Soil Intake Rates and Application Rates in Sprinkler-Irrigated Orchards

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INTRODUCTION

The California State Water Code requires anyone discharging waste that could affect the waters of the state to obtain a permit or coverage under a waiver. Agricultural runoff, whether from irrigation or rainfall, that leaves a property has been determined to likely contain waste (sediment, nutrients, chemicals, etc.).

Compliance under the Irrigated Lands Conditional Waiver is available to agricultural landowners who have runoff from their property caused by irrigation practices or winter rainfall. The California Water Code does not impact the property owner if no runoff from any source leaves a property.

If the sprinkler application rate is greater than the soil's infiltration (intake) rate, water will pond on the soil surface and then run off. Water from sprinklers should infiltrate where it lands on the soil in order to minimize runoff and maintain the application uniformity of the sprinkler system. A high application uniformity allows a manager to irrigate efficiently while ensuring that the entire crop is adequately irrigated.

SOIL INTAKE RATE

In general, the intake rate of lighter-textured (sandy) soils is higher than that of heavier-textured (clay) soils. However, sprinkler irrigation with very-high-quality water can lead to surface runoff even on sandy soils.

Matching the sprinkler application rate to the soil intake rate is difficult because the rate at which water infiltrates into soil is complex. First, the intake rate varies with time: it is high when water is first applied and decreases with time (fig. 1). Runoff is therefore more likely to occur the longer the irrigation lasts. On soils with low intake rates and a greater runoff potential, growers often irrigate more frequently with shorter set times to minimize water runoff. Matching the sprinkler application rate to the final, or basic, intake rate (fig. 1), as opposed to the initial rate, is critical to minimizing runoff. This final intake rate may be reached a number of hours into irrigation. The sprinkler application rate should not exceed this final intake rate if runoff is to be prevented.

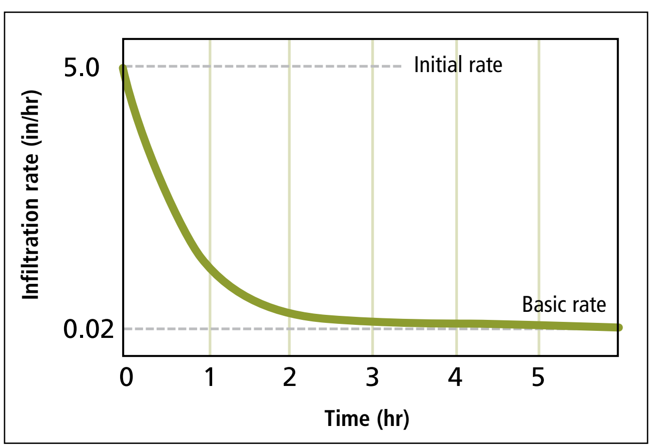

Figure 1. Idealized intake rate versus time.

Second, orchard floor management can significantly affect the soil intake rate. Machinery traffic through the orchard, especially when the soil is wet, can compact the soil and decrease the intake rate. Soils recently worked to reduce surface sealing often have a significantly higher intake rate, but this effect may not remain after one or two irrigations. In addition, a cover crop in the orchard may increase the water intake rate by protecting the soil from compaction caused by water droplets, keeping the soil permeable, and slowing water runoff from the field, which allows more time for infiltration to occur.

Table 1. Recommended maximum application rates for soils of various textures

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

Source: NRCS 1984.
Note: Metric conversion: 1 in = 2.54 cm.

Figure 2. Sprinkler nozzle. The size is stamped on the hexagonal surface of the nozzle. *Photo:* Lawrence J. Schwankl.

Figure. 3. Pressure gauge fitted with a pitot tube to measure sprinkler nozzle pressure. *Photo:* Lawrence J. Schwankl.

Third, the slope of the land also affects the soil intake rate, since water runs off faster from an orchard with a slope than it does from a level orchard.

Fourth, the chemical composition of the soil and the irrigation water can affect the intake rate and amount of runoff.

MATCHING SPRINKLER APPLICATION RATE TO THE SOIL INTAKE RATE

Determining the design application rate of a sprinkler irrigation system is a challenge, but three approaches may provide guidance. The approaches include using the soil texture for guidance, using the application rate of an existing sprinkler system with similar soil conditions as guidance, and running a sprinkler test at the proposed orchard site.

Using Soil Texture as Guidance

The soil type in the orchard can provide some guidance as to an appropriate application rate. Table 1 shows the recommended maximum sprinkler application rates for various soil types and slopes. This information can be a first step in determining the sprinkler application rate. Remember that orchard floor management can also be extremely important in determining the soil intake rate.

Evaluating an Existing Sprinkler System

Another approach is to examine nearby orchards with similar soil and orchard management conditions whose sprinkler irrigation systems do not cause runoff for guidance on sprinkler application rates.

The application rate of a sprinkler system, usually measured in inches per hour (in/hr), is determined from the sprinkler discharge rate and the spacing of the sprinklers. The discharge rate of a sprinkler, measured in gallons per minute (gpm), is controlled by the sprinkler nozzle size and the sprinkler operating pressure.

Table 2 lists sprinkler discharge rates for various nozzle sizes and operating pressures. The greater the nozzle size operated at a given pressure, the greater the sprinkler discharge rate. The nozzle size is frequently engraved on the side of the nozzle (fig. 2), or it can be determined by testing the nozzle opening with drill bits of a known size. The operating pressure can be determined by placing a pressure gauge fitted with a pitot tube (fig. 3), available at most irrigation supply stores, into the water stream just outside the nozzle opening (fig. 4).

The sprinkler discharge rate can also be quickly determined by using a short length (approximately 4 feet) of garden hose, a 5-gallon bucket, and a stopwatch (fig. 5). By placing the hose over the sprinkler nozzle and directing

Table 2. Sprinkler discharge rates (gpm) for various nozzle sizes (in) and pressures (psi)

Pressure (psi)	Nozzle size (in)										
	3/32	7/64	1/8	9/64	5/32	11/64	3/16	13/64	7/32	15/64	1/4
20	1.17	1.60	2.09	2.65	3.26	3.92	4.69	5.51	6.37	7.32	8.34
25	1.31	1.78	2.34	2.96	3.64	4.38	5.25	6.16	7.13	8.19	9.32
30	1.44	1.95	2.56	3.26	4.01	4.83	5.75	6.80	7.86	8.97	10.21
35	1.55	2.11	2.77	3.50	4.31	5.18	6.21	7.30	8.43	9.69	11.03
40	1.66	2.26	2.96	3.74	4.61	5.54	6.64	7.80	9.02	10.35	11.79
45	1.76	2.39	3.13	3.99	4.91	5.91	7.03	8.30	9.60	10.99	12.50
50	1.85	2.52	3.30	4.18	5.15	6.19	7.41	8.71	10.10	11.58	13.18
55	1.94	2.64	3.46	4.37	5.39	6.48	7.77	9.12	10.50	12.15	13.82
60	2.03	2.76	3.62	4.50	5.65	6.80	8.12	9.56	11.05	12.68	14.44
65	2.11	2.88	3.77	4.76	5.87	7.06	8.45	9.92	11.45	13.21	15.03
70	2.19	2.99	3.91	4.96	6.10	7.34	8.78	10.32	11.95	13.70	15.59
75	2.27	3.09	4.05	5.12	6.30	7.58	9.08	10.66	12.32	14.19	16.14

Note: Metric conversions: 1 gal = 3.785 l; 1 in = 2.54 cm; 1 psi = 6.89 kPa.

Table 3. Average application rates for various sprinkler discharge rates (gpm) and areas of coverage (ft^2)

Sprinkler area (ft^2)	Sprinkler discharge rate (gpm)							
	0.75	1.00	1.25	1.50	1.75	2.00	2.25	2.50
500	0.14	0.19	0.24	0.29	0.34	0.39	0.43	0.48
550	0.13	0.18	0.22	0.26	0.31	0.35	0.39	0.44
600	0.12	0.60	0.20	0.24	0.28	0.32	0.36	0.40
650	0.11	0.15	0.19	0.22	0.26	0.30	0.33	0.37
700	0.10	0.04	0.17	0.21	0.24	0.28	0.31	0.34
750	0.10	0.13	0.16	0.19	0.22	0.26	0.29	0.32
800	0.09	0.12	0.15	0.18	0.21	0.24	0.27	0.30
850	0.08	0.11	0.14	0.17	0.20	0.23	0.25	0.28
900	0.08	0.11	0.13	0.16	0.19	0.21	0.24	0.27
950	0.08	0.10	0.13	0.15	0.18	0.20	0.23	0.25
1,000	0.07	0.10	0.12	0.14	0.17	0.19	0.22	0.24
1,050	0.07	0.09	0.11	0.14	0.16	0.18	0.21	0.23
1,100	0.07	0.09	0.11	0.13	0.15	0.18	0.20	0.22
1,150	0.06	0.08	0.10	0.13	0.15	0.17	0.19	0.21
1,200	0.06	0.08	0.10	0.12	0.14	0.16	0.18	0.20
1,250	0.06	0.08	0.10	0.12	0.13	0.15	0.17	0.19
1,300	0.06	0.07	0.09	0.11	0.13	0.15	0.17	0.19
1,350	0.05	0.07	0.09	0.11	0.12	0.14	0.16	0.18
1,400	0.05	0.07	0.09	0.10	0.12	0.14	0.15	0.17
1,450	0.05	0.07	0.08	0.10	0.12	0.13	0.15	0.17
1,500	0.05	0.06	0.08	0.10	0.11	0.13	0.14	0.16
1,550	0.05	0.06	0.08	0.09	0.11	0.12	0.14	0.16
1,600	0.05	0.06	0.08	0.09	0.11	0.12	0.14	0.15

Note: Metric conversions: 1 gal = 3.785 l; 1 ft^2 = 0.093 m^2.

Figure 4. Determining the sprinkler operating pressure using a pitot tube and pressure gauge. *Photo:* Lawrence J. Schwankl.

Figure. 5. Determining the sprinkler discharge rate by collecting a measured discharge for a recorded period of time. *Photo:* Lawrence J. Schwankl.

Figure 6. Temporary hand-move orchard sprinklers. *Photo:* Lawrence J. Schwankl.

the water into the bucket and timing how long it takes to fill the bucket, the discharge rate from the sprinkler can be determined by the following formula.

Sprinkler discharge rate (gpm) = 300 ÷ time to fill a 5-gallon bucket (sec)

Note that the value 300 in the above formula is a unit conversion constant. For example, if it takes 150 seconds to fill the 5-gallon bucket, the sprinkler discharge rate is 300 ÷ 150 seconds = 2 gpm. Measurements should be taken at various locations within the orchard since sprinkler discharge rates vary with the pressure differences in the orchard.

Once the discharge rate of the sprinkler and the sprinkler spacing are known, the sprinkler application rate can be determined using the following formula.

Application rate (in/hr) = [96.3 × Sprinkler discharge rate (gpm)] ÷ [Sprinkler spacing along row (ft) × Sprinkler spacing across row (ft)]

For example, if the sprinkler discharge rate is 1.0 gallons per minute and the sprinkler spacing is 48 feet along the tree row and 20 feet across the tree row, the application rate is [96.3 × 1.0 gpm] ÷ [48 ft × 20 ft] = 96.3 ÷ 960 = 0.1 in/hr.

Table 3 can also be used to determine the sprinkler system application rate. The sprinkler area in square feet (ft^2) is determined by multiplying the sprinkler spacing along the row (in feet) by the sprinkler spacing between rows (in feet). For the previous example, the sprinkler area is 20 ft × 48 ft = 960 ft^2. In Table 3 the sprinkler application rate for 960 ft^2 at a sprinkler discharge rate of 1.0 gpm is 0.1 in/hr, the same value obtained by using the formula.

Testing Application Rates at the Proposed Orchard Site

If a similar sprinkler-irrigated orchard is not available, perform a test at your orchard site to estimate the application rate that will not cause runoff. Install temporary trial sprinklers with different application rates (fig. 6). Place small containers (catch cans) on the soil to measure the application rate. If a straight-sided container (e.g., a coffee can) is used, the depth of water collected during the test can be measured with a thin ruler to determine the application rate, which is often measured in inches per hour (in/hr). If a container with sloping sides is used, determine the depth of water collected by the following formula.

Depth of water collected (cm) = Volume of water collected (ml) ÷ Area of catch can opening (cm^2)

Note that the area of the catch can opening equals 0.79 times the square of the catch can opening diameter. For purposes of metric conversion, 1 cm = 0.394 inch; 1 ml = 0.034 fluid ounce.

Choose locations where water is just beginning to run off to determine the appropriate application rate. Be sure to run the test for the same length of time as the expected irrigation set time since the latter stage of an irrigation is most likely to cause runoff. The sprinkler application rate finally selected for the sprinkler system should be somewhat less than the measured application rate that causes minimal runoff.

REFERENCES

NRCS (USDA Natural Resources Conservation Service). 1984. Sprinkle irrigation. National Engineering Handbook 15, chapter 11. NRCS Conservation Engineering Tools Web site, http://www.info.usda.gov/CED/ftp/CED/EFH-Ch15.pdf.

FOR FURTHER INFORMATION

Storing Runoff from Winter Rains (ANR Publication 8211), 2007.

Understanding Your Orchard's Water Requirements (ANR Publication 8212), 2007.

Measuring Irrigation Flows in a Pipeline (ANR Publication 8213), 2007.

Causes and Management of Runoff from Surface Irrigation in Orchards (ANR Publication 8214), 2007.

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