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Water Management and Irrigation Scheduling

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Water Management

Seasonal evapotranspiration (ET) or water use of a mature raisin vineyard can vary from 19 to 26 inches (483-1143 mm) in the San Joaquin Valley depending on canopy size. ET is a combination of the water evaporating from the soil surface (E) and transpiring from the leaves (T). Evaporative demand varies very little from season to season within the geographical boundary of the raisin industry.

The total amount of irrigation water applied, however, is often more than vineyard ET. An additional 6 to 8 inches (152 - 203 mm) of water may be needed some years for leaching salts and providing frost protection, and the efficiency of the irrigation system must be taken into account. Winter rainfall can offset irrigation requirements by 3 to 6 inches (76 - 152 mm) depending on the timing of the rainfall and the ability of the soil to store water. Typically, raisin vineyards are seasonally irrigated with 24 to 36 inches (610 - 914 mm).

In developing an irrigation strategy for grapevines, canopy development and the timing of the vine's growth stages should be taken into consideration. Water use by grapevines begins with budbreak. It gradually increases as the canopy develops and evaporative demand increases. The canopy is fully developed by early to mid-June, and peak water use will occur in June, July, and August. The effect of irrigation on vine growth and fruit development is best discussed by dividing the season into four stages. The irrigation stages depicted in this chapter should not be confused with the three stages of berry growth discussed elsewhere.

The first irrigation stage **(Stage One)** covers the period from shortly after budbreak to bloom (April 1 to May 10). The water requirement during this period is low with only 2.5 inches (64 mm) used during the 40-day period. Moisture stored in the soil from winter rains is usually adequate to meet vineyard water requirements during this time frame. Even with no spring irrigation, grapevines rarely exhibit symptoms of water stress during this period. The exceptions are vineyards on very sandy or shallow soils with limited soil water storage, or vineyards with cover crops. Irrigations that occur during Stage One are primarily for frost protection or to add to stored soil moisture. The danger of frost is high until mid-April after which the probability of frost diminishes rapidly.

The second stage **(Stage Two)** covers the period from bloom to veraison (May 10 to July 1). Veraison is the point when fruit begins to soften and usually occurs in late June or early July in the San Joaquin Valley. Grapevines use 4 to 7 inches (102 - 178 mm) of water during this period. Proper water management is critical during this time as cell division and elongation are occurring in fruit. Water stress at this time will reduce berry size and yield.

The third irrigation stage **(Stage Three)** covers the period from veraison to harvest (July 1 to September). Thompson Seedless vineyards, when harvested in early September, use 7 to 9 inches (178-229 mm) during this 60-day time frame. Raisin growers generally terminate irrigations 2 to 6 weeks prior to harvest, depending on soil type, to allow time for terrace preparation. Drip irrigation of raisin vineyards may continue up until a few weeks before harvest. Irrigations may be cut back in order to impose moderate stress and reduce shoot growth in vigorous vineyards between veraison and harvest. Excessive irrigation during this period can delay fruit maturity, encourage bunch rot, delay or reduce wood maturity.

The last irrigation stage **(Stage Four)** is the postharvest period that concludes with leaf abscission (early November). The length of this period depends on harvest date. Water use during this 60-day period (for Thompson Seedless harvested early September) is 4 to 6 inches (102-152 mm). Irrigations at this time should be applied in amounts to maintain the canopy but not encourage growth. Excessively vigorous vines will continue to grow or start new growth after harvest and fail to ripen wood if supplied with excessive water. Mild to moderate water stress may be beneficial by stopping shoot growth and promoting wood maturity; however, vines should not be allowed to defoliate. In late October or early November, when temperatures are too low to encourage shoot growth, a heavy irrigation is recommended to replenish some of the soil water reservoir and satisfy the leaching requirement. Vines that are extremely water stressed during this time period may have delayed shoot growth the following spring.

The approximate water use or ET of a Thompson Seedless raisin vineyard during the four above-mentioned irrigation stages can be found in Table 1. Tables 2 and 3 give seasonal water use on a daily basis for a small canopy vine shading 50 to 60 percent of the land surface (a vineyard using a single wire trellis) and a large canopy vine shading 75 percent of the land surface (a vineyard using a crossarm trellis). The seasonal water use for raisin vineyards, Tables 2 and 3, is based on historic reference ET (ET_o) and was developed by research in commercial raisin vineyards and using a weighing lysimeter at the Kearney Ag Center. This water use information can effectively be used to schedule irrigations, particularly drip irrigation.

Scheduling Furrow Irrigated Vineyards

The principle of scheduling furrow irrigations can best be discussed using a water budget. The water budget balances vineyard water use with the size of the soil water reservoir. Irrigations should occur when 30 to 50 percent of the soil water reservoir has been depleted by vine ET, and irrigation should be sufficient to refill the reservoir. The soil water reservoir is based on the available water-holding capacity of the soil (which varies with soil texture) and the depth of the root system.

Available soil water content, rooting depth, and allowable depletions for several different soil textures are given in Table 4. Available water is the difference in volumetric water content between field capacity and the permanent wilting percentage (or point) of the soil. Allowable depletion represents the amount of water that can be readily extracted by the grapevines, before stress begins to occur. For a mature vineyard with a fully developed root system, the allowable depletion is about 2 inches (51 mm) for a sandy soil and 4 inches (102 mm) for a loam or fine sandy loam soil.

The ET of a large canopied vineyard during the month of July is about 0.2 inch (5 mm) per day (Table 3). Therefore, vines growing on sandy soil will require irrigation about every 10 days to avoid water stress (2 inches [51 mm] allowable depletion for a sandy soil/0.2 inch [5 mm] per day). In contrast, a vineyard on a fine sandy loam can go 20 days between irrigations (4 inches [102 mm] allowable depletion for a fine sandy loam soil/0.2 inch [5 mm] per day).

The above examples illustrate an important point: the water use of vines (with similar canopy) is the same regardless of soil type. It is much more difficult to efficiently furrow irrigate vineyards on sandy soil compared to a finer textured soil: more water is lost below the root zone. This difference in irrigation efficiency gives the false impression that the water use of vines on sandy soil is higher than on finer textured soils. Typical irrigation efficiency, allowable depletion, amount of water applied each irrigation, number of irrigations per season, and total water applied for different soil texture classes are given in Table 5.

Irrigation Cutoff

Irrigations must be cut off early enough before harvest to allow drying of the soil surface for preparation of a dry terrace by harvest: irrigations should be cut off 2 to 4 weeks for sandy soil and 4 to 6 weeks for fine textured soils (Table 6). An early cutoff date to purposely impose severe stress to the vine does not promote more total grape sugar or improve raisin grade. A cutoff date that is too early results in some leaf defoliation occurring by harvest, and defoliation is excessive by the time raisins are boxed. This level of stress, if repeated yearly, can weaken the vineyard, reduce production, and should be avoided.

An earlier cutoff date is advisable when in past years vines are still growing vigorously at harvest. Fruit maturity can be delayed when shoots continue to actively grow from veraison to harvest. Also, vines that continue to actively grow until late in the season may develop many poorly matured canes (not woody). This can make it difficult for a pruner to find a sufficient number of mature, fruitful canes. Poor cane maturity can be a serious problem with young, excessively vigorous vineyards. To manage this problem, irrigations should be cut off early enough to slow or stop most shoot growth by harvest.

Postharvest Irrigation

By mid-October, the vineyard is normally terraced back, disced, and prepared for a postharvest irrigation. In some instances vines may have gone for 2 months without an irrigation. Sixty percent or more of the available water in the root zone will have been depleted by October, and vineyards will exhibit symptoms of water stress, in varying degrees. Thus, an irrigation after harvest in October is recommended to replenish soil moisture in the root zone and/or leach salts.

Vineyards on sandy or shallow soils have a much smaller soil water reservoir; therefore, they may be stressed by the time harvest is complete. These vineyards should be irrigated immediately after harvest. In contrast, excessively vigorous vineyards on deep soils with high water-holding capacities should not be irrigated postharvest until late October or November. This will help reduce late season growth and improve cane maturity. Postharvest irrigation can be delayed on vineyards that have been defoliated by insects or mites to prevent excessive late season growth.

Scheduling Drip Irrigations

There is much less soil water storage with drip (one-third to one-fourth as much as with furrow irrigation) which makes frequent irrigations necessary to avoid water stress. By June, about 30 percent or less of the root system may be found in the wetted soil volume directly beneath the emitter. Less than 15 percent of the root system may be wetted if the soil has slow infiltration characteristics. Drip irrigations should be applied frequently (every 1 to 4 days during the summer months) and with enough water to satisfy the vine’s water use over that interval.

The drip irrigation schedules (Tables 2 and 3) indicate how much water should be applied on a daily basis during the season. The schedule given in Table 2 provides daily water use for a vineyard with a 50 to 60 percent canopy which is typical of most raisin vineyards using a single wire trellis system. Table 3 gives daily water use for a vineyard with a 75 percent canopy which is typical for vineyards using a crossarm trellis system.

It is easy and practical to use Tables 2 or 3 to schedule drip irrigations. For example, to schedule irrigations during the first week of July for a large canopied vineyard, use Table 2. The schedule indicates that the vineyard's water use is 3550 gallons per acre (33,202 liters/hectare) per day; therefore, irrigate with 3550 gallons per acre every day (plus an efficiency adjustment - see below) to replenish the soil water extracted. To schedule irrigations every other day, apply 7100 gallons (66,404 1/ha) plus the efficiency adjustment (2 days x 3550 gallons); to schedule irrigations every fourth day, then apply 14,200 gallons (132,808 1/ha) plus the efficiency adjustment (4 days x 3550 gallons). During summer months, irrigation intervals should not exceed every 4 days because of restricted soil water storage and the potential for vine stress between irrigations. To calculate gallons per vine per day, divide the gallons per acre value by the number of vines per acre. For example, if the vineyard has an 8 x 12 ft. (2.4 x 3.6 m) vine and row spacing, then divide 3550 (gallons per acre per day) (33,202 1/ha) by 454 (vines per acre) (1,122 vines per ha) which equals 7.8 gallons (29.6 liters) per vine per day.

Irrigation amounts shown in Tables 2 and 3 do not account for irrigation efficiency of the drip system. Most drip systems have an emission uniformity or water application efficiency of 70 to 90 percent. Schedule amounts given in Tables 2 and 3 must be increased accordingly to compensate for the efficiency of the drip system. For example, the schedule indicates that 3550 gallons per acre (33,202 1/ha) per day should be applied the first week in July, and the emission uniformity of the drip system is 90 percent. Therefore, 3944 gallons per acre (36,887 1/ha) per day should be applied. This is calculated as follows: 3550 gallons (33,202 liters)/ .90 = 3944 (36,891).

Drip irrigations should be cut back beginning July or early August to 50 to 75 percent of schedule amounts (Tables 2 and 3) to slow shoot growth in vigorous vineyards. Drip irrigations are usually discontinued 1 or 2 weeks before harvest to allow for the preparation of a dry terrace. Irrigating during harvest is risky since a rupture in the system could result in flooding and damage to the raisin crop, although some growers on very sandy soils will irrigate during the sun drying process.

After raisins are boxed, drip irrigation should commence by applying enough water to rewet the soil to 3 or 4 feet (0.9 - 1.2 m) beneath the dripper. This may take 15,000 to 30,000 gallons per acre (140,290 - 280,581 1/ha) for sandy or fine sandy loam soils, respectively. After rewetting the root zone, begin drip irrigation using amounts shown in the schedule (Tables 2 and 3). Less water (50 percent of schedule amounts) or no water should be applied to vigorous vineyards showing active shoot growth until late October when low temperatures no longer encourage growth.

Irrigation Scheduling Using Current Weather Information

Seasonal evaporative demand remains fairly constant from year to year in the San Joaquin Valley; therefore, the irrigation schedules found in Tables 2 and 3 provide a practical guide in scheduling irrigations. When using these tables, irrigation amounts can be increased during unseasonable hot weather and decreased during unseasonable cool weather by 15 to 25 percent: Common sense should prevail and tensiometers or other soil/plant based irrigation monitoring tools should be used to verify the accuracy of the irrigation schedule.

If more precise irrigation scheduling is required, current (or real-time) ET_o data can be used and are available from the California Irrigation Management Information System (CIMIS). The information needed in scheduling irrigations throughout the current growing season are daily ET_o values and reliable crop coefficients or RDI factors. The seasonal crop coefficients at full ET and RDI factors for Thompson Seedless grapevines were developed at the Kearney Ag Center (Figure 1). Daily vine ET equals ET_o multiplied by the crop coefficient or RDI factor for that day. The uppermost data set in Figure 1 represents the crop coefficient for vines growing in the weighing lysimeter (100% of ET). However, since yields were maximized with water application amounts at 80 percent of full vine water use, most raisin growers would use the seasonal 80 percent RDI_F. For vineyards that are weak or the vines are smaller, the seasonal 60 percent RDI_F may be more appropriate. Therefore, the following equation can be used to schedule irrigations in raisin vineyards:

$$ET_C = ET_o \, RDI_F$$

The specific RDI_F to be used can be found in Figure 1. Using this method to determine vine water use, one is able to compensate with a fair degree of accuracy for changes in daily evaporative demand during the current growing season and canopy size or trellis type used.

Water Use In Vineyards With Cover Crops

The irrigation schedules presented in Tables 2 and 3 and the crop coefficients and regulated deficit irrigation factors presented above are for vineyards without cover crops. Additional water should be applied when cover crops are grown to avoid vine water stress, unless it is the grower's objective to purposely slow the growth of an excessively vigorous vineyard.

Studies at the Kearney Ag Center showed that the amount of additional water will vary with the type of cover crop and management of the cover. In one study a continuous cover crop (bromegrass seeded during the winter, followed by resident vegetation in the summer) increased water use 46 percent compared to the bare soil surface treatment. Bromegrass, killed after seed shattering (in May) increased water use 19 percent compared to no vegetation. A rye/vetch cover crop incorporated into the soil the second week of July required 35 percent more irrigation water.

Evaluation Of Irrigation Scheduling And Amounts

There are several methods to validate irrigation schedules and/or amounts. Symptoms of water stress in vineyards are usually not visible in the San Joaquin Valley until mid-May to early June. The approximate date is dependent upon soil texture and rooting depth in the vineyard. The first visible sign of water stress is a decrease in the angle formed by the axis of the leaf petiole and the plane of the leaf blade. As water stress increases, shoot growth slows and internode growth is inhibited. As water stress becomes more acute, the shoot tips and tendrils die. Finally, under extreme water stress leaf abscission occurs, originating with the most mature leaves and progressing towards the shoot tip. This level of stress is usually not observed in the San Joaquin Valley until late June or early July.

A tensiometer can be an important tool for monitoring the accuracy of irrigation scheduling. Tensiometers measure the soil's matrix potential. Shoot growth will slow when tensiometer readings average -40 centibar in most of the root zone, and defoliation will begin when readings exceed -80 centibar (the upper limit of a tensiometer). Waterlogged conditions are indicated when tensiometers read below -10 centibars. Two tensiometers should be placed side by side with one monitoring the 18- to 24-inch (0.45-0.6 m) depth and the other monitoring the lower soil profile, the 36- to 48-inch (0.9-1.2 m) depth. Tensiometers should be placed down the vine row; one tensiometer site for every 20 acres (8 ha) is adequate.

When drip irrigations are effectively scheduled, tensiometers will give a constant reading of -10 to -20 centibar (kPa) until irrigations are cut back or terminated prior to harvest; then the readings will become more negative. This is consistent with the principle of drip irrigation, frequent irrigations with steady state soil moisture. With furrow irrigation, soil moisture levels and, subsequently, soil matrix potential fluctuate considerably in the root zone, corresponding to the water budget principle of scheduling furrow irrigations. Typically, vines are furrow irrigated when soil matrix potentials at the 2-foot (0.6 m) depth approach -40 to -50 centibars, and after a successful irrigation, the soil matrix potential will increase to -10 to -15 centibars indicating the soil reservoir was recharged. Monitoring tensiometers placed at both 2 and 4 feet 0.6-1.2 m) below the surface will indicate the depth of water penetration.

There are several other methods to validate and/or schedule irrigations in vineyards. Soil water content can be monitored with a hydroprobe. One would base the next irrigation event when a predetermined minimum soil water content was measured. Plant-based measures of vine water stress, such as predawn or midday leafwater potential measurements, have been used for other crops. One would irrigate when a predetermined value of leaf water potential was measured. Grapevines are generally not considered to be stressed if midday values of leafwater potential are no lower than -10 bars (-1.0 MPa).

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Table 1. Approximate raisin vineyard water use during four seasonal irrigation stages.[1]

Irrigation stage	Phenological events	Approximate dates	Days in Irrigation stage	Vineyard water use during irrigation stage (inches/acre)[6] Small canopy	Large canopy
One[2]	Budbreak to Bloom	(April 1) (May 10)	40	2.0	2.5
Two[3]	Bloom to Veraison	(May 10) (July 1)	51	5.6	7.5
Three[4]	Veraison to Harvest	(July 1) (Sept 1)	62	8.0	10.7
Four[5]	Harvest to Leaf fall	(Sept 1) (Nov 1)	61	3.8	5.1
Total vineyard water use for season				19.4	25.8

[1] Based on Thompson Seedless.

[2] Water requirement during irrigation Stage One is supplied primarily by soil moisture stored from winter rains (except for vineyards on very sandy or shallow soils). It is difficult to stress vines during this stage. Withholding irrigations may help improve berry set.

[3] Don't stress vines during irrigation Stage Two: cell division and berry growth is occurring during this period and the fruit is very susceptible to sunburn at this time.

[4] Deficit irrigation during irrigation Stage Three (50% to 75% of ET) will have minimal or no effect on yield. Excessive irrigation can increase rot and delay fruit maturity.

[5] Apply enough water to maintain canopy during irrigation Stage Four. Avoid excessive growth or premature defoliation.

[6] Multiply inches/acre by 62.8 to calculate centimeters/hectare.

Table 2. Drip irrigation schedule (vine water use) for a small canopy vineyard or one using a single wire trellis system in the San JoaquinValley.[1,2]

		Gal/Acre/Day[3,4,5]			Gal/Acre/Day[3,4,5]
APRIL	1-7	500	JULY	1-7	3550
	8-14	750		8-14	3700
	15-21	1000		15-21	3800
	22-30	1200		22-31	3750
MAY	1-7	1550	AUG	1-7	3650
	8-14	1800		8-14	3550
	15-21	2050		15-21	3400
	22-31	2300		22-31	3300
JUNE	1-7	2650	SEPT	1-7	3100
	8-14	2900		8-14	2850
	15-21	3200		15-21	2650
	22-30	3350		22-30	2400

[1] Vineyard canopy covers 50% to 60% of the land surface during summer months.

[2] Schedule amounts must be increased according to the efficiency of the drip system.

[3] Divide values by number of vines per acre to determine gallons/vine/day.

[4] Divide values by 27,154 to calculate inches/day.

[5] Multiply values by 9.35 to calculate liters/hectare.

Table 3. Drip irrigation schedule (vine water use) for a large canopy vineyard or one using a trellis with a crossarm.[1,2]

		Gal/Acre/Day[3,4,5]			Gal/Acre/Day[3,4,5]
APRIL	1-7	700	JULY	1-7	4700
	8-14	1000		8-14	4900
	15-21	1300		15-21	5050
	22-30	1650		22-31	5000
MAY	1-7	2050	AUG	1-7	4900
	8-14	2400		8-14	4800
	15-21	2700		15-21	4550
	22-31	3100		22-31	4400
JUNE	1-7	3550	SEPT	1-7	4100
	8-14	3900		8-14	3800
	15-21	4250		15-21	3500
	22-30	4500		22-30	3200

[1] Vineyard canopy covers 75% or more of the land surface during summer months.
[2] Schedule amounts must be increased according to the efficiency of the drip system.
[3] Divide values by number of vines per acre to determine gallons/vine/day.
[4] Divide values by 27,154 to calculate inches/day.
[5] Multiply values by 9.35 to calculate liters/hectare.

Table 4. Representative values for available water content, rooting depth, and allowable depletions for different soil types.

			Allowable depletion	
Textural class	**Available water (in/ft)[1,4]**	**Root zone depth (ft)[5]**	**Percentage[2]**	**Amount (in)[3,6]**
Loamy sand	0.8	4.5	50	1.8
Sandy loam	1.6	3.5	50	2.8
Fine sandy loam	2.4	3.5	50	4.2

[1] Available water can be thought of as the difference in volumetric water content between field capacity and permanent wilting percentage. Values within textural classes should be considered rough estimates.
[2] Percent allowable depletion represents how much available water that can be extracted before the next irrigation. Irrigation should occur when 30% to 50% of the available water is depleted throughout the root zone to avoid stress: 50% depletion is used in this example.
[3] Values obtained by multiplying available water x root zone depth x % allowable depletion. Irrigation must take place after the vineyard has used this amount of water to avoid stress. Inches x 27,154 equal gallons/acre allowable depletion.
[4] Multiply values by 7.74 to calculate centimeters per meter.
[5] Multiply values by 0.305 to calculate meters.
[6] Multiply values by 2.54 to calculate centimeters.

Table 5. Recommended irrigation amounts for varying soil types and corresponding irrigation efficiency.

Textural class	Irrigation efficiency (%)	Allowable depletion[2,5] (inches)	Irrigation amount[3,5] (inches)	Irrigation amount[4,6] (gal/a)	Number irrigations per season	Total water applied for season (inches)[5]
Loamy sand	50	1.8	3.6	97,000	11	40
Sandy loam	60	2.8	4.7	126,000	7	33
Fine sandy loam	70	4.2	6.0	162,000	5	30

[1] Irrigation efficiency is defined as the percentage of applied water that remains in the root zone and is available for crop uptake.

[2] Values obtained from Table 4.

[3] Values obtained by dividing allowable depletion by irrigation efficiency and indicate how much water should be applied each irrigation.

[4] Values obtained by multiplying acre-inch by 27,000 gals/acre-inch to determine gallons. Working with gallons rather than inches is sometimes more useful. For example: to apply 125,000 gallons per acre using a pump discharging 450 gals/min will require 277 minutes. By keeping a record of the number of hours a pump is used on a block of grapes, the application amount can be easily determined.

[5] Multiply values by 2.54 to calculate centimeters.

[6] Multiply values by 9.35 to calculate liters per hectare.

Table 6. Suggested irrigation cutoff dates for raisin vineyards in the San Joaquin Valley.

Soil type/rooting depth	Cutoff date
fine sandy loam (deep)	July 15 to 22
sandy loam (deep)	July 22 to 31
loamy sand or shallow (hardpan)	August 1 to 10

NOTE: Irrigations must be cut off early enough to allow preparation of a dry terrace by harvest (2 to 4 weeks for sandy soil and 4 to 6 weeks for fine textured soil).

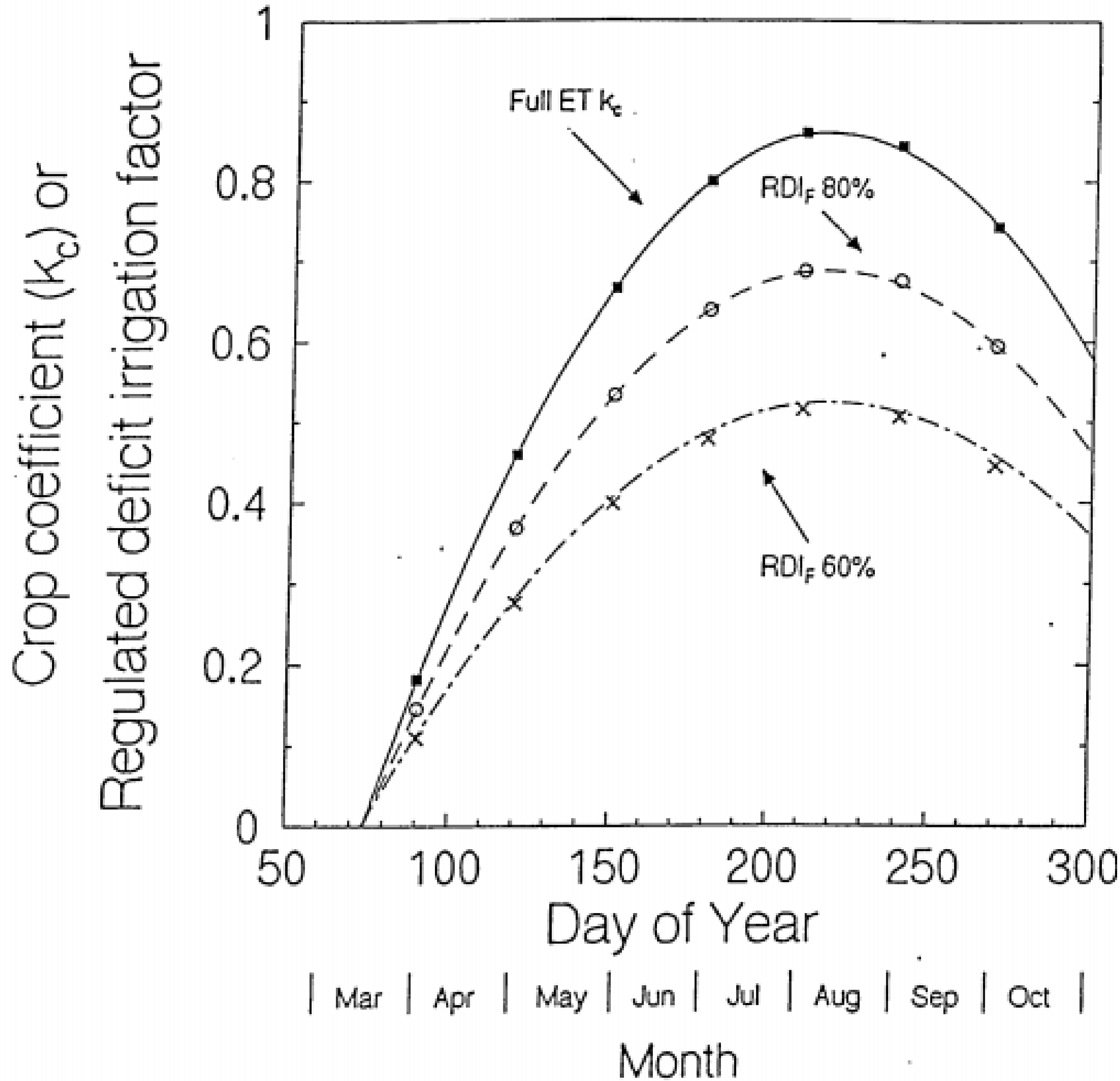

Figure 1. The seasonal crop coefficients for non-water-stressed Thompson Seedless grapevines grown in a weighing lysimeter at the Kearney Agricultural Center (full ET k_c). The seasonal regulated deficit irrigation factors (RDI_F) were obtained by multiplying the seasonal k_c by either 60 or 80%. The following equations were obtained for each data set:

$$\text{Full ET } k_c = -1.11 + 0.0181x - 0.0000416x^2$$
$$RDI_F\ 80\% = -0.89 + 0.0145x - 0.0000333x^2$$
$$RDI_F\ 60\% = -0.67 + 0.0109x - 0.0000249x^2$$

where x equals day of year. Day of year 1 is January first.