Evaluating Drip Irrigation in Eastern Vineyards

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Irrigation is often and correctly regarded as a supplement to rainfall, and most of the irrigation in Eastern vineyards has been in areas most likely to have consistent drought conditions. In the southeastern states, sprinkler irrigation is used for two purposes: for frost protection and for irrigation. According to Dr. Jim Ferguson, Irrigation Engineer at the University of Arkansas, the higher capital cost of solid set sprinkler irrigation (typically $1200 to $1500 per acre as opposed to $1000 to $1200 for drip irrigation) combined with the lower operating costs for drip irrigation (typical fuel costs for sprinkler irrigation of $60 to $80 per acre as opposed to $20 to $30) is one reason for looking closely at drip irrigation, or trickle irrigation as it is frequently called. A second reason, if water resources are limited, is that drip irrigation uses less water since the application efficiency of drip irrigation systems is higher than that of sprinkler systems. Thirdly, fertilization is much more practical with drip irrigation (applying nutrients through the irrigation system is called fertigation). Finally, drip irrigation doesn't wash off sprays that have been applied for disease and insect control.

Drip, or trickle, irrigation is based on the concept that the best use of available water resources and the best plant performance comes from preventing rather than relieving moisture stress. Studies have shown that trickle irrigation not only increases yields during dry summers by as much as 40% for some varieties, but that the effects of irrigating or not irrigating carry over to subsequent years. Even in years with normal rainfall, yields tend to be higher in vineyards that have been irrigated in previous years. Vines that have suffered moisture stress in dry years may have their vigor and performance affected in the following years. The economic return from irrigation can be enhanced either by increasing yield or avoiding a reduction in yield. Research at the University of Arkansas has shown that growers in areas subject to low rainfall summers automatically adjust the fruit load (the number of fruiting nodes left per vine) to a level that would allow for the fruit to mature even under drought conditions. Drip irrigation is another way of bringing about peace of mind and lessening the risks in grape growing by controlling a major variable that impacts on yield, vine vigor and fruit quality.

Drip irrigation maintains favorable soil moisture conditions on only a portion of the root system. By applying water in measured quantities under low pressure (15 pounds/square inch or less) at slow rates (up to 1 1/z gallons/hour) and at frequent intervals, it is possible to maintain part of the soil at or near optimal moisture content. An emitter is located at each side of the evenly spaced vine to give a drop-by-drop discharge pattern that provides the same amount of water to every single vine in the vineyard. The capacity of the drip system should be adequate to replace water that is lost from the soil by transpiration and evaporation. In Eastern vineyards, soil moisture may be replenished throughout the root zone, but the need to supplement this sometimes irregular supply of moisture in high producing vineyards has become obvious.

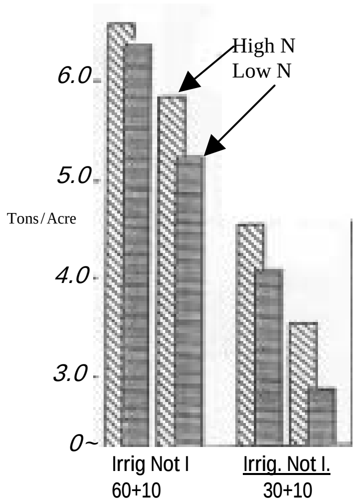
One of the essential requirements for an efficient and reliable drip irrigation system is good quality water. Water from ponds, lakes and rivers contains a variety of contaminants, both inorganic and organic in nature. Since unfiltered water tends to plug emitters, selecting the right filtration system is critical to sustained effective operation.

A proper filtering system and properly engineered water mains and submains are critical to the success of the drip system. Charts are available to help determine the correct diameter and length of lateral lines. It will usually pay to consult an irrigation engineer on the design of the total system.

Effects of Irrigation

Experiments were conducted at the University of Arkansas to study the effects of drip irrigation, fruit load (pruning severity) and nitrogen on the yield and quality of Concord grapes. The use of irrigation was not studied by itself because these other factors are completely interrelated. The study was established in a mature vineyard trained to a Geneva Double Curtain system which had never received supplemental irrigation prior to this study.

Some vines were left without irrigation while others were drip irrigated to maintain optimal moisture in the drip zone to a depth of two feet. Where the vines were irrigated, soil moisture tension was maintained between 100-200 millibars (determined with a tensiometer) at a two-foot depth. The nonirrigated vines ranged from 750-800 millibars of moisture tension at that depth.



Effects of irrigation, nodes/vines, and nitrogen on yield of Concord grapes. (Source: Spayd and Morris)

Figure 1

Table 1. Principal effects of irrigation, pruning severity and nitrogen on pruning weight and juice quality at harvest of Concord grapes

Main effect	Pruning wt. (lbs/vine)	Soluble solids %	Tartaric acid %	Absorbance at 520 nm
Irrigation				
Irrigated	2.6	18.1	0.68	0.32
Not irrigated	1.8	18.9	0.67	0.37
Pruning severity				
30+10	2.4	18.8	0.68	0.37
60+10	2.2	18.1	0.66	0.32
Nitrogen				
Low	2.2	18.4	0.69	0.35
High	2.4	18.6	0.66	0.34

(Source: Spayd and Morris)

Vineyards were balanced-pruned to either a 30+10 level (30 nodes left for the first pound of dormant prunings and 10 additional buds for each additional pound of prunings) or a 60+10 level to adjust fruit loads. These two pruning severities were established on six-node canes. Two nitrogen levels were established using either no nitrogen for the two year period or 135 pounds of actual nitrogen per acre the first year and 200 pounds of actual nitrogen the second year. A factorial design with 4-vine plots replicated six times was used, and all treatments were imposed on the same vines each year.

Sampling of fruit started when the 30+10 irrigated plots reached a level of soluble solids of 11.5% and continued at two-week intervals. The percent of soluble solids and acidity were determined on the raw, non-heated juice. Titratable acidity, expressed as percent tartaric acid, was determined by titration. For color analysis, absorbance was read at 520 nm.

Through the reduction in pruning severity, yield was increased by about 2.3 tons per acre with no reduction in vine size. The highest yielding treatment (60+10 irrigated, high nitrogen) and the lowest yielding treatment (30+10 not irrigated, low nitrogen) differed in yield by almost 4 tons per acre (see Figure 1).

By the time of final harvest, juice acidity was not affected by irrigation (Table *1*). Juice quality was reduced at the 60+10 schedule as indicated by the lower percent of soluble solids and poorer color, but tartaric acid did not differ. The increased nitrogen had a greater effect on pruning weights on the nonirrigated plots, probably due to shoot and foliage growth early in the growing season before the summer dry spells. It must be remembered that adequate levels of soil moisture are usually available both at the beginning of the growing season and during the time of rapid shoot elongation. Long term application of nitrogen over additional years does increase vine vigor, however, and it is critical that the grape grower constantly monitor and maintain vine vigor. But, it should be noted in this study that irrigation had more of an impact on pruning weights than any of the other experimental variables (Table 1). As maturity progressed, the percent of soluble solids and color increased across all treatments, and all treatments produced juice of acceptable quality (15 percent soluble solids or more) by harvest (Table 1 and Figure 2). The highest level of soluble solids was maintained by the 30+10 non-irrigated vines.

Fruit maturity was delayed by irrigation and lower pruning severity as indicated by a reduction in the percent of soluble solids and color. The acidity was greater in juice from irrigated plots on the initial sample date, but differences in acidity at harvest were not significant.

In a study designed to predict Concord grape maturation, the author and colleagues found that using degree-day accumulations and effective heat unit summations did not prove to be methods that were superior to use of the number of calendar days for predicting grape maturation. Predictions based on the development from 8 to 16% soluble solids were more accurate than predicting from peak bloom (when 50% of clusters showed bloom). Variations between years and between vineyard locations within a given year prevented making accurate predictions from any of the three methods. Other deterrents in predicting development of soluble solids included the cultural variables of fruit load and soil moisture (Table 2). Although fruit maturity was delayed when vines were irrigated and/or pruned to 60+10 nodes per vine, these high yielding, low soluble solids treatments may not produce the desired high quality grapes in eastern states where frost would not allow a sufficient delay in harvest to obtain the desired quality or desired color and soluble solids levels. Therefore, high yields that would delay maturity would be a major concern in either irrigated or non-irrigated vineyards in regions with short growing seasons and/or with cultivars that normally could have problems reaching maturity before frost.

Costs of Establishing Drip Irrigation

The budget for a typical irrigated vineyard for 40 acres of production is shown in Table 3 and uses 1995 prices for new equipment. These figures were originally prepared for low summer rainfall conditions such as are found in Arkansas. These estimates reflect the cost of applying an average of 15 acre-inches of water per acre per season (gross application). While this is the amount of supplemental water that may be required to mature grapes in a high yielding vineyard under Arkansas conditions, it would be expected that fewer inches of supplemental irrigation would be required in the cooler regions of the eastern United States and in regions that may receive a more even distribution of rainfall during the growing season. Requirements will vary depending on the climate, site and the soil's texture and moisture retention capabilities. In the budgets shown in Table 3, water acquisition was assumed to be from an on-farm or nearby surface source such as a pond or spring. If a grower must get water from a well, costs would have to reflect the additional requirements. It is to be emphasized that this is for a "typical" installation. It uses a diesel engine powered pump unit and 1320 foot laterals. Every irrigation situation is unique and requires proper design to operate effectively.

Possible variation extremes in development of soluble solids due to irrigation, fruit load and vines within the same vineyard

Variable	Yield (mt/ha)	Date of 8% Sol. Sol.	Date of 16% Sol. Sol.	Days from 8% to 16% Sol. Sol.	Prediction' error (days)
Irrigated'					
High yield					
Plot 1	22.0	July 29	---'	---	--
Plot 2	24.5	July 28	---	-----	
Low yield					
Plot 1	11 .4	July 25	Aug. 21	27	0
Plot 2	10.6	Aug. 2	Sept. 3	32	+5
Not Irrigated					
High yield					
Plot 1	11.5	July 23	Sept. 6	45	+15
Plot 2	12.8	July 29	Sept. 7	40	+13
Low yield					
Plot 1	6.7	July 28	Aug. 21	24	-3
Plot 2	6.8	July 25	Aug. 25	31	+4

' Based on 27 days required from 8% to 16% soluble solids development.
[2]Soil moisture tension maintained between 100-200 mb.
[3]Fruit did not reach 16% soluble solids by Sept. 8.
+ indicates soluble solids development later than forecast.

Table 2

For an estimated 40-acre vineyard, the following assumptions would apply to the irrigation system:

1. A diesel, two-cycle, 80-cubic-inch engine is the pump power source (20 hp manufacturer's rating).
2. Pumping head is 80 psi with water flow rate of 300 gal/min.
3. Pump efficiency is rated at 60% with a 14-year life for the pumping system with zero salvage value.
4. Although manufacturers have limited warranties, the trickle irrigation delivery system is expected to last 10 years with proper maintenance.
5. Emitters in the trickle system operate at 15 psi.
6. The irrigation laterals are suspended 18 inches above the ground by #11 wire with emitters placed every 4 feet.
7. Rates for insurance, taxes and annual interest are 0.6, 0.5 and 9.5%, respectively, on average investment.

The irrigation system for a typical 40-acre vineyard consists of a power set (pump), which is directly connected to the main header or irrigation pipe that lies across one end of the vineyard. Suspended above the ground, along the rows, are smaller, lateral lines with in-line emitters. This particular layout will provide ample irrigation for optimum grape production throughout the season. The vineyard also consists of 24-ft turn rows and 20-ft end rows for ease of machinery operation and maneuvering. With this additional spacing it is noted that land acreage needed to cultivate 40 acres of plants is increased to 44.2 acres, which accounts for the added spacing.

Currently there is interest in subsurface irrigation by burying the drip lines. A sizable research project is underway at the California State University at Fresno, and the first results are expected to be available in the fall of 1997.

Sources

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Table 3 **Grape Irrigation System: Calculations for Annual Amortization, Fixed and Variable Costs for a 40-acre Vineyard (1995)**

Item	Expected Years of Life	Annual New Cost ($)	Annual Amortization Charge' ($)
Power Set	14	9,550.00	1,261.24
Pipe: main-headers (1,892 ft) and laterals with in-line emitters (88,000 ft)'	10	23,437.92	3,732.87
Filtration system'	20	1,600.00	181.78
Tensiometer 24 in (5)	5	125.00	32.55
Tensiometer service kit	5	28.00	7.29
Wire'	30	3,484.80	350.33
Clips	10	980.00	156.08
TOTALS		39,205.72	5,722.14
		Annual Costs ($) per Acre	**Annual Costs ($) per Acre-Inch**
Annual Amortization[4] Charge	5,722.14 / 40	143.05	9.54
Taxes[5]	39,205.72/2 (0.005) / 40	2.45	0.16
Insurance[5]	39,205.72/2 (0.006) / 40	2.94	0.196
TOTALS: Annual Fixed Cost for Irrigation		148.44	9.90

Annual Variable Costs - Irrigation System

Item	Cost of New Equipment ($)	Maintenance and Repair Coefficient	Cost per hour of operation ($)	Annual Cost ($) Hours per Year	Annual Cost ($) per Acre	Annual Cost ($; per Acre-Inch
Pump Set	9,550.00	0.07	--	--	33.43	2.228
Distribution	23,437.90	0.005	--	--	5.86	0.391
Fuel	.00	0.00	0.705	1,049	18.38	1.235
Filter	1,600.00	0.10	--	--	8.00	0.533
TOTAL: Irrigation Equipment Variable Cost					65.67	4.387
Irrigation Labor Cost					12.56	0.837
TOTAL: Variable Cost					78.23	5.224

' New costs amortized at 9.5% for the expected years of life.
2 Installation charge included.
3 Automatic media filter, 320 gal/min with sand separator and safety screen, automatic back flush (top of the line).
4 Estimates of the annual fixed irrigation costs were calculated on the basis of per acre (40-acre vineyard) and per acre-inch (assuming 15 acre-inch application).
5 New costs were divided by two to approximate the average value over the life of the system for annual taxes and insurance.

Spayd, S.E. Effect *of* Irrigation, Nodes/Vine, Nitrogen and Years on the Yield and Quality *of* 'Concord' Grapes. M.S. Thesis, University of Arkansas.

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