Basics of Water Balance in New York Vineyards

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In the humid climate of New York and the Northeast, rainfall is erratic and therefore drought stresses are not easy to predict. Do we have significant problems due to drought (significant enough to change cultural practices or invest in irrigation)? We know the answer depends on how dry the seasons are, how much water our vineyard soil holds, how much the vines need. Since we cannot predict the weather, we must take a risk assessment approach, and then evaluate methods to reduce risks we find. To do that we need to understand the factors that either increase or reduce our risks of significant loss from drought stress.

Factors That Increase or Reduce Risk of Loss Due to Drought Stress

Risk is related to the balance of supply to demand for water. The lowest risk of loss due to drought occurs when the water supply is high and the demand is low, Conversely, when the supply is low and the demand is high, the risk is high and the potential benefits of irrigation are greatest. Besides seasonal rainfall several factors are involved in the total risk, and they should be evaluated separately since some cannot be easily changed while others can be (Table 1).

Table 1. Factors involved in determining risk of losses due to water stress in vineyards,

Water Supply Factors
- Soil Water Holding Capacity and Depth
- Rooting Depth of Vines
- Competing Plants in the Vineyard
- Rainfall, Runoff and Evaporation

Water Demand Factors
- Weather
- Age of Vines and Leaf Area
- Training System
- Crop Levels

Soil Water Holding Capacity and Depth. Heavier soils like silts and clays hold more water per cubic foot than the lighter sands. Compared to a clay soil, the same volume of sandy loam will hold only 50% as much water. This difference can be overcome, however, if the lighter soil allows a greater depth of rooting, such as the deep gravels of the Chatauqua belt where significant rooting to 6 feet or more has been shown, Many heavier soils hold more water per inch, but may have restrictive layers that may reduce the total rooting volume.

Rooting Depth. Regardless of the soil depth, "available" water is that in the rooting zone of the grapes. Mature grapevines typically can root quite deeply, so rooting of these vines is normally limited by some restrictive impermeable layer of compacted or stony soil, However, very young vines have restricted root systems in both extent and density for several years, so this must be considered even if the soil would allow potentially deep rooting. Thus, both rooting depth and water holding capacity are important to the final reservoir of soil water available. Then, the potential available water = rooting volume X soil water holding capacity.

Competing Plants in the Vineyard. Grapevines are not the only plants in a vineyard using water. Weeds and cultivated cover crops also compete for water, and are an important part of vineyard water balance. We do not think that grapes compete very well with weeds and cover crops since grapevine root systems have very low density (i.e. not very many roots per cubic foot of soil) compared to the other plants. Recent studies with Bob Pool and Rick Dunst on row middle cover crop effects on mature Concords in Western NY have concluded that:

(1) Competitive effects of covers on vines is primarily for water.
(2) When actively growing and green, all cover crop species were about equally competitive.
(3) Mowing, in general, had only a small and temporary effect on water use by covers; mowing is not particularly effective in saving much water.
(4) Competition drops off markedly if and when the cover crop goes dormant and turns yellow or brown; herbicide treatment gives the strongest effect.

(5) The period around bloom and the following 4-6 weeks is the critical time when competition for water reduces vine growth; this is why current no-till herbicide at bloom treatments have evolved.

In cases where other factors only cause a moderate risk of water stress, changes in floor management such as switching between bloom herbicide and permanent grass sod, can make significant shifts in risk, Moving to a water-conserving floor management system may eliminate the need for irrigation in some cases.

WATER DEMAND

Weather Affects Demand. The greatest controller of demand is obviously the weather. Hot, dry weather as in 1991 can evaporate 8-9 inches of water from an open pan while cool summer months as in 1992 may evaporate less than 5 inches, This means that in some years no vineyard will need irrigation, but in some years many will benefit. Some of the greatest benefits of irrigation are that a guaranteed water supply will maintain continued productivity from year-to-year, helping to avoid the ups and downs of production following variable years. Another aspect to remember is that drought just means lack of rainfall; this does not always mean vines will be stressed, A cool drought may not have much effect due to low demand for water. Similarly, hot, dry periods in between rains may cause stress due to exceptionally high demand even with normal rainfall.

Training System Effects on Water Demand. Water use by vines is driven by the drying capacity of the air (temperature and humidity) and by the amount of sunlight energy absorbed by the vines. This factor of sunlight capture by different training systems is the basis of improved productivity by systems like GDC since the sunlight capture drives photosynthesis. But, when the pores in the leaves open up to allow the carbon dioxide in, water vapor escapes from the leaves at the same time. So, productive systems generally use more water than less productive systems. In the case of grapes, the divided canopies like GDC and Open Lyre that capture more sunlight (60-70% of available sunlight at full canopy) than single curtains (40-50%) will use and need more water. Also, since they carry heavier crops, they tend to be more sensitive to drought stresses that develop.

How Much Water Do Vines Need In NY? Our recent studies indicate that at full canopy in average Julys and Augusts single curtain Concord grapevines in Western

NY use about 30-40 gallons of water per vine per week (young vines with less leaf area and sunlight capture will use proportionately less). That works out to just about 3 1/2 inches of water per month for an acre of vineyard. Interestingly, that is very near the 50-year monthly average rainfall for the season for Fredonia. *It should be noted that these are needs of just the vines not the whole vineyard.* Of course, with natural rainfall not all the water gets to the root zones of the grapes as there are losses from soil and canopy evaporation and runoff, and usage by competing weeds or cover crops. In general, then the natural rainfall is probably not adequate alone, but the soil water reservoir fills in the difference. It appears that the needs of the traditional single curtains with conventional pruning and crop levels are well balanced to the available water supply in Western NY.

This is all fine until we begin to push the vineyard our of this balance, Heavily-cropping GDC systems need more water as do minimal pruned systems that uses much more water in the early season (we would guess an extra 10 gallons per vine per week or an extra 3/4 inches per month), In a 12-year-long study Bob Cline in Ontario found that GDC vines clearly benefited from supplemental irrigation while conventional single curtains did not. Similarly, we have shown that the effects of drought (or benefits of irrigation) are greater on minimally pruned vines compared to conventional single curtains.

VINE RESPONSES TO WATER STRESS

Besides the actual stress levels that may develop, it is important to understand how and when the vines respond to those stresses. The most obvious example is that we may have very long periods with low precipitation, but if it occurs in the winter when the vine is dormant, there is no problem.

Shoot Growth, The most sensitive process in the vine to water stress is shoot growth. It reduces almost directly with any level of stress. This may be bad for vines needing growth, such as young vines or juice grapes that need to maintain vines size. But it may be beneficial for wine grapes that have excessively dense canopies, In arid climates, withholding irrigation in mid-season to stop shoot growth is practiced.

Berry Development Early growth of the berries in the first 3-4 weeks after bloom is due to cell division to produce new cells and is quite sensitive to water stress. Since the stress appears to reduce cell numbers, the effects can persist for the rest for the

season (Fig. 1). Again, for juice grapes this will reduce yields, but this may be excellent for wine grapes that produce greater extract with more intense flavors with smaller berries (more skin/volume),

Berrv Sizing and Ripening. Mid-&d later-season drought stress has different effects in that once grape berries are near or after veraison, they are strikingly resistant to water stress. In the first few weeks after veraison, the berry growth and sugar accumulation are hardly affected by drought, even quite severe drought, Final sizing and sugar accumulation will be inhibited by continued drought however in the last few weeks before harvest. Although smaller berry size is desirable in wine grapes, too much stress seems to inhibit many late season flavor development processes, and lead to concentrated, but dull and simple wines.

Cropping Increases Sensitivity to Water Stress. Supporting a crop is a stress on a vine, so heavily-cropping vines tend to react more sensitively to added stresses like water stress, We have found that the reduction in Brix in Concord vines cropped at 8 tons/acre was about twice that of vines cropped at 4 tons/acre. So, drought in a heavy crop year can have a double whammy, So, irrigation will probably have greater and greater benefits as we push yields upward.

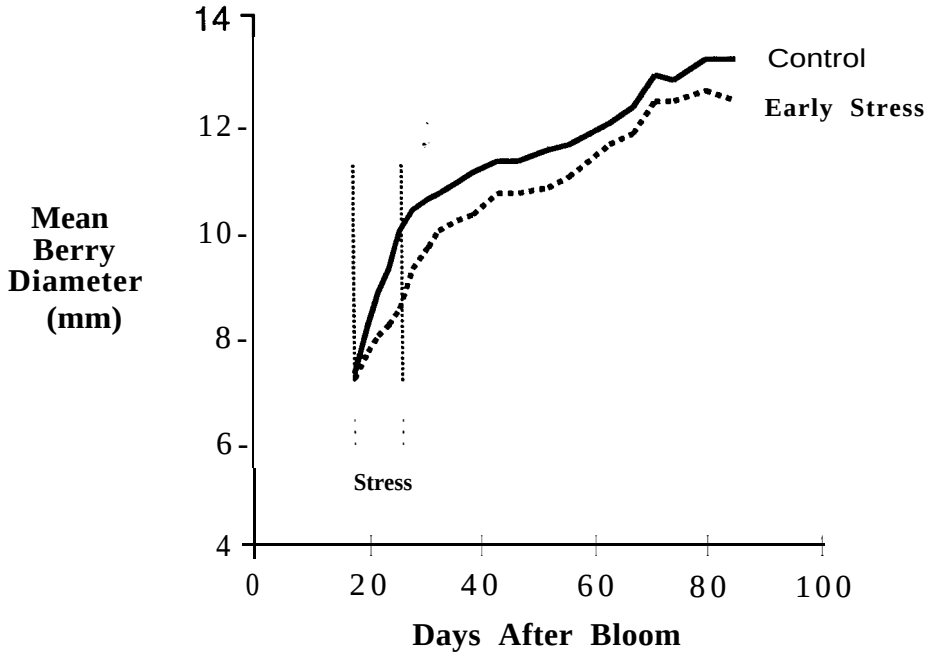

Fig. 1, Growth curves of Pinot Noir grape berries that were well-watered (Control) or were water stressed for only a 10 day period in the cell division growth period after bloom. Data of S, Poni and A. Lakso.

I feel that as yields are pushed higher and the production needs to be a stable as possible, then water management will be a critical component. This may be in the form of just good evaluation of your site, changes in floor management, or perhaps micro-irrigation. These conclusions may be totally different, however, for high-value vinifera vineyards that have lower yields and more severe pruning, Additionally, best vinifera wine quality comes from situations where there is some stress on the vines and berry size is small, In this case more competitive covers may be needed and irrigation only needed to avoid extreme stress. The principles still apply, but the actions may be very different in a winegrape versus a juice grape vineyard.

VINE WATER USE

Weather conditions - Hot sunny dry conditions cause maximum water use

Canopy Fill - Early season or young vines with < full canopies use less

Seasonal Sunlight interception - GDC or Minimal Pruning capture more sunlight so need more water

Type of Vine and Use

- Native juice grapes usually produce best with near-maximum water (Niagaras seem to need more water than Concords)
- Vinifera wine grapes produce optimum canopies, berry size and wine quality with some stress, especially after canopy fill (some evidence that Whites require better water status than Reds for best wine quality)

Estimates of *Maximum* Mid-summer Water Use per Vine (Acre-inch = about 27,000 gallons)

Note that minimally-pruned vines will tend to have similar mid-summer water use rates to normally-pruned vines, but have higher early-season water use, giving perhaps 10% higher total seasonal water use.

Vineyard	Water Use in Gal. per Vine per: Day	Week	Water Use in Gal. per Acre per: Day	Week	ac-inch
	Single Curtains				
Vinifera	4-5	30	2,500	18,000	(0.7")
Concord/Niagara	5-6	40	3,500	24,000	(0.9")
Minimal Pruned Concord/Niagara	5-6	40	3,500	24,000	(0.9")
	Double Curtains				
Concord GDC	7-8	50	4,300	30,000	(1 .1")

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CONCLUSIONS

Any practice that is based on weather-controlled resources like water is complex and variable with the weather. This requires we understand risk to make the best decisions, From the discussion above, we can conclude several things.

- Irrigation is not always needed in NY vineyards; risks vary based on several factors.
- A risk assessment should be done for each vineyard as each vineyard is a unique combination of the risk factors.
- Greatest risk is in young vineyards on shallow, light soils.
- Divided or minimal pruning/training systems need more water

- Floor management of competing plants is a very important component of water management.
- *Vinifera* vineyards with severe pruning and low crops have very different water management needs.