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VITICULTURE & ENOLOGY

Maintaining and Operating Resource Efficient Irrigation Systems for Vineyards

Kaan Kurtural | University of California, Davis

WHAT DOES IT TAKE TO BE RESOURCE-EFFICIENT?

Good System Design

✓Accurate & Skilled
✓Flexible Operation

DESIGN

Proper **Installation**
Regular **Maintenance**
System **Evaluation**

MAINTENANCE

Defined Irrigation Strategy

- Full Irrigation
- Deficit Irrigation (SDI, RDI)
- Homogeneously or VRI

Accurate
Irrigation Scheduling
& Control

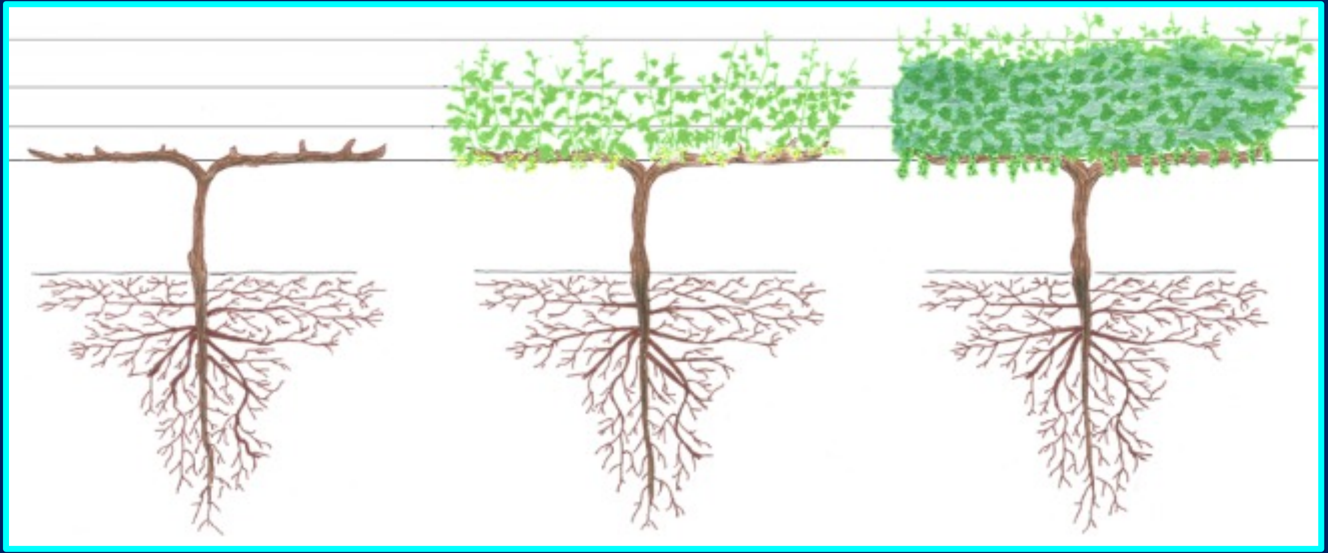
Schedule Implementation
& Feedback

OPERATION

WHAT IS THE MOST ADEQUATE IRRIGATION METHOD FOR GRAPEVINE?

Root system of mature grapevine consists of woody root frame with smaller absorbing roots branching in multiple directions:

- ✓ Mine the soil deeply and horizontally
- ✓ Thrive in soils with good balance between water and air (un-saturated soils)
- ✓ Do not enjoy soil compaction, waterlogging and long wet-dry cycles



Low volume micro-irrigation systems (drip & micro-sprinkler) are mostly used for grapevine: careful management of timing and amounts of irrigation & nutrient applications

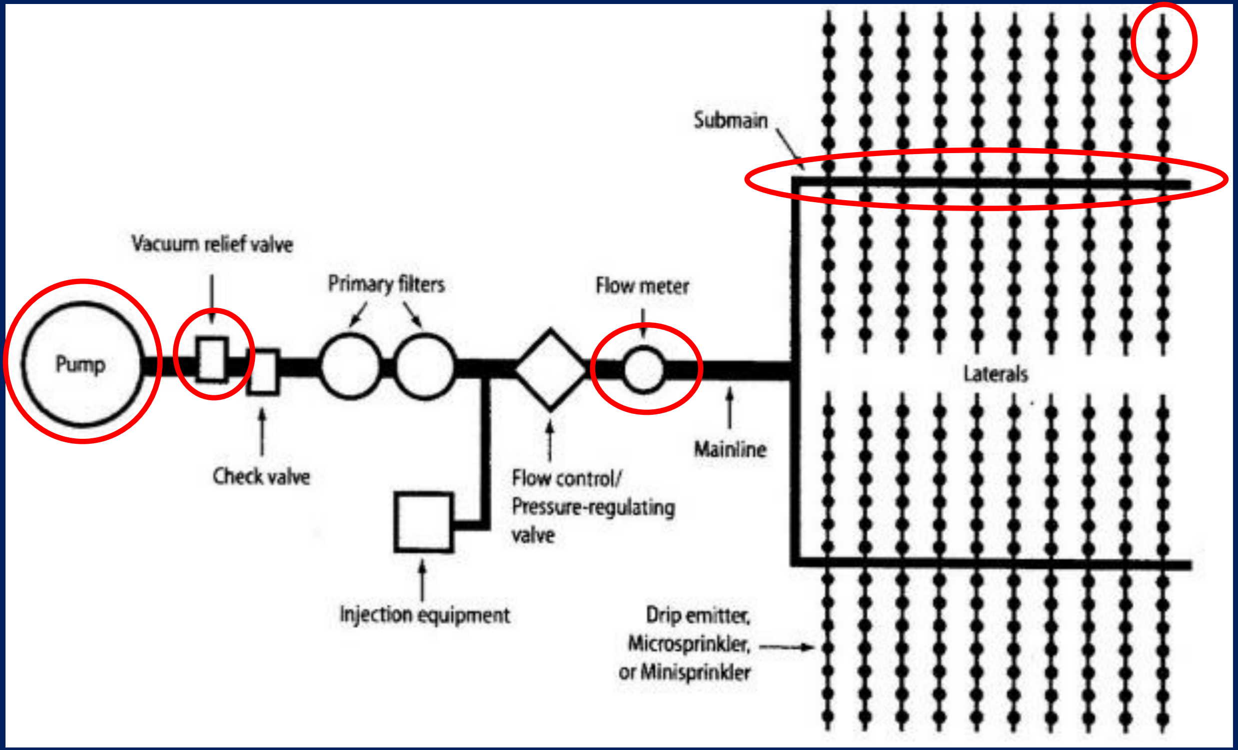
Surface and sprinkler irrigation have been associated with high incidence of fungal diseases to leaves, canopy and clusters.

DESIGN STAGE - Aspects where to focus attention:

- ✓ Preliminary site evaluations (water supplies, soil texture and variability, slope, aspect, vine spacing & row orientation, trellis system, projected canopy size at full development)
- ✓ Define the **Water Application Rate** (in./hr) and **Max Irrigation Depth** (in.) based on soil properties (**infiltration rate**; **water holding capacity**, slope, etc.) and crop ET

Rule of Thumb: Apply the peak daily ET (in/day) in 16-20-hr set time max

Size the different system's components from downstream to upstream



- ✓ Calculate flow and friction losses along the pipe system
- ✓ Size the various parts with sufficient capacity to ensure the routine and max system's load
- ✓ Ensure operational flexibility to the system

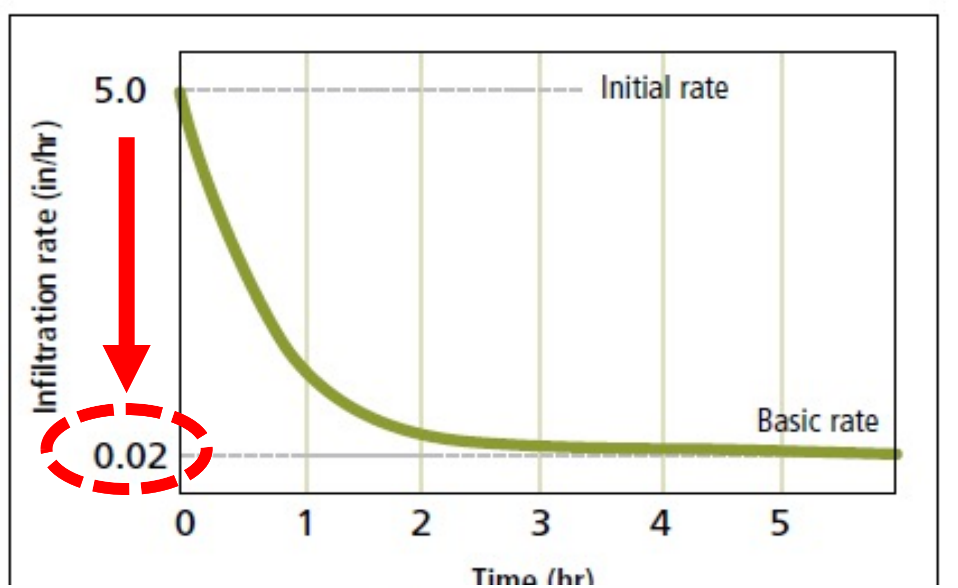
Flexibility of Operation => range of operating conditions (Q, P) (adjusting operation to various system's loads)

During its lifetime, the irrigation system may be operated under different conditions:

- Water needs of young vines are small, then increase with time (+ Q, P)
- Blocks at different elevations and distances from the water supply (± P)
- Blocks with different emitters (application rates), due to soil differences (≠ Q, P)
- Composite systems (different flow rate and pressure => drip and micro-sprinkler, single and dual-line, alternating or solid irrigation, etc.) => (≠ Q, P, F)
- Groundwater level fluctuating or decreasing with time, pump wearing (+ P)

1st RULE OF THUMB:

APPLICATION RATE (in/hr) << SOIL INTAKE RATE (in/hr)



System	Appl. Rate (in./hr)
Surface Irrigation	0.40 – 0.45
Sprinkler Irrigation	0.12
Micro-sprinkler	0.05
Drip Irrigation	0.01 - 0.03

Soil type	Maximum application rate (in/hr) at slope		
	0–5%	5–8%	8–12%
coarse sandy soil	1.5–2.0	1.0–1.5	0.75–1.0
light sandy soil	0.75–1.0	0.5–0.8	0.4–0.6
silt loam	0.3–0.5	0.25–0.4	0.15–0.3
clay loam, clay	0.15	0.10	0.08

2nd RULE OF THUMB:

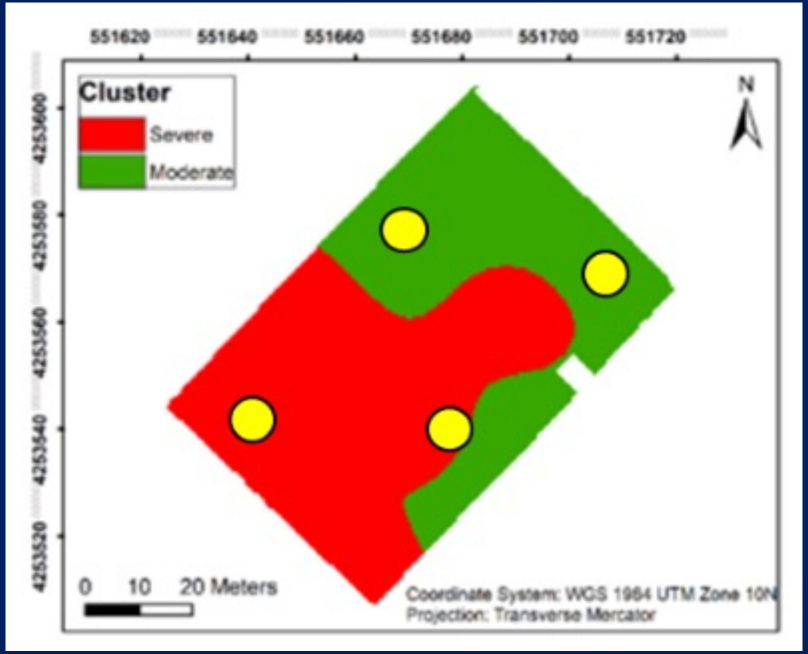
MAX APPLIED WATER (in) << WATER HOLDING CAPACITY (in)

Ranges of Water-Holding Capacities for different soil types (W_A = FC - WP)

Soil texture	Water-holding capacity Range In./ft	Average In./ft
1. Very coarse texture—very coarse sands	0.38-0.75	0.50
2. Coarse texture—coarse sands, fine sands, and loamy sands	0.75-1.25	1.00
3. Moderately coarse texture—sandy loams	1.25-1.75	1.50
4. Medium texture—very fine sandy loams, loams, and silt loams	1.50-2.30	2.00
5. Moderately fine texture—clay loams, silty clay loams, and sandy clay loams	1.75-2.50	2.20
6. Fine texture—sandy clays, silty clays, and clays	1.60-2.50	2.30
7. Peats and mucks	2.00-3.00	2.50

Assessing the spatial variability of soil features

Cost: $40-60 per acre



ET-BASED CALCULATION OF MAX WATER DEPTH X IRRIGATION (D_{GMAX})

$$D_{GMAX} = (\text{Max } ET_{Daily} \times \text{Irrig. Frequency}) / Eff_{APP}$$

Max ET_{Daily} = 0.20 in

=> Max $AW_{3\text{-}day}$ = 0.6 in/0.85 = 0.7 in (< 24 hr)

System	Eff_{APP}
Surface Irrigation	70-85%
Sprinkler Irrigation	70-80%
Micro-sprinkler	80-90%
Drip Irrigation	85-95%

Micro-irrigation systems are typically designed for the lowest cost => to deliver the peak ET/water needs in 24-hr set (better in ~ 16-20-hr)

$$T_{IRR} = \frac{D_{G\,MAX}}{Appl.\ Rate} = \frac{D_{G\,MAX}}{< Soil\ Intake\ Rate}$$

System	Appl. Rate (in./hr)
Surface Irrigation	0.40 – 0.45
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Drip Irrigation	0.01 - 0.03

SOIL-BASED CALCULATION OF MAX DEPTH X IRRIGATION (D_{GMAX})

$$D_{GMAX} = \left[\left(\frac{MAD}{100} * \frac{P_W}{100} * W_a * Z_E \right) / Eff_{APPL.} \right]$$

D_{GMAX} (in.) = Max. Gross Depth of water to apply per irrigation

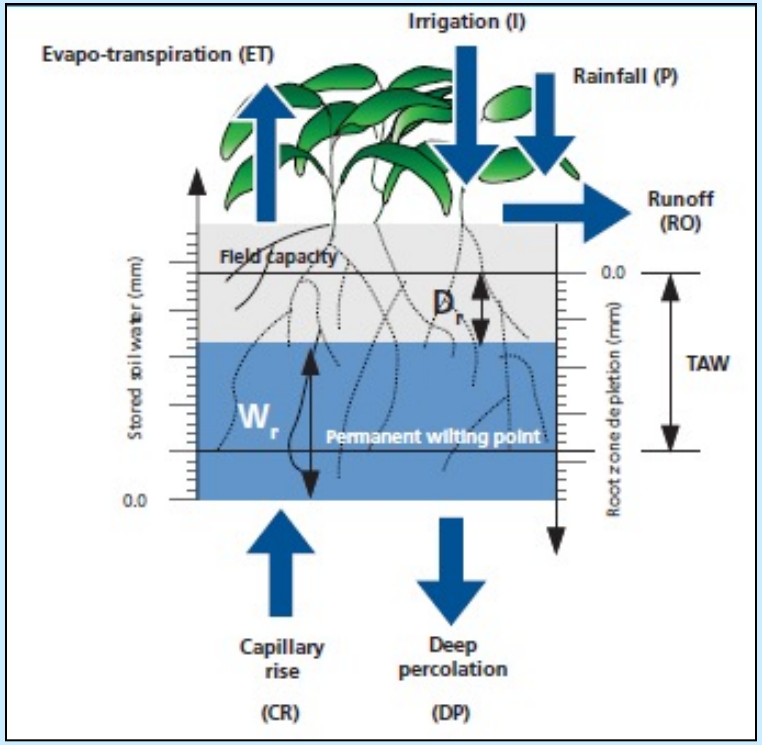
W_a (in./ft.) = Water-holding Capacity of the soil (FC-WP)

MAD = Management Allowable Depletion (moisture depletion threshold for no stress)

P_W (%) = Percent Wetted Area

Z_E (ft.) = Effective Root Depth (60-70% of actual root depth)

$Eff._{APPL.}$ = Application Efficiency of the selected irrigation method



How to convert water depth (in.) to gallons per plant?

$$Water\ volume\left(gals/day\right) = Water\ Depth\ (in/day) * crop\ spacing\ (ft^2) * 0.623$$

Crop Spacing (ft^2) = row spacing × plant spacing	Evapotranspiration (inches per day)							
	0.05	0.1	0.15	0.2	0.25	0.3	0.35	0.4
100	3	6	9	12	16	19	22	25
200	6	12	19	25	31	37	44	50
400	12	25	37	50	62	75	87	100
600	19	37	56	75	93	112	131	150
800	25	50	75	100	125	150	174	199
1000	31	62	93	125	156	187	218	249
1200	37	75	112	150	187	224	262	299
1400	44	87	131	174	218	262	305	349
1600	50	100	150	199	249	299	349	399
1800	56	112	168	224	280	336	392	449
2000	62	125	187	249	311	374	436	498
2200	69	137	206	274	343	411	480	548
2400	75	150	224	299	374	449	523	598

From Larry Schwankl, Blaine Hanson, and Terry Prichard, *Low-Volume Irrigation*. University of California, Davis, 1993.

Calculation Example

Mature vineyard: Cabernet Sauvignon, 5 ft. x 6 ft. spacing, VSP trellis

Irrigation system: Single dripline

Root depth, Z = ~ 5 ft.

Effective rooting depth, Z_E = 70% x 5 ft. = 3.5 ft.

Wetted area, P_W = 25%

Sandy loam soil

F.C. = 3.25 in./ft

P.W.P. = 1.67 in./ft

T.A.W. = 3.25 – 1.67 = 1.60 in/ft

M.A.D. = 50 % of T.A.W. = 0.5 x 1.60 in/ft = 0.80 in/ft

Max gross irrigation depth to apply

$\mathbf{D_{GMAX}}$ = (MAD * TAW * Pw * Z_E)/Eff_A = (0.5 * 1.60 in/ft * 0.25 * 3.5 ft)/0.85 = **0.8 in.**

Vol (gal/plant) = D_{GMAX} x Spacing x 0.623 = 0.8 in. x 5 ft x 6 ft x 0.623 **= 15 gals/plant**

Typical Flow Rates and Pressures

Drip & Micro-sprinklers: 0.5-30 gph @ operating pressures of **20-35 psi**

- Micro-irrigation emitters require only 7-12 psi (drippers - fanjets);
- Filtering and delivering water to emitters on flat grounds typically require additional 15-25 psi;
- Filters are the critical system's components, requiring around 15-25 psi (30-35 psi if of back-flushing type);

Most Relevant System's Components

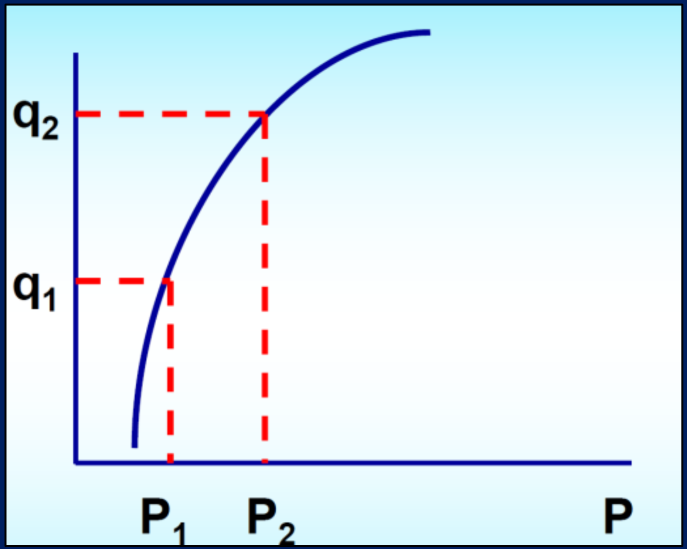




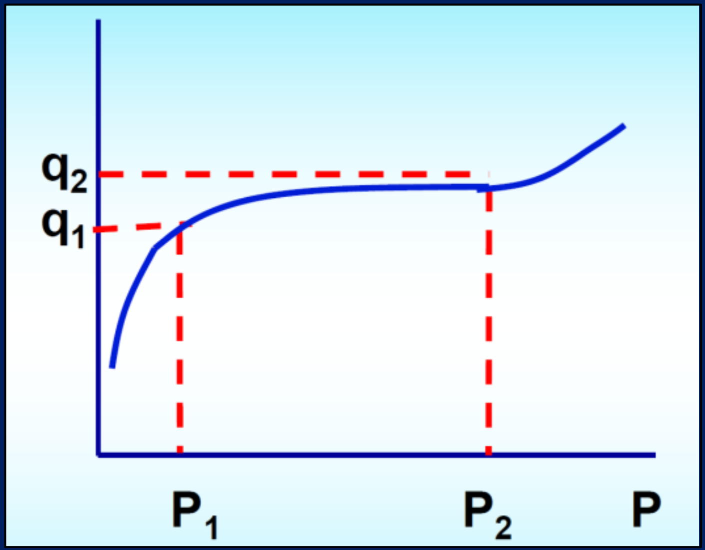
Monitoring Flow and Pressure is crucial to detect problems and correcting them in timely manner

$$q = k \cdot P^x$$

NON-PC EMITTERS (x > 0.5)



PC EMITTERS (x < 0.5)



ENERGY REQUIREMENTS FOR IRRIGATION

It takes 1.37 whp-hr/ac-ft of water per foot of lift

(power the pump must provide to lift 1 ac-foot of water by 1 foot)

FUEL SOURCE	PUMP OUTPUT
ELECTRICITY	0.885 whp-hr/kWh
NATURAL GAS (925 BTU)	61.7 whp-hr/MCF
NATURAL GAS (1000 BTU)	66.7 whp-hr/MCF
DIESEL	12.50 whp-hr/gal
PROPANE	6.89 whp-hr/gal

Source of Energy	Energy Units to Lift Water
Electricity	1.55 kWh/ac-ft per foot of lift
Natural Gas (925 BTU)	0.022 MCF/ac-ft per foot of lift
Natural Gas (1000 BTU)	0.020 MCF/ac-ft per foot of lift
Diesel	0.10 Gal/ac-ft per foot of lift
Propane	0.20 Gal/ac-ft per foot of lift

Source: Nebraska Pumping Plant Performance Criteria (NPPPC)

Mature Vineyard with Micro-Sprinkler vs. Drip Irrigation

Vineyard ($ET - R_{EFF}$) = 18 in. => 1.5 ft. of water per season

Area = 40 acres

Irrigation methods: <u>Micro-Sprinkler</u> (35 psi) vs. <u>Drip Irrig.</u> (25 psi) @ pump outlet

Water Lift = 100 ft. (from aquifer level to ground)

$TDH_{MICRO\text{-}SPR.}$: 100 ft + (35 psi x 2.31 ft/psi) = **180 ft.**

TDH_{DI}: 100 ft + (25 psi x 2.31 ft/psi) = **158 ft.**

Total ac-ft $_{MICRO\text{-}SPR.}$ = 1.5/0.80 = **1.9 ac-ft**.

Total ac-ft $_{DI}$ = 1.5/0.90 = **1.7 ac-ft**

Diesel => 0.10 gal/ac-ft per foot of lift

System	$Eff._A$
Gravity (surface)	0.70
Drip & SDI	0.90
Micro-sprinkler	0.80
Sprinkler	0.75

Average Price of Diesel for Ag.= **$2.50 per gallon**

Volume of Diesel for Micro-Sprinkler: 40 ac x 1.9 ac-ft x 180 ft x 0.10 gal/ac-ft = **1,368 gal**

Cost for Micro-Sprinkler irrigation: 1,368 gal x $2.50 per gallon = **<u>$3,420</u>**

Volume of Diesel for Drip Irrigation = 40 ac x 1.7 ac-ft x 158 ft x 0.10 gal/ac-ft = **1,075 gal**

Cost for Drip Irrigation: 1,075 gal x $2.50 per gallon = **<u>$2,690</u>**

SOME RECOMMENDATIONS

Have a professional system evaluation at least every 2-3 years

DU and application rate tend to change over time

Know your system application rate & DU

⇒ Key elements for scheduling irrigations

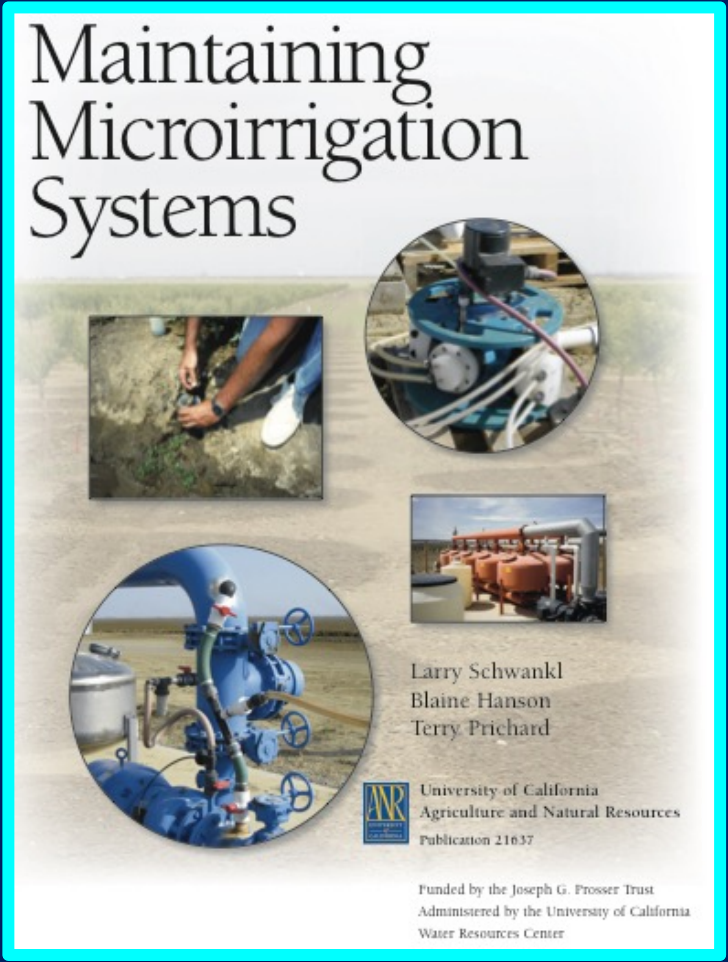
(time to run the system = water to be applied/application rate)

Monitor the system periodically to spot and correct problems

(check mainly flowrate and pressure at critical points)

HIGH SYSTEM EFFICIENCY REQUIRES SIGNIFICANT EFFORTS IN ROUTINE MAINTENANCE

- ✓ Checking for leaks (farm equipment & animals)
- ✓ Back-flushing filters (manually or automatically)
- ✓ Periodically flushing main, submain and laterals (in that order)
- ✓ Chlorinating for organic material: continuous (1-2 ppm) or periodic (10-50 ppm)
- ✓ Acidifying (lowering Ph. < 7-5) to avoid/remove precipitates
- ✓ Cleaning or replacing clogged emitters and other components



Publication available at:

http://anrcatalog.ucdavis.edu/Details.aspx?itemNo=21637

CLOGGING IS THE MAIN CAUSE OF POOR SYSTEM D.U.

<u>Main causes of clogging include:</u>

- ✓ Suspended material in irrigation water
- ✓ Chemical precipitation in emitters
- ✓ Biological growth in emitters
- ✓ Root intrusion
- ✓ Soil ingestion

Types of clogging manageable through chemical injection

Types of clogging	Action	Remedial
Slimy bacteria	grow inside pipes & emitters	chlorine, ozone, citric acid, Phyto-C3
Iron & Manganese oxides	bacteria oxidize iron and manganese	chlorine, phosphate, Phyto-C3, aeration in ponds
Iron & Manganese sulfides	toxic to plants even in small concentrations	aeration, chlorination, Phyto-C3 and acid injection
Calcium & Magnesium Carbonates	clogging emitters	lowering pH to 7, sulphuric and phosphoric acid injection, Phyto-C3
Plant roots entry into emitters	clogging emitter from outside	acid injection, embedded herbicides

An average pipe flow velocity of 1.0 ft/s can be assumed.

Divide this velocity into the longest pipe distance in the system (from pump to farthest emitter) and determine the adequate injection time and rinse time

Phyto-C3TM Organic Evaluation at Oakville Station

- Aim of this trial was to evaluate the Phyto-C3 in a developing vineyard in coastal California
- C. Sauvignon/110R
- Objectives:
  - Identify distribution uniformity pre and post cleaning
  - Evaluated the dosage (RCBD w/ 4 reps)
  - 0 ppm
  - 2 ppm
  - 4 ppm
- Components of yield
- Berry composition
- Soil health aspects

Distribution Uniformity at Old Federal Vineyard 7

- Rain water captured in basin
- Berkeley pump (100 gpm) delivers to irrigation manifold
  - 30 psi at each manifold
  - Dual line 600 mm hose, Four, 2 L/h emitters per plant
  - Injection ports at each manifold
- Vineyard size 2.3 acres
- Spaced 9’ x 6’ Cabenert Sauvignon/110R
- Planted 2019
- DU measured 6/21/2021 and 8/16/2021 using UC ANR Methodology

Distribution Uniformity Results at OFV 7

Factor	Pressure	DU
Pre cleaning *	22 b	0.74 b
Post cleaning	28 a	0.92 a
t-test	0.0001	0.0001

- Vineyard pre-irrigated for one hour
- 2.5 litre of Phyto-C3 was injected via 2000 L nurse tank
- on 6/22/2021 and let sit overnight
- Regular irrigation resumed the following day

Dosage Trial of Phyto-C3™

- Conducted in OFV 11 (Organic designate)
- Three treatments applied via Venturi injectors
  - 0 ppm (Control)
  - 2 ppm
  - 4 ppm
- Irrigated weekly/dosed weekly
- Experimental design
  - RCBD with 4 replicates
  - 20 experimental plants per replicate/treatment
- Plant primary metabolism
- Plant secondary metabolism
- Soil microbiome and health assessment

Components of Yield 2021

Factor	Berry w (g)	Cluster wt (g)	Yield (kg/vine)
Control	1.96 b	103.34	1.13 b
2 ppm	1.99 ab	110.93	1.57 b
4 ppm	2.12 a	112.98	2.89 a
Pr>F	0.0367	0.8088	0.0117

Phyto-C3 Organic performed similarly to Conventional Product
Instead of injecting at pump head, Venturi injector at line delivered fresher mix

Berry Composition

Factor	TSS (%)	Juice pH	TA	Anthocyanin (mg/berry)
Control	24.2	3.61	0.72	0.93
2 ppm	22.0	3.55	0.74	1.17
4 ppm	22.6	3.56	0.74	0.97
Pr>F	0.1574	0.3722	0.8271	0.0922

Berry composition was not adversely affected

The greater yield with Phyto-C3 resulted in similar fruit composition to untreated control

Two modes of action:

Cleaning of lines, greater water availability through better DU

Biostimulant activity as previously reported with conventional product line

Ongoing work with Phyto-C3

- For cleaning out lines:
  - 32 oz per acre is correct rate
  - Improvement in pressure
  - Improvement in DU
- Continued dosing
  - Increase in berry mass compared to Control
  - Increase in cluster mass compared to Control
  - Increase in yield compared to control
  - No adverse effects in primary metabolites
  - No adverse effects in color composition or content

IRRIGATION SYSTEM EVALUATION

OBJECTIVES:

- ✓ Average Application Rate (in/hr)
- ✓ System Distribution Uniformity, D.U. (%)
- ✓ Identify main problems & corrections

WHAT PARAMETERS ARE MEASURED IN THE FIELD?

FLOWRATE

PRESSURE

CALCULATING DISTRIBUTION UNIFORMITY

$$D.U. = \frac{average\ flow\ of\ lowest\ 25\%\ emitters\ measured}{average\ flow\ of\ all\ emitters\ measured}$$

EXAMPLE OF D.U. CALCULATION IN A VINEYARD

0.98 gph	0.89 gph	0.95 gph	0.94 gph
0.99 gph	1.05 gph	0.99 gph	1.00 gph
1.15 gph	0.70 gph	1.05 gph	1.01 gph
0.98 gph	0.97 gph	0.96 gph	0.94 gph

The total number of emitters measured: 16
(=> 25% * 16 emitters = 4 emitters)

The average flow of all emitters measured: 0.97 gph

The average flow of the lowest 4 emitters measured (25%): 0.87 gph

The Distribution Uniformity = 0.87/0.97 = 90%

Collection time:	0.5	minutes
Hose pressure at emitters:	24.5	psi
	Collected volume:	
#1	258	mL
#2	304	mL
#3	290	mL
#4	320	mL
#5	288	mL
#6	305	mL
#7	312	mL
#8	220	mL
#9	310	mL
#10	320	mL
#11	315	mL
#12	307	mL
#13	305	
#14	312	
#15	297	
#16	304	

The average flow rate was	8.9101	gph.
The average application rate was	0.0357	in/hr.
The Flow DU for this location was	87.7764	%

Distribution Uniformity.. 85%

How your system rates:

Poor	Fair	Good	Very Good	Excellent
			X	
74 or below	75-79	80-84	85-89	90 and up

ADDITIONAL INFORMATION FROM SYSTEM EVALUATION

DRIP/MICRO EVALUATION: PROBLEMS NOTED

Ref. #

5 The field DU is considered poor

Pressure problems

Manifold inlet pressure variation is a significant problem

Possible causes of manifold inlet pressure variation include:

6 -Lack of pressure regulation;

consider installing manifold pressure regulators

Hose inlet pressure variation is a significant problem

Possible causes of hose inlet pressure variation include:

9 -Defective regulators

10 -Inlet pressure lower than pressure regulator's operating range

12 Some pressures found in the field were very low

Other problems noted

27 Fertilizer injector located downstream of filter

31 High pressure losses at pump station

34 Small wetted soil area

DRIP/MICRO EVALUATION: PROBLEMS NOTED

Ref. #

3 The field DU is considered OK

Pressure problems

Hose inlet pressure variation is a significant problem

Possible causes of hose inlet pressure variation include:

8 -Lack of pressure regulation;

consider installing hose pressure regulators

Other problems noted

27 Fertilizer injector located downstream of filter

30 No flow meter