Root Biology in Grapes
A Case Study of the Effects of Canopy Pruning and Irrigation on Concord Root Dynamics

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Goals of the Research

Our research goals are to increase the efficiency and stability of production of high quality grapes in the Northeast via improved understanding of soil and root-related stresses and optimizing cultural practices related to root function. The specific approach is to examine grape root system growth, development and distributions in response to pruning severity, drought/irrigation, differential crop loads, competition with other plants (cover crops, weeds), rootstock selection, and soil structure. We hope that by understanding the relationship of root development and structure to root function (water and nutrient uptake, storage of carbohydrates and nutrients) root management will become an integral part of the crop management system.

Prior to this work, our knowledge of Concord root systems was limited to a few root mapping studies that indicate only distributions. Nothing was known about root growth and lifespan dynamics, or function. Thus, as a first step we monitored yearly patterns of new root production and fine root lifespan of Concord grapevines under different cultural practices. Here we summarize findings to date in a four-year study of root growth and turnover in mature Concord vines with conventional versus minimal pruning, with and without supplemental drip irrigation. We relate patterns of root growth and turnover to environmental conditions, weather patterns, and crop yield.

Materials and Methods

The field site was located in Fredonia, NY at Cornell University's Vineyard Laboratory. Soil is a well-drained Chenango gravelly loam. Mature, 25-yr-old Concord grapevines with high permanent arms 1.8 m above the ground and growing 2.4 m apart in rows and 2.7 m apart were used for the study. The treatments of balanced versus minimal pruning with and without irrigation were initiated in 1991 when vines were 11yr old. The experimental design was a 2 x 2 factorial in four replicate blocks of 5 vines each. Pruning occurred on dormant vines in November –December. In balanced pruning, 44 buds per kg of stems pruned the previous winter were left on the vines; this is the historically recommended method in the Lake Erie region because it maintains shot vigor. Minimal pruning consists only of undercutting the hanging vines to 1 m above the ground to keep shoots off the ground. Irrigation was supplied as needed based on climatological data and predicted evapotranspiration of the vines. Crop data was collected from 1992-2000. In 1997-2000 video recordings of roots were taken with a remote video camera in clear minirhizotron tubes inserted under 64 vines. Images were processed in the laboratory as previously described (Comas et al. 2000). Observations began in March and were taken every two weeks into December. Soil moisture was also monitored with two neutron probe tubes per plot, located near the minirhizotron tubes.

Results

Weather Patterns. The years of 1997-2000 were extremely variable in temperature and precipitation, which allowed an important opportunity to examine and compare root dynamics under a wide range of weather conditions. The spring of 1997 was very cool giving a late bloom, and water stress remained relatively low, as the growing season rainfall was about 30% above average. Crop levels were moderate in 1997 following 1996, which was a very cold year with heavy crops. The 1998 growing season was abnormally warm in the spring following an exceptionally mild winter. This led to warmer spring air and soil temperatures and a grape bloom that was 2 weeks earlier than normal. Rainfall was slightly lower than normal, and coupled with the warm temperatures, significant water stress developed in some plots. In 1999, the weather was warm, similar to 1998, but the summer rainfall was even lower. This led to some marked water stress that reduced vine growth and function in July-September. The 2000 growing season was relatively cool and cloudy with few dry periods; the crops were similar to 1999 and relatively large. Therefore, we had a large range of climatic and crop load combinations.

Yield Patterns in Relation to Pruning and Irrigation 1997-2000. Yields were moderate in 1997, and low in 1998 due to poor growing conditions in 1997. In 1999, yields were high following the low yields and good weather of 1998, and the 2000 yields were generally about average. Over the 11 years of this trial, (a) minimal pruning gave significantly higher and more stable yields than the balance pruned; and (b) irrigation had its most positive effects on yield in the minimal pruning treatment (averaging about 1 ton/acre), probably due to the higher total light interception and water use caused by the early canopy development.

Total Root Production. Irrigation, or drought had major effects as root production declined markedly in the dry 1998 and the very dry 1999. This decline did not occur in 1998 and 1999 in the irrigated treatments. The low production level in 1999 probably was due to heavier crop loads in the irrigated treatments and a combination of the drought and the heavy crop in the controls. Pruning did not appear to have much effect on total root production. Minimal pruning did not appear to debilitate root system growth as had been feared with the heavier crops produced by the lack of pruning. With irrigation, it appears that the minimally-pruned vines have been able to support both continued heavy cropping and continued root production. Overall, the differences among the years seem to be due to the differences in weather and crop loads:

- The short fairly cool growing season of 1997 appeared to restrict root production to only the mid-season period.
- The warm spring in 1998 allowed an early root flush in spring that was not seen in 1997 or 1999.
- The highest total root production occurred in 1998 which was a very long growing season and had lighter crops.
- 1999 provided good growing conditions if irrigated, but the heavier crops likely limited total root production compared to 1998. The combination of drought and heavy crops had very detrimental effects on root production in 1999.

Root Survivorship. Based on detailed analyses of individual root survivorship and mortality in 1997 and 1998 by proportional hazards regression the following points have evolved:

- Pruning does not have clear effects as balanced pruning gave shorter root lifespans in 1997, but longer in 1998.
- Root lifespan was negatively related to the previous years' crop load rather than to the current year's crop load. This effect will be examined further in 1999 and 2000 where there were greater variations in crop load.
- New roots produced early in the season around bloom had a shorter lifespan than those produced late in the growing season. This may be related to the much warmer temperatures in the mid-season that may cause faster aging or may stimulate soil pests or pathogens.
- Deeper roots had longer lifespans than shallow roots. Most roots were produced in the top 40 cm, however.
- Thicker diameter new roots lived longer on average than the thin new roots.

Conclusions

Based on 11 years of the viticultural trial, 3 years of root production data, and 2 seasons of analysis of root mortality, the following conclusions can be made:

- Minimal pruning of Mature Concord grapes (in a good site) gave significantly higher and more stable yields than balance pruning, but fruit Brix levels were lower.
- Irrigation had its most positive effects in the minimal pruning treatment, and few long-term effects on the balance pruning treatment.
- Root production varied from season to season, with only a single mid-season peak in the cool, wet 1997, but several peaks of production in warmer, drier years.
- Root production was not apparently affected by pruning.
- Root production was strongly stimulated by irrigation in dry years.

- In irrigated vines, total new root production varied slightly from year to year while in non-irrigated vines, total new root production declined dramatically from the wet 1997 season, to 60% as many in the dry 1998 season, to 30% as many the very dry 1999 season.
- In irrigated vines, August root growth was highly influenced by crop level.
- The most notable difference in root production between irrigated and non-irrigated treatments was the lack of August root growth in non-irrigated treatments.

- Root lifespan was negatively related to the previous years' crop load rather than to the current year's crop load. Pruning and irrigation effects on root lifespan, however, were not yet clear.
- Roots produced early in the season, around bloom, and in shallow soil, had shorter lifespan than those produced late in the season or in deep soil.

Literature Cited

Comas LH, Eissenstat DM, Lakso AN. 2000. Assessing root death and root system dynamics in a study of grape canopy pruning. New Phytologist 147: 171-178