Progress report

Virginia Wine Board, 8 February 2010

Title: Optimized grape potential through root system and soil moisture manipulations

Principal Investigator: Tony K. Wolf, Virginia Tech

Objectives:

1) Evaluate the impact of complete ground cover vs. under-trellis weed control, three rootstocks, and three root manipulation techniques as means of regulating the vegetative/reproductive balance of Cabernet Sauvignon clone #337 (VA site)
2) Evaluate cover crop species and root pruning to impose water stress on Cabernet Sauvignon vines (NC site)

Accomplishments/Benefits to date:

Objective #2 is mostly completed and graduate student Gill Giese is writing his dissertation and will be reporting on the root-pruning and cover crop effects at Viticulture 2010 (New York State industry meeting) and other meetings, as well as writing papers on his work. The focus of this report is Objective #1, which involves a project at the AHS AREC in Winchester, VA. Specifically, objective #1 aims to explore the impact of under-trellis cover crop, rootstock, and root manipulation on the extent and duration of vegetative vine growth, and the impact on fruit composition and, ultimately, wine quality attributes of Cabernet Sauvignon. Vines were in their fourth leaf in 2009. Following our proposed procedures, extensive data were collected on vine shoot growth rate, canopy development (leaf area and degree of lateral shoot development), vine water status and photosynthetic (gas exchange) performance, components of crop yield and primary fruit chemistry and fruit color. To extend and more completely interpret our preliminary results, additional data were collected on fruit color density and total phenolics, and ^{13}C isotope discrimination (as a measure of water stress). Small-lot (20-L), triplicate samples of wines were made from four of the 18 treatment combinations of 2009. Those wines are currently being assessed for stability and will undergo a preliminary sensory evaluation in March 2010.

Preliminary findings: The experiment was designed as a strip-split-split field plot that consists of under-trellis cover crops (UTCC) (creeping red fescue) versus a standard herbicide strip as a main plot. Within the main plot, three rootstocks are compared as sub-plots: 101-14, 420-A, and riparia Gloire. The rootstock plots are further divided into sub-sub plots that compare the use of root-restriction bags (RBG) versus no root manipulation (NRM). A third sub-sub plot treatment, originally planned as root-pruning, is being converted to head-training and cane-pruning as a comparison against RBG and NRM which are cordon-trained and spur-pruned. Main plots (and all sub-plots) are replicated six times and buffer panels and guard rows of Petit Manseng are used to separate main plots and cover crop vs. herbicide sub-plots.

Our underlying hypothesis is that the competitive nature of the under-trellis cover crop and the root restriction afforded by a fine mesh root bag can be effectively used to limit vegetative development of vigorous vines and that by so doing, the fruit composition can be favorably affected by changing berry geometry or possibly by altered berry biochemistry, such as through altered synthesis or degradation rates of compounds such as methoxypyrazines that contribute vegetative character to Cabernet Sauvignon. The use of three different rootstocks adds another dimension to the hypothesis in that the rootstocks vary in scion vigor, or so the literature would suggest. The scope of the project is ambitious and our goal over the past two seasons (2008 and 2009) has been primarily to determine how predictably the vegetative growth of the vines can be affected by our treatments, and what impact this has on rate of fruit ripening as judged by primary fruit chemistry and berry color density. This report summarizes some of the salient findings thus far.

Shoot development: Shoots were selected on treatment vines in early May and their length measured on a regular basis each season to establish rates of shoot growth. Cabernet grafted to 101-14 or 420A rootstocks grew at essentially the same rate throughout the period from 23 May to 16 June 2008 (**Table 1**); however, the rootstock effect was not significant in 2009 (data not shown). Both UTCC and root-restriction (RBG) significantly depressed shoot growth rate in 2009; the data for under-trellis cover crop (UTCC) vs. vines grown on herbicide strips are depicted in **Figure 1** for the period 22 May – 17 June 2009. Vines grown with UTCC had shorter shoots, that ceased growth earlier than did shoots of vines grown with an herbicide strip under the trellis.

Table 1 - Shoot growth rate (cm/day) for non-root-restricted (NRR) and root-restricted (RR) vines on three rootstocks, from 23 May to 16 June 2008.

Rootstock	NRR	RR	Average*
101-14	2.6	1.4	2.0 a
420-A	2.5	1.3	1.9 a
riparia	1.9	0.9	1.4 b

Effect	p-value
Rootstock	<0.0001
RM	<0.0001
Rootstock X RM	0.0381

*Values not bearing the same lowercase letter differ at $p = 0.05$

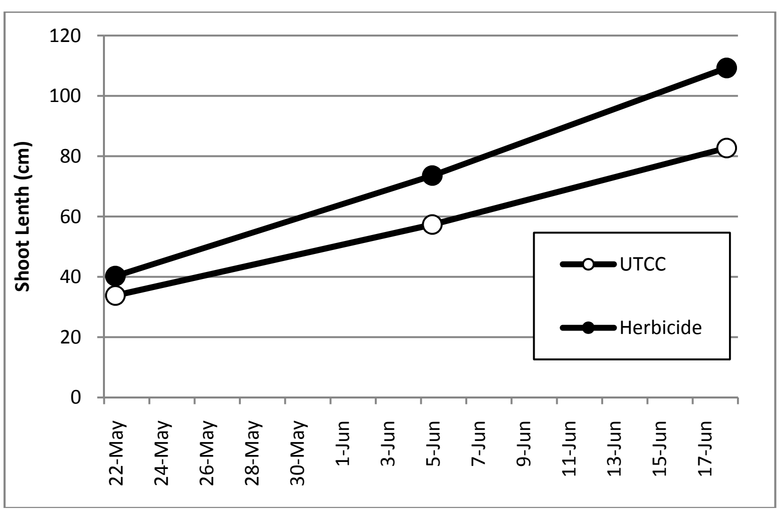

Figure 1. Shoot length by ground cover treatment in early 2009.

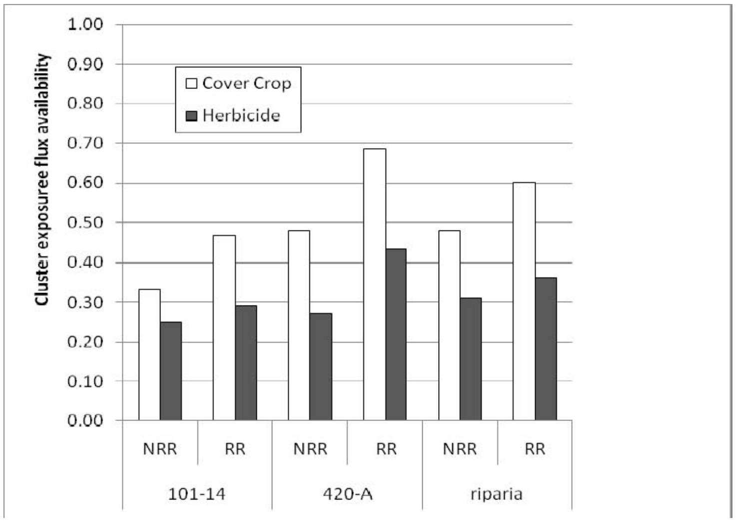

Figure 2. Cluster exposure flux availability. This is a measure of how much of the available sunlight reaches fruit clusters. Note that vines grown with under-trellis cover crops had greater fruit cluster exposure – because they had less leaf shading.

Both rootstock and root manipulation affected the degree of lateral shoot growth development, with riparia Gloire having the least lateral leaf area development and 420-A the most (data not shown). Rootbags were particularly effective in suppressing lateral leaf area development with riparia and 420A rootstocks. A benefit of the suppressed lateral development is a reduced need for lateral shoot removal as part of selective defoliation of fruit zones if one wishes to increase fruit exposure. Canopy transects – passing a thin probe through the canopy to quantify leaf layers and the degree of fruit exposure – and measures of sunlight penetration of the canopies were also done during the 2008 and 2009 seasons and illustrated treatment effects. For example, the data in **Figure 2** illustrate the cluster exposure flux availability (CEFA), a measure of sunlight penetration into the fruit zone. Vines grafted to riparia rootstock tended to have somewhat greater CEFA values than did those vines grafted to the other rootstocks. Root-restriction (RR) and UTCC (Cover crop) led to significant increases in measured CEFA values. Simply put, smaller vines caused by UTCC, root-restriction, and rootstock (to some extent) were associated with greater fruit cluster exposure.

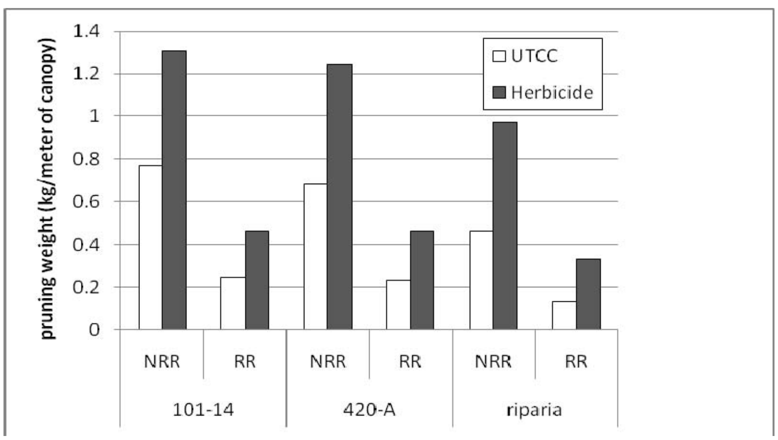

Figure 3. Cane pruning weights by treatment following the 2008 growing season.

Cane pruning weights following the 2008 season are shown in **Figure 3**. As anticipated, riparia Gloire rootstock resulted in slightly lower pruning weights than did the other 2 rootstocks. Both UTCC and root restriction further depressed cane pruning weights. What is desirable? Generally, balanced vines have cane pruning weights in the range of 0.30 to 0.90 kg/m of canopy. Thus, root-restriction was overly suppressive, while herbicide strips generally resulted in excess growth (the exception being with riparia rootstock). Pruning weights were collected in late-January 2010 from treatment vines and cane pruning weights appear to be very similar from 2008 to 2009 (data not shown).

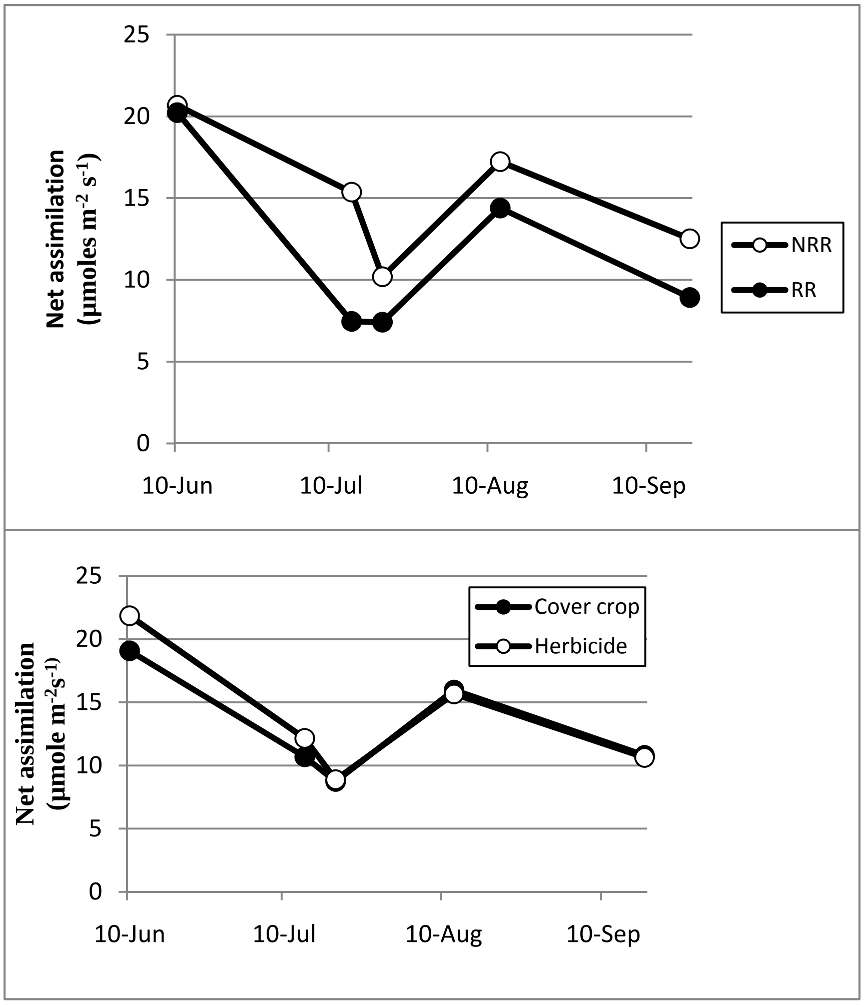

Figure 4. Net assimilation (this means how much carbon is being fixed by photosynthesis) as affected by root restriction (upper plot) or by cover crop (lower plot).

Gas Exchange and water potential: Leaf gas exchange (net assimilation, stomatal conductance, and transpiration), as well as mid-day stem water potential (Ψ_{stem}) were measured weekly during the 2009 season, starting 10 June (**Figure 4**). Net assimilation was generally unaffected by either floor management (cover crop vs. herbicide strip), or by rootstock (data not shown), and varied somewhat as a function of background precipitation (met data collected but not shown here). On the other hand, root restriction did result in a persistent reduction in net assimilation (Figure 4, upper figure), compared to non-root-restricted vines, and this response was easily explained by the reduced Ψ_{stem} of the root-restricted vines (**Figure 5**). The reduction in photosynthesis did not, with the crop levels we allowed in 2009, prevent us from ripening crop (see fruit chemistry for a qualification of this statement).

Yield components: Yield per vine was affected by all three treatment factors. Berry weights were reduced by UTCC and root restriction in both seasons and by rootstock in 2009. Berry weights at harvest were 1.40 g/berry for 420-A and 101-14, and 1.51 g/berry for riparia. Riparia also had greater cluster weights, berries per cluster and crop per vine than did the other two rootstocks. We intentionally limited crop on root-restricted vines in order to target a desired leaf area to crop ratio. Yields were generally higher on the herbicide plots than on the cover crop plots for any of the three rootstocks. Part of the reason for this difference owes to greater berry size with vines on the herbicide plots. This is not surprising and if our goal was simply to promote greater yields, we would argue for using weed-free strips under the trellis as a management tool. If, however, the conditions that cause lower berry weights and lower yields also translate into higher fruit and wine quality, there may be a compelling reason to use under-trellis cover crops.

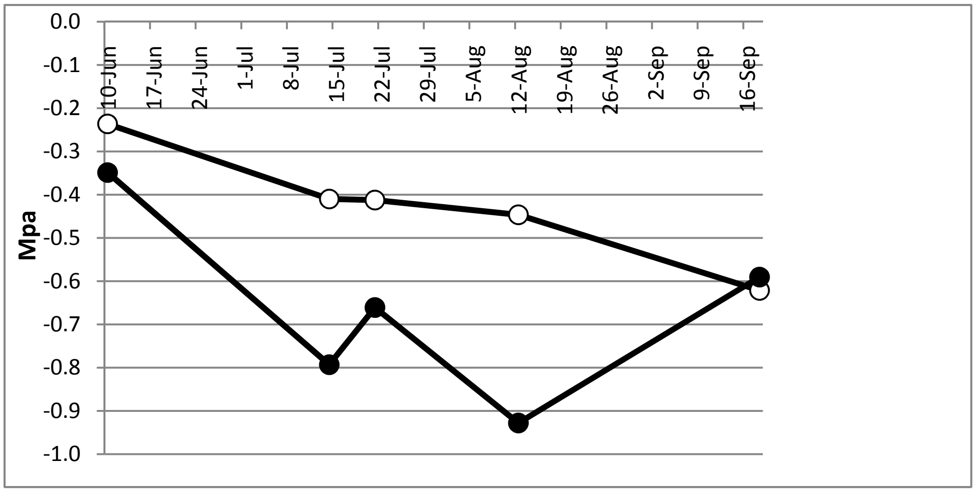

Figure 5. Mid-day stem water potential as a function of root restriction in 2009. The more negative the MPa value, the more stress the vines are under.

Fruit chemistry: Berries were sampled at two-week intervals throughout the growing seasons and somewhat more frequently just prior to harvest. Primary fruit chemistry at harvest is provided in Table 2. While there are slight differences in Brix between treatments, we intentionally sought to harvest the grapes at essentially the same maturity (Brix) level in order to standardize the subsequent measures of secondary metabolites at the same sugar levels. Where we fell short of that goal was with root-restricted vines in 2008. Grapes of vines grown with UTCC averaged approximately 1.0° greater Brix than vines grown on herbicide strips in 2008. Rootstock did not affect Brix and root restriction has caused a reduction in Brix both seasons, but more so in 2008. We were more careful about selectively irrigating the RR vines in 2009. This increased need to monitor vine water status is one management cost associated with root restriction and the use of UTCCs.

Fruit pH was affected by UTCC in 2008 and by root manipulation in 2008 and 2009, while TA was affected by cover crops in 2008 and by root manipulation in 2009; the treatment effects were not large.

In addition to primary fruit chemistry, we also measured the following with fruit collected at harvest in 2009:

- Yeast-assimilable nitrogen (YAN) was not significantly affected by treatment; however, UTCC vines tended to have lower lower YAN values (e.g., 132 mg/L) than did herbicide plot vines (e.g., 139 mg/L).
- Total phenolics, but not color density, were increased by UTCC.
- Root restriction had a significant effect on ^{13}C isotope discrimination in berries. This provides further evidence that RR vines were under more prolonged water stress than were the non-root-restricted vines.

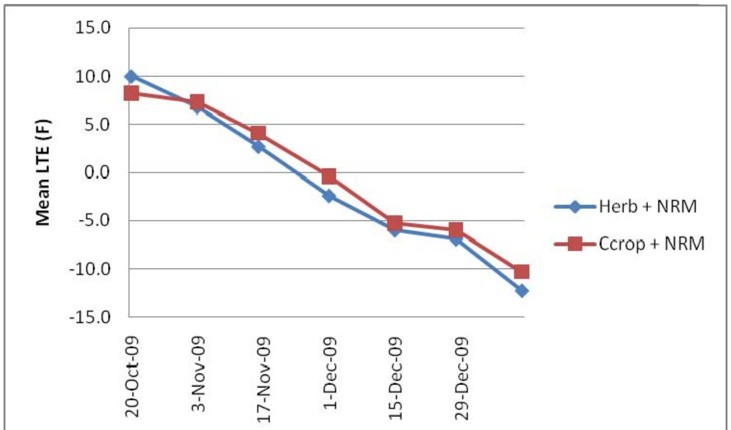

Figure 6. Mean Low Temperature Exotherm temperature of dormant buds of two treatments over the 2009/2010 winter. "Herb + NRM" = vines grown with an herbicide strip and roots unrestricted. "Ccrop+NRM" = vines with cover crops and unrestricted roots.

Bud cold hardiness: We began doing routine (bi-weekly) measures of bud cold hardiness during the 2009/2010 winter. Only 4 treatment combinations are being compared this winter, two of which are shown in **Figure 6**. To date, we have seen no ill effects of treatment on bud cold hardiness. As an aside, we are pleased with the degree of cold acclimation attained with these vines this winter. The last measurement made to date was 11 January 2010, and it appears that buds were still increasing their hardiness at that date (the mean Low Temperature Exotherm (LTE) temperature is roughly the temperature required to kill 50% of buds in the field.

Table *2* - Primary fruit chemistr*y at harvest*, 2008 and 2009. The sub-table here shows which treatment effects, if any were statistically significant. NS denotes a non-significant effect. A number means that the effect was significant at least at the 95% level of probability – or simply put, there was a 95% (or better) likelihood that differences seen between treatments were due to treatment effects and not to chance.

			2008	2009	2008	2009	2008	2009
UTGC	Rootstock	RM	Brix		pH		TA (g/L)	
UTCC	101-14	NRR	24.2	23.6	3.4	3.3	4.9	7.0
		RR	23.3	22.7	3.4	3.4	4.4	5.6
	420-A	NRR	23.9	23.2	3.4	3.3	4.4	8.0
		RR	23.9	22.8	3.5	3.4	4.1	5.8
	riparia	NRR	23.5	23.4	3.4	3.3	4.8	7.2
		RR	22.8	22.6	3.5	3.4	5.1	6.0
Herbicide	101-14	NRR	23.1	23.1	3.3	3.4	6.1	6.9
		RR	22.0	22.7	3.3	3.4	5.9	5.7
	420-A	NRR	22.4	22.7	3.2	3.3	5.8	7.6
		RR	21.6	22.3	3.2	3.3	5.9	6.3
	riparia	NRR	22.4	23.2	3.2	3.4	6.2	7.6
		RR	21.5	22.2	3.2	3.3	6.1	6.4

Significance of effect	p-value					
UTGC	0.0023	ns	0.015	ns	0.0162	ns
Rootstock	ns	ns	ns	ns	ns	ns
Rootstock X UTGC	ns	ns	ns	ns	ns	ns
RM	0.001	0.0044	0.035	0.0109	ns	0.0009
RM X UTGC	ns	ns	0.0353	0.0003	ns	ns
RM X Rootstock X UTGC	ns	ns	ns	ns	ns	ns

Wine-making: Wines were made from 4 of the treatment combinations in 2009 and are currently undergoing assessment for chemical and microbiological stability. Post-fermentation analyses revealed that malic acid was reduced by root-restriction (more open canopy = greater fruit exposure) and pH was *decreased* (3.5 in RR and 3.7 in non-root-manipulated treatments). This is desirable. Alcohol did not differ among treatments (about 13.5%). Interestingly, color density and total phenolics were both greater in wines made from root-restricted vines compared to wines made from non-root-restricted vines. This might relate to lower crop levels with the RR vines, and it could also relate to lower vine nitrogen levels in those vines, as measured by bloom-time leaf petiole analyses.

Conclusions: Some very preliminary findings are that under-trellis cover crops, choice of rootstock, and use of root restriction bags can all be used to alter the vegetative growth of vigorous vines. We can also alter berry weights which, under some conditions, may translate to increased grape and wine quality. The use of root restriction bags offer a means of dramatically controlling the *duration* of vegetative growth, although water management will be increased to avoid over-stressing the vines. The small volume of bag that we chose to use may have been smaller than optimum, and a side project is now underway to explore several larger volumes of root containment. Restriction of vegetative growth has several positive benefits: less labor needed to hedge vines; less labor needed to thin out lateral shoots; more optimal sunlight exposure of clusters; possibly less vegetative tones in fruit if leaf area development after veraison contributes to herbaceous character of wines. Again, this is a preliminary report, and a full exploration of impacts on secondary metabolites and, ultimately, wine-making will be needed to fully understand the potential value of the treatments that we are investigating. Nonetheless, we are excited about the preliminary findings and possibilities for proactively achieving a more balanced vine.

General summary of project: The overall goal of this research is to explore and be able to recommend practical measures that growers can use to achieve more optimal vine balance. The problem being addressed by the research is the condition of excessive vegetative growth of vines in a humid (as opposed to arid) climate. Excess vegetation is associated with fruit shading, inferior wine potential quality, and increased disease problems in fruit and foliage. Growers can and do counter these problems with a range of canopy management measures, including selective leaf and lateral shoot removal, and shoot hedging, all of which increase management costs. Rather than modify existing, remedial canopy management, our research addresses the fundamental cause of excess vegetative vigor and growth. The research project at Winchester (objective #1) has, in its first 2 seasons, shown that under-trellis cover crops, riparia Gloire rootstock, and a novel means of root-restriction, are all effective means of suppressing both the duration and the extent of vegetative development. The treatments used in this project have resulted in vines that are overly vigorous (conventional management), to optimal size, and to those that are too small and lack the capacity for profitable crop production. Given this range of responses we can ask specific questions that were previously confounded by continued leaf area development. For example, we now have a research platform for asking whether it is the *duration* of shoot growth or simply the *amount* of fruit shading caused by leaf area that produces undesirable, herbaceous character in some Cabernet grapes and wine. In addition to creating a more desirable canopy architecture, certain treatments have resulted in decreased berry size, increased juice and wine total phenolics, and decreased wine acidity. Thus, wine quality has potentially been improved as well. Our research with objective #1 aims to further characterize wine quality effects of treatment, to more specifically identify the level of water stress associated with shoot growth cessation, and to characterize how under-trellis cover crops may affect soil "health" as measured by the diversity of soil flora and fauna. While we have a means of regulating vine vegetative development, the "cost" of this tool is a greater need to monitor vine water status to avoid excessive water stress.

Objective #2 involves a multi-year project conducted by PhD graduate student Gill Giese in Dobson NC. Various vineyard floor cover crops (vs. an herbicide strip under trellis) and root-pruning (or not) have been evaluated with vigorous Cabernet Sauvignon vines in a commercial vineyard. Major findings from the NC study are that all 5 cover crops evaluated were effective in achieving a more optimal vine balance, although some grasses performed better than others. Root pruning was also effective in reducing vine size and creating a more optimal canopy architecture, but root-pruning requires high energy input compared to the use of competitive cover crops. Although treatments have been effective in reducing vigor and vine size, the effects on fruit composition and berry weights have been less obvious in the North Carolina study. This may relate to the deep rooting observed with vines in that study. Mr. Giese has presented his findings at industry meetings in North Carolina, Virginia, California and New York.