Orchard Irrigation
Determining the Application Rate & Uniformity of a Microirrigation System

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Determining the application rate of microirrigation systems can be confusing because irrigation scheduling and tree water use information is usually presented in inches per day (in/day), while discharge from microirrigation emitters is measured in gallons per hour (gph). The following may be helpful in determining required operating times for microirrigation systems.

The water use of the tree **and** the application rate of the microirrigation system determine how long the drip and microsprinklers should be operated.

Drip Emitters and Microsprinklers

Step 1 in determining the required operating time is to convert the tree water use (ET) information (usually available in inches per day) to gallons per day of tree water use. The following formula may be used (or see Table 1):

$$\text{Water use by the tree (gal/day)} = \text{Tree spacing (ft}^2\text{)} \times \text{Tree water use (in/day)} \times 0.623$$

Example: Tree spacing = 16 ft. x 22 ft. = 352 ft^2 Tree water use = 0.3 in./day

$$\text{Water use by the tree (gal/day)} = 352\ ft^2 \times 0.3\ in/day \times 0.623 = 66\ gal/day$$

Table 1. Tree water use (gallons/day) for various plant spacing and tree water use (in/day).

Tree spacing (ft^2)	ET (in/day)							
	0.05	**0.1**	**0.15**	**0.2**	**0.25**	**0.3**	**0.35**	**0.4**
50	2	3	5	6	8	9	11	12
100	3	6	9	12	16	19	22	25
150	5	9	14	19	23	28	33	37
200	6	12	19	25	31	37	44	50
250	8	16	23	31	39	47	55	62
300	9	19	28	37	47	56	65	75
350	11	22	33	44	55	65	76	87
400	12	25	37	50	62	75	87	100
450	14	28	42	56	70	84	98	112
500	16	31	47	62	78	94	109	125

Tree spacing (ft^2) = row spacing (ft) x tree spacing with the row (ft)

Step 2 is to determine the average application rate and application uniformity of the microirrigation system.

Step 2.1 Collect water from selected drip emitters or microsprinklers. Drip emitter or microsprinkler discharge may vary with system pressure. For example, a 1 gallon per hour (gph) dripper may not actually be discharging at 1.0 gph. Discharge rates of microirrigation systems with pressure-compensating (PC) drippers or microsprinklers are not as affected by system pressure differences.

If there are multiple irrigation blocks, each block should be evaluated separately since they may be operating at different pressures. In addition, you might sample at any other spots where you suspect there could be a difference in the pressure and discharge rate. For example, sample at low or high elevation areas in the orchard. More drippers or microsprinklers than suggested below should be sampled on large irrigation blocks (greater than 20 acres).

Step 2.2 Sample drip emitters or microsprinklers at the following locations. See attached Microirrigation System Evaluation Form:

Head of the system - 4 near the head of the lateral
- 4 near the middle of the lateral
- 4 near the end of the lateral

Middle of the system - 4 near the head of the lateral
- 4 near the middle of the lateral
- 4 near the end of the lateral

Tail end of the system - 4 near the head of the lateral
- 4 near the middle of the lateral
- 4 near the end of the lateral

Step 2.3 For drip irrigation systems, collect water for 30 seconds in a 100 ml graduated cylinder. Use Table 2 to convert the amount of water collected from each sampled emitter to the discharge rate in gallons/hour for that emitter.

For microsprinklers, collect water for 30 seconds in a 500 or 1000 ml graduated cylinder. Use Table 3 to convert the collected water volume to microsprinkler discharge rate (gallons/hour).

The following examples are summarized on the attached Sample Data Sheet.

Example

Determine Average Application Rate

Drip Emitters

For each irrigation block, calculate the average of all your discharge rate measurements. If you measured the output of 36 drip emitters, find the average discharge rate (gph) of the 36 emitters.

Average discharge rate of all emitters = 1.04 gph (see sample data sheets)

If there are 4 drip emitters per tree

Application rate per tree(gph)	=	*1.04 gph per dripper*	x	*4 drippers per tree*	=	*4.16 gph/tree*

Average Application Rate is 4.16 gph/tree

Microsprinklers

For each irrigation block, calculate the average of all your discharge rate measurements. If you measured the output of 36 microsprinklers, find the average discharge rate (gph) of the 36 microsprinklers.

Average discharge rate of all microsprinklers = 10.41 gph (see sample data sheets)

If there is one microsprinkler per tree

Application rate per tree(gph)	=	*10.41 gph per micro*	x	*1 micro per tree*	=	*10.41 gph/tree*

Average Application Rate is 10.41 gph/tree

Table 2. Determining drip emitter discharge rate in gallons per hour (gph) using a graduated cylinder

Milliliters of water collected in 30 seconds	Drip emitter discharge rate (gallons/hour)
10	0.32
12	0.38
14	0.44
16	0.51
18	0.57
20	0.63
22	0.70
24	0.76
26	0.82
28	0.89
30	0.95
32	1.01
34	1.08
36	1.14
38	1.20
40	1.27

A 100 ml graduated cylinder works well. These are available in many hardware stores. If possible, use a glass cylinder because it is easier to read than plastic.

Values in Table 2 were calculated using the following equation:

Drip emitter discharge rate (gph)	=	**Water (ml) collected in 30 seconds**	x	**0.0317**

Table 3. Determining microsprinkler discharge rate in gallons per hour (gph) using a graduated cylinder

Milliliters of water collected in 30 seconds	Drip emitter discharge rate (gallons/hour)
200	6.34
220	6.97
240	7.61
260	8.24
280	8.88
300	9.51
320	10.14
340	10.78
360	11.41
380	12.05
400	12.68
420	13.31
440	13.95
460	14.58
480	15.22
500	15.85
520	16.48
540	17.12
560	17.75
580	18.39
600	19.02

A 500 or ml graduated cylinder works well. These are available in many hardware stores.

Values in Table above were calculated using the following equation:

Drip emitter discharge rate (gph) = Water (ml) collected in 30 seconds x 0.0317

Using a Flowmeter to Determine How Much You Are Applying

An alternative method of determining the average depth of applied water (inches) during an irrigation set is to monitor the flow meter (if available) at the pump or irrigation turnout. The following formula can then be used:

$$\text{Applied depth of water (inches)} = \frac{\text{Pump discharge (gpm)} \times \text{Irrigation time per set (hrs)}}{449 \times \text{Acres irrigated per set}}$$

Determine the Emission Uniformity

Each drip emitter or microsprinkler in the orchard will be discharging water at a different rate. This discharge variability is due to manufacturing variation between emitters, pressure differences in the system, and any emission device clogging which may be occurring. We need to compensate for the variability when we determine how much to irrigate.

The microirrigation system's application uniformity is quantified using a measurement called the Emission Uniformity (sometimes referred to as the Distribution Uniformity). The Emission Uniformity (EU) is defined as:

To determine the average discharge rate (gph) of the low 25% of sampled emitters or microsprinklers, the discharge rate of each of the sampled emission devices should be ranked from lowest to highest. If you are familiar with computer spreadsheet use, this becomes very quick and easy. Then 25% of the drippers or microsprinklers with the lowest discharge rate should be averaged together. For example, if 36 emitters were monitored, the average of the 9 emitters with the lowest discharge rates would be determined.

Examples:

Drip System (see sample data sheets)

Average discharge rate of all sampled emitters = 1.04 gph
Average discharge rate of the low 25% sampled emitters = 0.98 gph

Average Emission Uniformity is 94% (This is excellent)

Microsprinkler System (see sample data sheets)

Average discharge rate of all sampled emitters = 10.41 gph
Average discharge rate of the low 25% sampled emitters = 9.29 gph

Average Emission Uniformity is 89% (This is very good)

Step 3 is to determine the irrigation system operation time in hours per day.

Step 3.1 The irrigation amount (*gross* irrigation amount) includes the water you have chosen to replace (*net* irrigation amount) *plus* some additional water to account for the inefficiencies of the irrigation system. The irrigation amount is determined as:

Irrigation efficiency is difficult to quantify but if the drainage* and the runoff is minimal, then irrigation efficiency can be approximated using the emission uniformity. The above equation becomes:

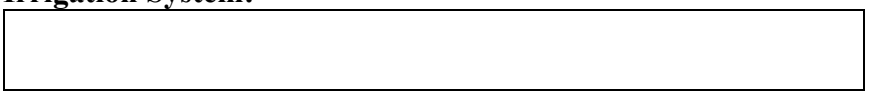
Example:

Net irrigation amount = 66 gal per tree per day (from Step 1)
Average drip application rate per tree = 4.16 gph (from Step 2 example)
Drip System Emission uniformity = 94% (from Step 2 example)

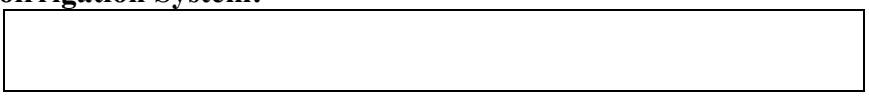
Average microsprinkler application rate per tree = 10.41 gph (from Step 2 example)
Microsprinkler System Emission uniformity = 89% (from Step 2 example)

Example (cont.):

Drip Irrigation System:



Microirrigation System:



Step 3.2 To determine the hours of drip or microsprinkler operation per day, the Gross Irrigation Amount (gal/day) and the Average Application Rate (gal/hr) are used as follows:

$$\text{Hours of operation per day} = \frac{\text{Gross Irrigation Amount (gal/day)}}{\text{Avg. Application rate (gal/hr)}}$$

Example (cont.):

Drip emitters: Tree water use (gal/day) = 70 gal/day *(Step 3.1)*
Application rate (gal/hr) = 4.16 gal/hr *(Step 2.3)*

Hours of operation per day = 70 gal/day ÷ 4.16 gal/hr
= **16.8 hrs/day**

Microsprinklers: Tree water use (gal/day) = 74 gal/day *(Step 3.1)*
Application rate (gal/hr) = 10.41 gal/hr (Step 2.3)

Hours of operation per day = 74 gal/day ÷ 10.41 gal/hr
= **7.1 hrs/day**

* Drainage is water that has moved below the tree's root system.

Table 4 gives the same hours of operation for these examples.

Table 4. Hours of operation per day for various application rates (gal/hr) and tree water use (gal/day).

Tree Water Use	Application rate (gal/hr)										
(gal/day)	**1**	**2**	**4**	**6**	**8**	**10**	**12**	**14**	**16**	**18**	**20**
5	5.0	2.5	1.3								
10	10.0	5.0	2.5	1.7	1.3	1.0					
15	15.0	7.5	3.8	2.5	1.9	1.5	1.3	1.1			
25		12.5	6.3	4.2	3.1	2.5	2.1	1.8	1.6	1.4	1.3
50			12.5	8.3	6.3	5.0	4.2	3.6	3.1	2.8	2.5
75			18.8	12.5	9.4	7.5	6.3	5.4	4.7	4.2	3.8
100				16.7	12.5	10.0	8.3	7.1	6.3	5.6	5.0
125				20.8	15.6	12.5	10.4	8.9	7.8	6.9	6.3

Example: Summary

In order to match tree water use in this example, the drip irrigation system would need to be operated nearly 17 hours per day, while the microsprinkler system would need to be operated a little over 7 hours per day.

The drip system would need to be operated every day when tree water use is high as in this example (0.3 in/day). It would be preferable to not operate the microsprinklers every day though. Longer microsprinkler set times encourages deeper water penetration, so an irrigation interval of 3 days would be suggested.

During periods of lower tree water use, the irrigation interval of both the drip and microsprinkler systems would be adjusted to match the lower tree water requirements.

Microirrigation Evaluation Form

Location: _____ **Date:** _____
Observer: _____
Comments: _____
_____
_____
_____
Microirrigation System Layout (sketch) including emitter sampling locations:

Microirrigation Evaluation Form

Sampled Drip Emitter	Location	Water (ml) collected in 30 seconds	Emitter discharge rate (gph)	Ranking
1	_____	_____	_____	_____
2	_____	_____	_____	_____
3	_____	_____	_____	_____
4	_____	_____	_____	_____
5	_____	_____	_____	_____
6	_____	_____	_____	_____
7	_____	_____	_____	_____
8	_____	_____	_____	_____
9	_____	_____	_____	_____
10	_____	_____	_____	_____
11	_____	_____	_____	_____
12	_____	_____	_____	_____
13	_____	_____	_____	_____
14	_____	_____	_____	_____
15	_____	_____	_____	_____
16	_____	_____	_____	_____
17	_____	_____	_____	_____
18	_____	_____	_____	_____
19	_____	_____	_____	_____
20	_____	_____	_____	_____
21	_____	_____	_____	_____
22	_____	_____	_____	_____
23	_____	_____	_____	_____
24	_____	_____	_____	_____
25	_____	_____	_____	_____
26	_____	_____	_____	_____
27	_____	_____	_____	_____
28	_____	_____	_____	_____
29	_____	_____	_____	_____
30	_____	_____	_____	_____
31	_____	_____	_____	_____
32	_____	_____	_____	_____
33	_____	_____	_____	_____
34	_____	_____	_____	_____
35	_____	_____	_____	_____
36	_____	_____	_____	_____
37	_____	_____	_____	_____
38	_____	_____	_____	_____
39	_____	_____	_____	_____
40	_____	_____	_____	_____

Avg. discharge rate of all sampled emitters = _____gph
Avg. discharge rate of the low 25% of sampled emitters = _____ gph

= _____ x 100 = _____%

Microirrigation Evaluation Form – Drip System

Sampled Drip Emitter	Location	Water (ml) collected in 30 sec	Emitter discharge rate (gph)	Ranking
1		33	1.05	18
2		35	1.11	30
3		33	1.05	19
4		32	1.01	8
5		35	1.11	31
6		34	1.08	25
7		36	1.14	35
8		35	1.11	32
9		34	1.08	26
10		30	0.95	1
11		32	1.01	9
12		37	1.17	36
13		32	1.01	10
14		32	1.01	11
15		33	1.05	20
16		32	1.01	12
17		33	1.05	21
18		32	1.01	13
19		34	1.08	27
20		31	0.98	3
21		35	1.11	33
22		32	1.01	14
23		33	1.05	22
24		34	1.08	28
25		32	1.01	15
26		31	0.98	4
27		34	1.08	29
28		32	1.01	16
29		30	0.95	2
30		31	0.98	5
31		32	1.01	17
32		35	1.11	34
33		31	0.98	6
34		33	1.05	23
35		33	1.05	24
36		31	0.98	7

Avg. discharge rate of all sampled emitters = _1.04_ gph
Avg. discharge rate of the low 25% of sampled emitters = _0.98 gph

$$= \frac{0.98}{1.04} \times 100 = 94\ \%$$

Microirrigation System Evaluation Form – Microsprinkler System

Sampled Drip Emitter	Location	Water (ml) collected in 30 sec	Micro discharge rate (gph)	Ranking
1		313	9.93	10
2		310	9.83	7
3		333	10.57	20
4		317	10.04	14
5		313	9.93	11
6		300	9.51	4
7		310	9.83	8
8		353	11.20	30
9		317	10.04	15
10		320	10.14	17
11		300	9.51	5
12		220	6.97	1
13		317	10.04	16
14		347	10.99	26
15		313	9.93	12
16		293	9.30	2
17		310	9.83	9
18		333	10.57	21
19		333	10.57	22
20		343	10.88	25
21		367	11.62	33
22		313	9.93	13
23		357	11.31	31
24		293	9.30	3
25		347	10.99	27
26		357	11.31	32
27		300	9.51	6
28		387	12.26	34
29		393	12.47	36
30		333	10.57	23
31		327	10.36	18
32		327	10.36	19
33		347	10.99	28
34		350	11.10	29
35		387	12.26	35
36		340	10.78	24

Avg. discharge rate of all sampled micros = 10.41 gph
Avg. discharge rate of the low 25% of sampled micros = 9.29 gph

$$= \frac{9.29}{10.41} \times 100 = 89\ \%$$