Year-end Report
Virginia Wine Board, July 31 2013

Virginia Wine Board

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

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Objective: Evaluate in a factorial fashion 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.

Background:
The goal of this research is to explore practical means of favorably regulating vegetative development of vigorous grapevines to create more optimal canopy architecture, fruit ripening conditions, and ultimately improve wine quality potential. The research is based on the premise that highest wine quality potential is achieved when plant available water (PAW) is adequate, but not excessive, vegetative development ceases at or before veraison, berry size is relatively small, and canopy architecture affords adequate, but not excessive, fruit exposure. These conditions, referred to as “balance”, are difficult to achieve in Virginia due to the often surplus soil moisture conditions that are characteristic of Virginia’s humid (as opposed to arid) environment. Our research tests practical approaches to restrict excessive vine growth (vigor).

Details: The experimental vineyard was established in 2006. The experimental design is a strip-split-split field plot that consists of 3 treatment levels. The main plot is an under-trellis cover-crop of creeping red fescue (CC) that is compared with conventional herbicide strips under the trellis. Within this main plot is a sub-plot comparing three different rootstocks: 101-14, 420-A, and riparia Gloire. Within each of the rootstock sub-plots are sub-sub plots that compare root-restriction with no root manipulation. Root restriction was achieved at vineyard establishment by planting the vines in durable, water-permeable transplant bags used in the nursery industry (referred to in this report as “rootbag”). The bags confine the roots to a small volume of soil. The treatments are replicated six times in a randomized, complete block design which allows statistical analysis of data. An additional treatment ‘layer’ was added in the 2010 and 2011 seasons comprising two relative levels of water stress (high and low). Essentially, the “low” stress vines received a surplus of water while the “high” stress vines had water withheld sufficient to restrict vegetative growth and to reduce berry size, without substantially impacting photosynthesis.

The 2011 season represented the 6th growing season in which data were collected. We feel that the original objective (stated above) will be satisfactorily met by the end of the 2012 season. We also have wines made from this project starting with the 2008 vintage, and sensory analyses of

those wines will continue into 2013 and possibly beyond. Aside from the principal investigator (Wolf), the project has been conducted by graduate students Tremain Hatch (now research/extension associate at the Winchester AREC) and Cain Hickey.

Data collected between 2008 and 2012 illustrated how cover crops, rootstocks and root restriction could be used to modify vine pruning weights, canopy density, and the duration of shoot growth. These results have been presented:

- to the wine industry within Virginia (VVA meetings) and regionally (MD, PA, and NY);
- at scientific meetings (ASEV and the Eastern Section of the ASEV)
- in a scientific paper (Hatch, Tremain A., Cain C. Hickey, and Tony K. Wolf. 2011. Cover crop, rootstock, and root restriction regulate vegetative growth of Cabernet Sauvignon in a humid environment. Amer. J. Enol. Vitic. 62:208-311);
- on our website (http://www.arec.vaes.vt.edu/alson-h-smith/grapes/viticulture/research/ground-cover.html)
- provided part of the foundation for a successful ($3.8M) USDA/NIFA grant to the PI and others
- and our research plots, with their varied vine sizes and capacities, provided the stage for a very well attended and productive workshop offered in June 2012, and a follow-up Extension agent training workshop in June 2013 (see details on the agent training program at: http://www.smallfruits.org/Newsletter/Vol13-Issue3.pdf).

Progress since July 2012:

Data were collected for the last season in the 2012 season and part of the experiment was 'released' to other uses as part of a new research effort by graduate student Cain Hickey. Mr. Hickey completed his Master of Science degree in May 2012 and is now pursuing PhD studies with us in a separately funded (2013) Wine Board project.

Data were collected on the relative time to perform canopy management practices in plots during the 2012 season. Statistical analyses remain to be performed, but one of the obvious savings in time with the "low capacity", low vigor vines is with hand labor involved in shoot-hedging and leaf/lateral removal from the fruit zone.

Table 1. Time in minutes per vine or minutes per 5-vine plot to perform dormant pruning, shoot positioning, and shoot hedging on 4 treatment combinations during the 2012 growing season. NRM = non root-restricted, Herb strip = vines grown with conventional, under-trellis herbicide strip; cover crop = vines grown with creeping red fescue under the trellis; and rootbag = vines grown in rootbags. The most 'restrictive' treatment is the combination of rootbag and cover crop, which reduced dormant pruning, for example, by a minute per vine (16 hours/acre).

Treat	Dormant pruning (min/vine)	Shoot positioning (min/5 vines)	Shoot hedging (sum of 2x; min/5 vines)
NRM + Herb strip	2.52	2.43	0.80
NRM + Cover crop	2.20	2.33	0.63
Root bag + Herb strip	1.51	1.09	0.23
Root bag + Cover crop	1.51	0.76	0.10

Other activities during the first half of fiscal year 2013 included follow-up on wine analyses conducted on the 2009 and 2010 wines. Treatment-specific wines were also made in 2011; however, the 2011 wines were deemed unsuitable to expend time and effort on sensory or consumer preference analysis due to the poor quality of fruit. Four treatment wines from the 2009 season were evaluated by a descriptive sensory panel at Brock University in Ontario in December 2012 (Table 2). Treatments included herbicide strips vs. intra-row cover crops, and root-restriction vs. non-root-restricted. The wines were rated for both flavor and aroma descriptors on a 15-point linear scale. There were no significant differences in aroma amongst the 4 wines, but wines made from grapes of root-restricted vines were scored higher for red fruit, dark fruit and cooked fruit flavors (Table 2). The interpretation of these data is that the greater fruit exposure, lower crop levels, and/or reduced vegetative growth of the root-restricted vines led to the slight enhancement of fruit flavors in those wines. The fact that the wines were scored in the lowest third of the 15-point scale is a bit misleading – they were commercially acceptable wines, without defect, but lacked the complexity of wines that see M/L fermentation and aging in oak.

Table 2. Wine sensory scores for Red Fruit Flavor of 2009 wines (15-point linear scale)

Descriptor	Herbicide	Cover crop		No root restriction	Root restriction
Red fruit	3.31	4.06		3.31	4.06 ***
Dark fruit	3.74	4.46		3.74	4.46 **
Cooked fruit	3.57	4.08		3.57	4.08 *
Vegetal	4.62	4.49		4.62	4.49
Earthy	4.67	4.25		4.67	4.25
Spicy	3.86	3.59		3.86	3.59
Acid	7.66	7.68		7.66	7.68
Astringent	6.15	6.27		6.15	6.27
Mouthfeel	5.62	5.61		5.62	5.61

The 2010 wines were subjected to a consumer preference panel (75 panelists) in May 2012 at the University of Arkansas (Table 3). In this case, the vineyard treatments included root restriction (RBG) or no root restriction (NRM), high and low water stress, and the use of intra-row cover crops contrasted with the more conventional under-trellis herbicide strip. While specific differences were found between wines in certain attributes, such as color density, the panelists rated the wines from the different treatments equivocally and relatively highly. As with the 2009 wine sensory analysis, the 2010 wines showed relatively minor differences in consumer preference. Thus, despite fairly large differences in vine size (vegetative growth), the 2010 wines were similar. It may well be that the very favorable ripening conditions of 2010 would mask subtle differences in wines caused by our viticultural treatments.

Included with this report are data summarizing fruit chemistry, including total phenolics and color density of fruit between 2008 and 2011 (Table 4). Data are organized to show main effects of under-trellis floor management, rootstock, and year effects. Data for root-restriction (or not) are not included in this particular dataset. Use of under-trellis cover crops led to slight increases in soluble solids, total phenolics, and anthocyanins (Table 4), all of which would be considered

positive enhancements of wine quality potential within the ranges we measured. Rootstock effects were apparent in some cases, while vintage or year effects were perhaps most marked,e especially the contrast between 2010 and 2011.

Table 3. Hedonic and diagnostic consumer analyses of 2010 Cabernet Sauvignon wines performed at University of Arkansas (May 2012).

Attribute	RBG-LOW + Herb	RBG-HIGH + CC	NRM + CC	NRM + Herb
Appearance	7.3 a	7.2 a	7.1 a	7.4 a
Aroma	6.7 a	6.6 a	6.4 a	6.6 a
Vegetative aroma liking	6.1 b	7.0 a	5.9 b	6.1 b
Overall impression	6.6 a	6.5 a	6.3 a	6.4 a
Overall flavor	6.6 a	6.5 a	6.1 a	6.3 a
Astringency	6.5 a	6.2 a	6.1 a	6.0 a
Mouthfeel	6.5 a	6.4 a	6.2 a	6.1 a
Length of finish	6.1 a	6.2 a	6.2 a	6.1 a

Diagnostic analysis

Attribute	RBG-LOW + Herb	RBG-HIGH + CC	NRM + CC	NRM + Herb
Astringency strength	3.0 a	3.0 a	2.9 a	3.0 a
Vegetative aroma strength	3.1 a	2.9 a	3.0 a	2.9 a
Mouthfeel JAR*	64% JAR	53% JAR	67% JAR	64% JAR
Color JAR*	81 % JAR	73% JAR	81% JAR	85% JAR
Length of finish JAR*	64% JAR	61% JAR	60% JAR	57% JAR

RBG = Rootbag-grown vines
Low = Low water stress (ample moisture throughout season)
High = Higher water stress (irrigation limited to impose enough stress to limit vegetative growth and berry size, but not to limit photosynthesis [sugar production])

*JAR = just about right – values are percentage of panelists who judged the attribute “Just about right”.

Treatment values within a given row (attribute) followed by the same small case letter are not significantly different from other treatments for that attribute.

Table 4. Treatment and vintage effect on primary fruit chemistry (2008-2011) estimated skin phenolics and anthocyanins (2009-2011).

Treatment	Soluble solids (°Brix)	pH	TA (g/L)	Total phenolics (A_{280}, au)	Anthocyanins (A_{520}, au)
UTGC[a]					
CC	23.5 a	3.39	5.88	45.53 a	37.88 a
Herb	23.1 b	3.38	6.12	41.87 b	36.31 b
Stock					
101-14	23.6 a	3.42 a	5.76 b	44.33	38.43 a
420-A	23.1 b	3.34 b	6.29 a	41.81	35.70 b
riparia	23.4 ab	3.39 a	5.95 ab	44.97	37.16 ab
Year					
2008	23.2 b	3.32 b	5.36 b	n/a	n/a
2009	23.2 b	3.34 b	7.37 a	40.35 b	35.10 b
2010	25.5 a	3.44 a	5.43 b	42.84 b	38.35 a
2011	21.4 c	3.43 a	5.83 b	47.92 a	37.85 a
Significance[b]					
UTGC	0.0040	ns	ns	0.0015	0.0317
Stock	0.0012	<0.0001	0.0148	ns	0.0152
Year	<0.0001	<0.0001	<0.0001	0.0023	0.0094
UTGC x Stock	ns	ns	ns	ns	ns
UTGC x Year	0.0032	<0.0001	0.0076	ns	ns
Stock x Year	ns	ns	ns	ns	ns

[a]UTGC = under-trellis groundcover; CC = under-trellis cover crop; Herb = under-trellis herbicide strip.

[b]Significance of treatment effects and interactions: the numbers in this section of the table are the probabilities that treatments differ due to chance – the lower the number the greater the likelihood that differences are due to treatment, and not to chance. Differences are generally agreed to be due to treatment, and not chance, when these probability values are ≤ 0.05. If greater, the differences are considered non-significant (ns).

Discussion: Overall impression, overall flavor, astringency, and mouthfeel tended to be higher in small capacity vines that had greater fruit exposure. The scores for vegetative aroma were greatest in treatments that had the most exposed fruit and the greater water stress. Fruit exposure was positively correlated and water stress negatively correlated with total phenolics and anthocyanins. However, levels of phenolics and anthocyanins were not significantly different between RBG-LOW + Herb and either NRM treatment in 2010. Levels of total phenolics and anthocyanins were significantly different between RBG-HIGH + CC and NRM-None + Herb but not between RBG-HIGH + CC and NRM-None + CC. Treatments that tended to have higher phenolics also tended to have higher rankings for overall flavor, astringency, and mouthfeel; however, the diagnostic attributes such as astringency, mouthfeel, and color did not relate well to phenolic levels in the treatments.

Thus, while the analysis of the 2009 wines suggests that lower capacity vines might have some qualitative advantages in wine potential, the consumer panel rating of 2010 wines does not

reinforce that finding. But all of the 2010 wines were generally well rated and it may be that the ripening conditions of the warm, dry 2010 vintage masked treatment differences that otherwise might have been noted.

Under-trellis cover crops decreased vegetative growth more consistently than did rootstock choice, but root restriction bags tended to limit vegetative growth even more so than cover crops. As a consequence, fruit exposure was increased equally in vines grown with cover crops or root restriction compared to other treatments. Withholding irrigation water from vines did not result in any consistent increases in fruit exposure or decreases in vine size. Yields were highest in conventionally planted vines grown without root restriction or cover crops, both of which tended to decrease yields to a greater extent than did any of the rootstocks. Withholding irrigation water in the dry 2010 season tended to decrease yields compared to well-watered vines. Berry weights were decreased by root restriction, cover cropping, and deficit irrigation; these treatments tended to dehydrate vines, showing the close relationship between vine water status and berry expansion. Grape sugar and skin anthocyanins tended to be improved by cover cropping, root restriction, and the 101-14 rootstock. However, fruit composition was highly impacted by vintage, affirming that the climate of a vintage can often affect fruit composition to a greater extent than any of our imposed treatments.

Summary: Cover crop and root restriction treatments tended to confer all of the vine characteristics that generally improve fruit and wine quality; they reduced vegetative growth and berry size and increased fruit exposure, total phenolics and skin color density (anthocyanins). While there were sensory differences between young wines made from different treatments, “release ready” wines were not different enough to change consumer liking/disliking of any particular wine. Rather, treatments that reduced vine size and yield tended to improve fruit composition, but not to an extent that wine quality was substantially improved. The caveat being that the vintage in which compared wines were made from (2010) was a vintage that many would agree increased the probability of hitting the “premium wine target,” thus minimizing the likelihood of a significant treatment effect on fruit and wine quality. We suggest that cover crops are a good vineyard management tool for those looking to reduce vine size and vine vigor and decrease costs associated with pruning and canopy management. Conventionally planted (non-root restricted, non-cover-cropped) vines yielded as much as 1.8 tons/acre more than some treatments (data not shown in this report) and made wines that were not liked any less by consumers. Thus, it is difficult to argue against conventional vineyard management strategies in terms of producing a higher crop amount without any perceptible decline in wine quality.

Publications: We are nearing completion of a second journal paper on this work which we anticipate will be submitted in the fall, 2013 (“Multi-season effects of rootstock and intra-row cover crops on vine growth and fruit composition of Cabernet Sauvignon”). In addition, we are starting preparation of an extension bulletin describing the project, and illustrating the results obtained. This should be finished in the fall of 2013.

Impact Statement: In a broad sense, research conducted over a 4-year period has shown that under-trellis cover crops, riparia rootstock, and root containment (coupled with irrigation management) can be effective tools to desirably restrict the vegetative growth of vigorous grapevines. The accrued benefits, in terms of more favor canopy architecture, cluster exposure, and fruit composition offer means of reducing canopy management labor and possibly improving wine quality. The increased fruitfulness of vines grown on riparia rootstock can translate to increased vineyard profit. Treatment effects on wine quality potential are more subtle, and treatments will need to be scaled up to commercial size in order to fully evaluate those potential benefits. Vineyard management is increased with some of these tools, however, particularly in the area of irrigation and nutrient management.