05	0.14	0.84
	clay	0.05	0.15	0.9

\*Irrigation Association Landscape Irrigation Auditor Manual page 177

\*\*assume 50% dry down (managed allowable depletion) and 12 inch wetted depth



# Soil Texture

	Soil Texture	Infiltration Rate (in/hr)	Plant Avail Water (cm/cm)*	Irrig to Wet to Depth (in)**
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Medium	loam	0.4	0.16	0.96
	silty loam	0.25	0.2	1.2
	silt	0.3	0.2	1.2

Irrig to wet to depth

Desired depth to wet = 12"

$$= 12'' \times 0.2 \times 50\% = 1.2''$$

Plant avail water = 0.2

Assume 50% dry down

\*Irrigation Association Landscape Irrigation Auditor Manual page 177

\*\*assume 50% dry down (managed allowable depletion) and 12 inch wetted depth

# Run-time, Part 1

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	Soil Texture	Infiltration Rate (in/hr)	Plant Avail Water (cm/cm)*	Irrig to Wet to Depth (in)**
Medium	silty loam	0.25	0.2	1.2

---

- Calculating Run-time
  - Lower Boundary (LB)
    - PR = 1.35 in/hr
    - Irrigation to wet to depth = 1.2"

$$LB = \frac{\text{Irrig to Wet to Depth}}{PR} \times 60 = \frac{1.2}{1.35} \times 60 = 53 \text{ min}$$

# Run-time, Part 2

- Calculating Run-time with DU
  - Upper Boundary (UB)
    - Scheduling multiplier (SM)
      - $DU = 0.65$
    - Lower boundary (LB) = 53 min.

$$SM = \frac{1}{0.4 + (0.6 \times DU)} = \frac{1}{0.4 + (0.6 \times 0.65)} = 1.26$$

$$UB = LB \times SM = 53 \times 1.26 = 67 \text{ min}$$

# Developing An Irrigation Schedule

- Things you know
  - Distribution uniformity = 0.65
  - Precipitation rate = 1.35 in/hr
  - Soil texture
    - Lower boundary = 53 min
    - Upper boundary = 67 min
- This is **how much** to water
- Now we need to know **when** to irrigate

# Developing An Irrigation Schedule

- Things you need to know
  - Distribution uniformity
  - Precipitation rate
  - Soil texture
  - Landscape and plant coefficients ( $K_L$ )

# Landscape Coefficients

- Information on plant water use
  - WUCOLS

[www.ucanr.sites/WUCOLS](http://www.ucanr.sites/WUCOLS)



The screenshot shows the homepage of the WUCOLS IV website. The header features the title "WUCOLS IV Water Use Classification of Landscape Species" in a dark red banner. Below the header is a navigation menu with links for "Home Page", "User Manual", "Plant Search Instructions", "Plant Search Database", "Download WUCOLS IV Plant List", "Download WUCOLS IV User Manual", "Water Requirements for Turfgrasses", "Partners", and "Acknowledgements". The main content area is titled "Home Page" and includes a "GETTING STARTED" section with introductory text and a "Project Background" section. A photograph of a garden with purple flowers and green foliage is included on the right side of the page.

**WUCOLS IV**  
Water Use Classification of Landscape Species

Home Page

**GETTING STARTED**

If you are using the WUCOLS list for the first time, it is essential that you read the *User Manual*. The manual contains very important information regarding the evaluation process, categories of water needs, plant types, and climatic regions. It is necessary to know this information to use WUCOLS evaluations and the plant search tool appropriately. To access the *User Manual*, click on the tab (on left) and view specific topics.

Water conservation is an essential consideration in the design and management of California landscapes. Effective strategies that increase water use efficiency must be identified and implemented. One key strategy to increase efficiency is matching water supply to plant needs. By supplying only the amount of water needed to maintain landscape health and appearance, unnecessary applications that exceed plant needs can be avoided. Doing so, however, requires some knowledge of plant water needs.

WUCOLS IV provides evaluations of the irrigation water needs for over 3,500 taxa (taxonomic plant groups) used in California landscapes. It is based on the observations and extensive field experience of thirty-six landscape horticulturists (see the section "Regional Committees") and provides guidance in the selection and care of landscape plants relative to their water needs.

*Project Background*

The WUCOLS project was initiated and funded by the Water Use Efficiency Office of the California Department of Water Resources (DWR). Work was directed by the University of California Cooperative Extension, San Francisco and San Mateo County office. The first edition of the guide was completed in 1992. A second edition was published in 1994, and a third edition in 1999. In each new edition, additional species were evaluated and included.

*Current Update: The 4th Edition*

The 4th edition represents a substantial expansion in the number of plant evaluations. Over 1,500

WUCOLS IV provides an assessment of irrigation water needs for over 3,500 taxa.  
Photo by Ellen Zagory.

# Developing An Irrigation Schedule

- Things you need to know
  - Distribution uniformity
  - Precipitation rate
  - Soil texture
  - Landscape and plant coefficients ( $K_L$ )
  - Climate ( $ET_0$ )



# CIMIS

**C**alifornia  
**I**rrigation  
**M**anagement  
**I**nformation  
**S**ystem

- Collects weather info
- Estimates plant water use
- More than 120 stations

Water use reports are used with a crop or landscape coefficient to estimate site water use

<http://wwwcimis.water.ca.gov/cimis/>



# Climate

- Water use models
  - Based on weather data
  - Requires previous research
  - Crop specific
  - Easy to use

# Climate

- Water use models

Reference ET ( $ET_0$ ) is reported (CIMIS)

Crop coefficient ( $K_c$ ) is necessary

Determine  $ET_{crop}$  ( $ET_c$ ) to estimate crop water use

$$\text{so, } ET_c = ET_0 \times K_c$$

Example: citrus orchard

$$K_c = 0.65$$

If  $ET_0 = 0.5''$ , then

crop water use is  $0.325''$

$$(0.325 = 0.5 \times 0.65)$$

# ETo Zones Map

California Irrigation Management Information System (CIMIS)  
REFERENCE EVAPOTRANSPIRATION



Lambert Conformal Conic Projection  
©2017 North American Datum

Developed as a cooperative project between the  
State of California and the National Irrigation  
Association (NIA) and the National Water Research  
Institute (NWRI) of the United States Geological Survey  
(USGS).

Map Prepared by David W. Jones, 2009  
Data developed by National Irrigation Association and National Center for  
Background Data from Texas and USGS Sources

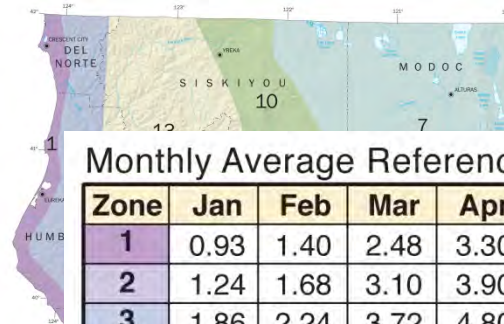
## Reference Evapotranspiration (ETo) Zones

- 1 COASTAL PLAINS NEAR FOG BELT  
Lowest ETo in California. Characterized by dense fog
- 2 COASTAL MIXED FOG AREA  
Less fog and higher ETo than zone 1
- 3 COASTAL VALLEYS AND PLAINS AND NORTH COAST MOUNTAINS  
More sunlight than zone 2
- 4 SOUTH COAST INLAND PLAINS AND MOUNTAINS NORTH OF  
SAN FRANCISCO  
More sunlight and higher summer ETo than zone 3
- 5 NORTHERN INLAND VALLEYS  
Valleys north of San Francisco
- 6 UPLAND CENTRAL COAST AND LOS ANGELES BASIN  
Higher elevation coastal areas
- 7 NORTHEASTERN PLAINS
- 8 INLAND SAN FRANCISCO BAY AREA  
Inland area near San Francisco with some marine influence
- 9 SOUTH COAST MARINE TO DESERT TRANSITION  
Inland area between marine and desert climates
- 10 NORTH CENTRAL PLATEAU & CENTRAL COAST RANGE  
Cool, high elevation areas with strong summer sunlight.  
This zone has limited climate data and the zones  
selection is somewhat subjective
- 11 CENTRAL SIERRA NEVADA  
Sierra Nevada Mountain valleys east of Sacramento  
with some influence from the Delta breeze in summer
- 12 EAST SIDE SACRAMENTO-SAN JOAQUIN VALLEY  
Low winter and high summer ETo with slightly  
lower ETo than zone 14
- 13 NORTHERN SIERRA NEVADA  
Northern Sierra Nevada mountain valleys with less  
marine influence than zone 11
- 14 MID-CENTRAL VALLEY, SOUTHERN SIERRA NEVADA,  
TEHACHAP & HIGH DESERT MOUNTAINS  
High summer sunshine and wind in some locations.
- 15 NORTHERN & SOUTHERN SAN JOAQUIN VALLEY  
Slightly lower winter ETo due to fog and slightly higher  
summer ETo than zones 12 & 14
- 16 WESTSIDE SAN JOAQUIN VALLEY & MOUNTAINS EAST  
& WEST OF IMPERIAL VALLEY
- 17 HIGH DESERT VALLEYS  
Valleys in the high desert near Nevada and Arizona
- 18 IMPERIAL VALLEY, DEATH VALLEY AND PALO VERDE  
Low desert areas with high sunlight and considerable  
heat advection

Monthly Average Reference Evapotranspiration by ETo Zone (inches/month)

Zone	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1	0.93	1.40	2.48	3.30	4.03	4.50	4.65	4.03	3.30	2.48	1.20	0.93	32.9
2	1.24	1.88	3.10	3.90	4.65	5.10	4.96	4.65	3.90	2.79	1.80	1.24	39.0
3	1.86	2.24	3.72	4.80	5.27	5.70	5.58	5.27	4.20	3.41	2.40	1.86	46.3
4	1.86	2.24	3.41	4.50	5.27	5.70	5.89	5.58	4.50	3.41	2.40	1.86	46.6
5	0.93	1.68	2.79	4.20	5.58	6.30	6.51	5.89	4.50	3.10	1.50	0.93	43.9
6	1.86	2.24	3.41	4.80	5.58	6.30	6.51	6.20	4.80	3.72	2.40	1.86	49.7
7	0.62	1.40	2.48	3.90	5.27	6.30	7.44	6.51	4.80	2.79	1.20	0.62	43.3
8	1.24	1.68	3.41	4.80	6.20	6.90	7.44	6.51	5.10	3.41	1.80	0.93	49.4
9	2.17	2.80	4.03	5.10	5.89	6.60	7.44	6.82	5.70	4.03	2.70	1.86	55.1
10	0.93	1.68	3.10	4.50	5.89	7.20	8.06	7.13	5.10	3.10	1.50	0.93	48.1
11	1.55	2.24	3.10	4.50	5.89	7.20	8.06	7.44	6.70	3.72	2.10	1.55	53.1
12	1.24	1.96	3.41	5.10	6.82	7.80	8.06	7.13	5.40	3.72	1.80	0.93	53.4
13	1.24	1.96	3.10	4.80	6.51	7.80	8.99	7.75	5.70	3.72	1.80	0.93	54.3
14	1.55	2.24	3.72	5.10	6.82	7.80	8.68	7.75	5.70	4.03	2.10	1.55	57.0
15	1.24	2.24	3.72	5.70	7.44	8.10	8.68	7.75	6.70	4.03	2.10	1.24	57.9
16	1.55	2.52	4.03	5.70	7.75	8.70	9.30	8.37	6.30	4.34	2.40	1.55	62.5
17	1.86	2.80	4.65	6.00	8.06	9.00	9.92	8.68	6.00	4.34	2.70	1.86	66.5
18	2.48	3.36	5.27	6.90	8.68	9.60	9.61	8.68	6.90	4.96	3.00	2.17	71.6

Variability between stations within single zones is as high as 0.02 inches per day for zone 1 and during winter months in zone 13. The average standard deviation of the ETo between estimation sites within a zone for all months is about 0.01 inches per day for all 200 sites.



Reference EvapoTranspiration (ETo) Zones

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Lowest ETo in California. Characterized by dense fog
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Less fog and higher ETo than zone 1
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More sunlight than zone 2
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Sierra Nevada Mountain valleys east of Sacramento with some influence from the delta breeze in summer
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Low winter and high summer ETo with slightly lower PPT than zone 12

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2	1.24	1.68	3.10	3.90	4.65	5.10	4.96	4.65	3.90	2.79	1.80	1.24	39.0
3	1.86	2.24	3.72	4.80	5.27	5.70	5.58	5.27	4.20	3.41	2.40	1.86	46.3
4	1.86	2.24	3.41	4.50	5.27	5.70	5.89	5.58	4.50	3.41	2.40	1.86	46.6
5	0.93	1.68	2.79	4.20	5.58	6.30	6.51	5.89	4.50	3.10	1.50	0.93	43.9
6	1.86	2.24	3.41	4.80	5.58	6.30	6.51	6.20	4.80	3.72	2.40	1.86	49.7
7	0.62	1.40	2.48	3.90	5.27	6.30	7.44	6.51	4.80	2.79	1.20	0.62	43.3
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12	1.24	1.96	3.41	5.10	6.82	7.80	8.06	7.13	5.40	3.72	1.80	0.93	53.4
13	1.24	1.96	3.10	4.80	6.51	7.80	8.99	7.75	5.70	3.72	1.80	0.93	54.3
14	1.55	2.24	3.72	5.10	6.82	7.80	8.68	7.75	5.70	4.03	2.10	1.55	57.0
15	1.24	2.24	3.72	5.70	7.44	8.10	8.68	7.75	5.70	4.03	2.10	1.24	57.9
16	1.55	2.52	4.03	5.70	7.75	8.70	9.30	8.37	6.30	4.34	2.40	1.55	62.5
17	1.86	2.80	4.65	6.00	8.06	9.00	9.92	8.68	6.60	4.34	2.70	1.86	66.5
18	2.48	3.36	5.27	6.90	8.68	9.60	9.61	8.68	6.90	4.96	3.00	2.17	71.6

# ETo Zones

Variability between stations within single zones is as high as 0.02 inches per day for zone 1 and during winter months in zone 13. The average standard deviation of the ETo between estimation sites within a zone for all months is about 0.01 inches per day for all 200 sites.

California  
REFERENCE EVAPOTRANSPIRATION



Lambert Conformal Conic Projection  
2027 North American Datum

Developed as a cooperative project between the State Water Resources Control Board and the State Water Resources Control Board.

Map Prepared by David W. Jones, 1999  
Data developed by Ronald C. Saylor, Senior Esting, and Michael Conner, MPhilThesis  
Background Data from Teale and USGS Sources



# Developing An Irrigation Schedule

- So,
  - We know how much to apply (1.2 in)
  - Replaces  $\frac{1}{2}$  of field capacity
- Then,
  - We need to estimate when that amount of water is used
  - We know our plants
  - We have info about the climate

# Developing An Irrigation Schedule

- Landscape and plant coefficients ( $K_L$ )
  - For this example, 0.4
- Climate (Water Use Rates)

Monthly Average Reference Evapotranspiration by ETo Zone (inches/month)

Zone	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
14	1.55	2.24	3.72	5.10	6.82	7.80	8.68	7.75	5.70	4.03	2.10	1.55	57.0

- For this example, we'll use  
October = 4.03 in/month
- $ET_{\text{day}} = 4.03 \text{ in} \div 31 \text{ days} = 0.13 \text{ in/day}$

# Developing An Irrigation Schedule

- How fast is our landscape using water?

- $ET_L = ET_{\text{day}} \times K_L$

- $ET_{\text{day}} = 0.13 \text{ in/day}$

- $K_L = 0.4$

$$ET_L = 0.13 \times 0.4 = 0.07 \text{ in/day}$$

# Developing An Irrigation Schedule

- Determine when to irrigate
  - Irrigation application = 1.2 in
  - $ET_L = 0.07$  in/day
- Accumulate  $ET_L$  daily
- When accumulated total reaches 1.2 in
- Irrigate!



# Developing An Irrigation Schedule

October

$$ET_{\text{day}} = 0.13$$

$$K_L = 0.4$$

$$ET_L = 0.07$$

$$\text{Irrig} = 1.2$$

Day	Total $ET_L$	Day	Total $ET_L$
1	0.07	11	0.77
2	0.14	12	0.84
3	0.21	13	0.91
4	0.28	14	0.98
5	0.35	15	1.05
6	0.42	16	1.12
7	0.49	17	1.19
8	0.56	18	0.06
9	0.63	19	0.13
10	0.70	20	0.20

$$\begin{array}{r}
 1.19 \\
 + 0.07 \text{ (} ET_L \text{)} \\
 \hline
 = 1.26 \\
 - 1.20 \text{ (Irrig)} \\
 \hline
 = 0.06
 \end{array}$$



# Developing An Irrigation Schedule

October

$$ET_{\text{day}} = 0.13$$

$$K_L = 0.4$$

$$ET_L = 0.07$$

$$\text{Irrig} = 1.2$$

Day	Total $ET_L$	Day	Total $ET_L$	Day	Total $ET_L$
1	0.07	11	0.77	21	0.27
2	0.14	12	0.84	22	0.34
3	0.21	13	0.91	23	0.41
4	0.28	14	0.98	24	0.48
5	0.35	15	1.05	25	0.55
6	0.42	16	1.12	26	0.62
7	0.49	17	1.19	27	0.69
8	0.56	18	0.06	28	0.76
9	0.63	19	0.13	29	0.83
10	0.70	20	0.20	30	0.90

# Developing An Irrigation Schedule

October

$$ET_{\text{day}} = 0.13$$

$$K_L = 0.4$$

$$ET_L = 0.07$$

$$\text{Irrig} = 1.2$$

Day	Total $ET_L$
1	0.07
2	0.14
3	0.21
4	0.28
5	0.35
6	0.42
7	0.49
8	0.56
9	0.63
10	0.70

- For more accuracy
  - Use actual daily ET
  - Obtain from CIMIS
  - Calculate & accumulate actual rather than historical  $ET_L$

# Developing An Irrigation Schedule

- Things you need to know
  - Distribution uniformity
  - Precipitation rate
  - Soil texture
  - Landscape and plant coefficients ( $K_L$ )
  - Climate ( $ET_0$ )

# More Things to Consider

- Adjust controllers monthly
  - Program for monthly changes in  $ET_{\text{day}}$
- Interval vs. duration
  - Increase interval between irrigations
  - DO NOT reduce run times
  - Affects wetting depth

# Precipitation Rates

- Precipitation rate
  - How fast water is applied
- Infiltration rates
  - How fast water enters soil



Photo: D. Franklin, Hunter

**Precipitation > Infiltration = RUNOFF**

# Precipitation Rates

- Note interval when runoff occurs
- Example:
  - Duration to runoff is 6 minutes
  - Upper boundary is 30 minutes
  - 6 minute duration, 5 times
  - "Cycle-Soak" or "Pulsing"

Precipitation > Infiltration = RUNOFF

# Delivery Method

- Upgrade sprinklers if possible
- At three study sites upgrades resulted in DU increases of 21%, 24%, and 18%



Photo: B. Baker



Run time = 4 minutes



Run time = 10 minutes



Photos: D. Franklin, Hunter



# Time of Day

- Why early in the day?
  - Lower temperatures
  - Less wind



# Deep irrigation

- Deep irrigation
  - Fills a larger volume of soil to provide water to plants
- Use a soil probe to check wetting depth



Photo: B. Baker

# Drip Irrigation

- Can it save water?
- Does it save water?

GENERAL GUIDELINES	TURF												SHRUB & GROUNDCOVER											
	CLAY SOIL			LOAM SOIL			SANDY SOIL			COARSE SOIL			CLAY SOIL			LOAM SOIL			SANDY SOIL			COARSE SOIL		
EMITTER FLOW	0.26 GPH			0.4 GPH			0.6 GPH			0.9 GPH			0.26 GPH			0.4 GPH			0.6 GPH			0.9 GPH		
EMITTER SPACING	18"			18"			12"			12"			18"			18"			12"			12"		
LATERAL (ROW) SPACING	18"	20"	22"	18"	20"	22"	12"	14"	16"	12"	14"	16"	18"	21"	24"	18"	21"	24"	16"	18"	20"	16"	18"	20"
BURIAL DEPTH	Bury evenly throughout the zone from 4" to 6"												On-surface or bury evenly throughout the zone to a maximum of 6"											
APPLICATION RATE (INCHES/HOUR)	0.19	0.17	0.15	0.30	0.27	0.25	0.98	0.84	0.73	1.48	1.27	1.11	0.19	0.16	0.14	0.30	0.26	0.23	0.73	0.65	0.59	1.11	0.99	0.89
TIME TO APPLY ¼" OF WATER (MINUTES)	80	89	97	50	55	61	15	18	20	10	12	13	80	93	106	50	58	66	20	23	26	13	15	17
Following these maximum spacing guidelines, emitter flow selection can be increased if desired by the designer. 0.9 GPH flow rate available for areas requiring higher infiltration rates, such as coarse sandy soils.																								

Note: 0.4, 0.6 and 0.9 GPH are nominal flow rates. Actual flow rates used in the calculations are 0.42, 0.61 and 0.92 GPH.

# Drip Irrigation

- Precipitation rates approach those of overhead
- Proper management is key

GENERAL GUIDELINES	TURF											
	CLAY SOIL			LOAM SOIL			SANDY SOIL			COARSE SOIL		
EMITTER FLOW	0.26 GPH			0.4 GPH			0.6 GPH			0.9 GPH		
EMITTER SPACING	18"			18"			12"			12"		
LATERAL (ROW) SPACING	18"	20"	22"	18"	20"	22"	12"	14"	16"	12"	14"	16"
BURIAL DEPTH	Bury evenly throughout the zone from 4" to 6"											
APPLICATION RATE (INCHES/HOUR)	0.19	0.17	0.15	0.30	0.27	0.25	0.98	0.84	0.73	1.48	1.27	1.11
TIME TO APPLY ¼" OF WATER (MINUTES)	80	89	97	50	55	61	15	18	20	10	12	13

# Drip Irrigation

- Precipitation rates approach those of overhead
- Proper management is key



# Drip Irrigation

- F
- C
- F



# Even More Things To Consider

- Prioritize plants that receive water
- Know water stress symptoms
- Precondition to enhance survival
- Manage salinity



# Managing Irrigation

- It's a "piece of cake"
  - There are a lot of ingredients needed to make the cake
  - There are several, distinct steps to put the ingredients together properly
  - Each has to be managed as part of a program
  - Changing one affects another
- The short version: "It's complex"

# Managing Irrigation

- Anyone can do a mediocre (or less) job
- Doing it well requires diligence
- We've gotten away with "good enough" because water supply wasn't an issue. Now it is.
- The question that will be asked:
  - Are the rewards worth the effort?

A low-angle photograph of a tree trunk and branches reaching towards a blue sky with green foliage. The tree trunk is on the right side, and the branches spread out towards the left and top. The sky is visible through the leaves.

**Thank you**  
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