Oregon Wine Advisory Board
Research Progress Report

1996 - 1997

Canopy Management Practices and Vine Performance

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ABSTRACT A factorial design was used to vary leaf canopy structure of mature Pinot noir grapevines during two consecutive seasons: shoot tipping at full bloom (yes or no), lateral shoot length (no laterals, laterals cut back to 4 leaves at full bloom, laterals allowed to grow undisturbed) and cluster zone leaf removal (leaf removal in the cluster zone or no leaf removal). Shoot tipping at bloom had the greatest effect on yield components, fruit composition, and vegetative growth. Tipping increased percent fruit set, berries per cluster, cluster weight, and yield to pruning ratio in both seasons. Shoot tip removal increased early shoot growth in the second season, main and lateral leaf size, and the contribution of lateral leaves to total leaf area. Tipping decreased the number of shoots per vine in the second season, clusters per vine in both seasons, must soluble solids, total amount of sugar exported with fruit harvest, leaf area per vine, pruning weight, and cane weight and length at mid-ripening. Increasing lateral shoot length increased must soluble solids in both seasons and dormant cane diameter the following winter. Vines with long laterals had lower yield to pruning ratios in the first season. Percent fruit set increased only in the absence of vegetative growing tips, either from the main or from lateral shoots. Leaf removal in the cluster zone four weeks after bloom had no impact on yield components but reduced must soluble solids in both seasons. It also reduced yield to pruning ratios in the first season and dormant cane diameter in the second season. Non-structural carbohydrate concentration in the permanent structure was not affected by any of the treatments but total content in the trunk increased with increasing lateral shoot length.

INTRODUCTION A significant problem in Oregon viticulture is the considerable fluctuation in yields due to poor fruit set. Weather patterns during bloom may greatly affect the number of berries set per cluster, but are not the only factor contributing to yield fluctuations: carbohydrate assimilation and partitioning also play decisive roles. During bloom, the actively growing shoot tip competes with the inflorescence for carbohydrates. Shoot tip removal eliminates this competition and additional carbohydrates are made available to the inflorescence, resulting in a higher probability of flowers setting into fruits.

To retain, hedge, or remove lateral shoots in grapevine canopies has been a matter of controversy in many wine grape production zones in the Old and New World. Lateral shoots are undesirable in vigorous vineyards because they lead to crowded canopies with excessive leaf layers, poor light interception, and poor microclimate, resulting in an imbalance favoring vegetative growth over fruit production. It has been shown that, in moderate vigor vineyards, lateral leaves improve fruit quality and are the most important contributors to sugar accumulation in the fruit during ripening, and to starch accumulation in the parent vine.

Photosynthetic rate of grapevine leaves increases until leaves attain full size (approximately 40 days after unfolding) and decreases steadily thereafter. During the fruit ripening period, leaves in the cluster zone are well over 40 days of age and have very low photosynthetic rates compared with fully expanded lateral leaves and main leaves located at the top of the canopy. These leaves can be eliminated without great loss in overall vine photosynthesis. With leaf removal in the cluster zone, there is an improvement in fruit microclimate contributing to fruit quality and decreasing Botrytis bunch rot incidence and severity. It may also improve the effectiveness of pesticide application by allowing better spray penetration.

In this study, the effect of shoot tipping, lateral shoot length, and cluster zone leaf removal on overall vine performance were evaluated.

MATERIALS AND METHODS

Experimental design

A factorial design was used to vary shoot tipping, lateral shoot length and cluster zone leaf removal. The experiment was carried out on 180 seventeen-year-old own-rooted Pinot noir grapevines during two consecutive seasons. Vines were spaced 6' x 9' (1.83m x 2.74m) and were cane pruned to four buds / m2 (11 buds / m row) in the first season and were balanced pruned to 28 buds / kg of one-year-old pruning wood in the second season. The following treatments were applied:

- Shoot tipping at full bloom, or no shoot tipping.
- Lateral shoot length: 1) no laterals, laterals removed weekly as they arose, starting at full bloom, 2) Short laterals: laterals cut back to 4 leaves at full bloom, and subsequent lateral growth removed weekly, 3) Long laterals: laterals allowed to grow undisturbed.
- Leaf removal in the cluster zone 4 weeks after bloom or no leaf removal. Treatment consisted of removing the leaves and laterals opposite to the clusters plus one leaf immediately above and below the cluster.

Each treatment combination was replicated 5 times in sets of 3 vines.

Fruit set

Prior to bloom, one inflorescence per vine was enclosed into a mesh bag to retain all shed flowers. The bags were removed at the end of July, four weeks after full boom, and all abscised flowers and fruitlets were counted. At harvest, these clusters were picked separately and frozen and the number of berries was later counted. The number of flowers was calculated as the sum of shed flowers and berries. Percent fruit set was calculated as the quotient of the number of berries at harvest and the total number of flowers per inflorescence.

Yield and fruit quality

The crop was harvested on October I in 1995 and on October 17 in 1996. The number of clusters per plant was recorded. One hundred berries from each replicate were chosen randomly to determine mean berry weight. Cluster weight was obtained dividing total yield by number of clusters. Number of berries per cluster was calculated dividing cluster weight by mean berry weight. A sample of 25 clusters per replicate was crushed for determination of soluble solids, pH and titratable acidity. Sugar per vine was calculated multiplying must sugar content in 'Brix (equivalent to percentage by weight of sucrose) by total yield per vine.

Canopy development and vine vigor

Trunk volume was estimated during pruning in 1996. For this purpose, the trunks were divided into n approximately cylindrical sections and the following formula was used:

$$V=\sum_{i=1}^{n}\left(\frac{d_i}{2}\right)^2 . \pi . L_i$$

d_i: diameter of the trunk section i with length
L_i: length of the trunk section i

Shoot length of one shoot per vine was measured on July 1, 1996 (full bloom) just prior to the execution of the shoot tipping treatments. Three shoots per replicate were collected on September 9, 1996 for growth analysis. Shoot length and diameter, number of main and lateral leaves were counted and primary and lateral leaf area was measured. Weight of the one year old prunings, including woody laterals, was recorded in 1995 and 1996. Cane weight was obtained by dividing pruning weight by number of canes.

Wood carbohydrate reserves

During pruning, wood samples from the trunk were collected and carbohydrates were extracted and analyzed using the method described by Candolfi-Vasconcelos and Koblet (1990).

Statistical analysis

The Statview statistical package was used for statistical analysis of data. Results were subjected to a 3-way analysis of variance (shoot tipping x lateral length x leaf removal). Waller-Duncan k-ratio test was used to compare means. Interactions between factors were rare, and the contribution of the interactions to the total variance was very small relative to the main effects. For this reason, we chose to present only the means of the main effects. For completeness, all significant interactions found are also reported in the tables.

RESULTS AND DISCUSSION

Yield and yield components

There was no effect of shoot tipping, lateral shoot length, or leaf removal on total yield per vine on the first season but shoot tipping decreased yields in the second season (Table 1). Percent fruit set, however, was higher for vines hedged at bloom during both seasons. As a result of these fruit set differences, final number of berries per cluster and cluster weight were also increased by shoot tip removal. Shoot tips compete with the developing inflorescences for assimilates. During bloom, the leaves in the mid and upper shoot section export carbohydrates to the shoot tip. After hedging, the direction of translocation is reversed: instead of moving upwards to the shoot tip, assimilates are diverted basipetally and made available to the developing inflorescences, resulting in improved fruit set. Fruit set was also favored by lateral shoot removal. During early stages of development, lateral shoots depend on assimilates provided by the main shoot for growth, competing with other vegetative and reproductive sinks. As soon as they have fully expanded leaves, laterals support their own growth and export the surplus of assimilates to the main shoot. The cluster zone leaf removal treatment was performed four weeks after full bloom, after the critical period for fruit set (until three weeks after full bloom) and therefore, no measurable effect on fruit set was observed. There was no treatment effect on berry weight.

Table 1: Effect of canopy management practices on yield, yield components, and relationships between vegetative and reproductive growth of Pinot noir grapevines.

		Tipping Main Shoots (A)			Lateral Length (B)				Leaf Removal (C)			Significant Interactions
		No	Yes	F	Absent	Short	Long	F	No	Yes	F	
Yield (kg/vine)	95	2.74	2.98	ns[1]	2.91	3.04	2.64	ns	2.97	2.75	ns	ns
	96	5.66	4.12	**	4.52	5.10	5.05	ns	4.51	5.27	ns	ns
Leaf : fruit ratio (cm²/g fruit)	96	15	11	**	9 b	14 a	15 a	***	15	10	**	ns
Yield : pruning ratio	95	2.2	4.1	***	3.6 a	3.3 a	2.6 b	***	3.5	2.9	*	ns
	96	5.8	7.8	**	7.5	6.8	6.1	ns	6.6	6.9	ns	ns
Percent fruit set	95	37	49	***	50 a	39 ab	39 b	***	42	42	ns	A X B**
	96	33	40	***	40 a	36 b	34 b	*	37	36	ns	ns
Yield per shoot	95	136	152	ns	147	154	131	ns	147	141	ns	ns
	96	227	246	ns	227	246	235	ns	229	243	ns	ns
Number of clusters per vine	95	32	30	ns	31	32	30	ns	31	31	ns	ns
	96	48	31	***	37	40	42	ns	37	43	ns	ns
Number of shoots per vine	95	20	20	ns	20	20	20	ns	20	20	ns	ns
	96	24	17	***	20	20	21	ns	20	21	ns	ns
Cluster weight (g)	95	87.1	98.9	*	95.7	96.6	86.6	ns	95.8	90.1	ns	ns
	96	115.9	130.9	**	124.5	126.2	119.5	ns	123.9	122.9	ns	ns
Berry weight (g)	95	1.3	1.26	ns	1.28	1.27	1.29	ns	1.27	1.29	ns	ns
	96	1.10	1.10	ns	1.10	1.11	1.09	ns	1.10	1.09	ns	ns
Number of berries per cluster	95	68	80	**	76	77	69	ns	77	70	ns	ns
	96	106	120	**	114	114	111	ns	113	113	ns	ns

[1] ns, *, ** and *** indicate not significant, and statistically significant at the 0.05, 0.01, and 0.001 levels of probability, respectively.
Values followed by the same letter within row sections do not differ significantly.

Shoot tip removal in the previous season, considerably reduced cane and pruning weights, affecting the number of buds left after balance pruning. Un-tipped vines, therefore, had more shoots and clusters per vine which resulted in higher yields in the second season.

Fruit composition

Must soluble solids was reduced by shoot tipping (Table 2). Brix increased with lateral shoot length and decreased with cluster zone leaf removal. Un-hedged vines and vines with lateral shoots had a higher proportion of young leaves in the canopy. Leaves start exporting assimilates when they reach 50% of their final size. It has been shown that the presence of fully expanded young leaves is advantageous for sugar accumulation in the fruit. There were no significant differences in titratable acidity among treatments during both seasons. Juice pH was lower in the absence of shoot tips and increased with lateral shoot length in the first season. There was no treatment effect on pH in the second season. Amount of sugar exported with fruit harvest was not influenced by any of the treatments in the first season but was reduced by shoot tipping and increased with cluster zone leaf removal in the second season. Leaf : Sugar ratio (leaf area available to produce one gram of sugar) decreased 27% with shoot tipping and 30% with cluster zone leaf removal. Removal of all lateral shoots reduced Leaf:Sugar ratio by 38-39% as compared to hedging the laterals or letting them grow undisturbed.

Table 2: Effect of canopy management practices on fruit composition, amount of sugar exported with harvest ((Brix/100) x yield) and leaf : sugar ratio (leaf area available to produce one gram of sugar) of Pinot noir grapevines.

		Tipping Main Shoots			Lateral Length				Leaf Removal			Significant Interactions
		No	Yes	F	Absent	Short	Long	F	No	Yes	F	
Soluble solids (°Brix)	95	23.1	22.5	***[1]	22.4 c	22.7 b	23.2 a	***	22.9	22.6	*	ns
	96	21.9	21.4	*	21.0 b	21.7 a	22.1 a	***	22.0	21.3	**	ns
pH	95	3.30	3.25	*	3.23	3.28	3.31	*	3.27	3.27	ns	ns
	96	3.16	3.13	ns	3.11	3.15	3.17	ns	3.16	3.13	ns	ns
Titratable acidity	95	6.92	7.23	ns	7.32	6.89	7.01	ns	7.20	6.95	ns	ns
	96	7.56	7.81	ns	7.93	7.71	7.42	ns	7.80	7.57	ns	ns
Sugar exported with harvest (g)	95	627	673	ns	655	695	600	ns	680	620	ns	ns
	96	1227	876	**	949	1102	1103	ns	985	1117	**	ns
Leaf : sugar ratio (cm²/g)	96	67	49	**	41 b	66 a	67 a	***	68	48	**	ns

[1] ns, *, ** and *** indicate not significant, and statistically significant at the 0.05, 0.01, and 0.001 levels of probability, respectively.
Values followed by the same letter within row sections do not differ significantly.

Canopy development and vine vigor

Early shoot growth was favored by shoot tipping the previous season (Table 3). There was no effect of lateral shoot length or cluster zone leaf removal on shoot length at bloom. Average leaf size (main and lateral leaves) increased with shoot tip removal (Table 3). It has been shown that one of the compensation mechanisms for leaf removal is the increase in the size of the remaining leaves. Removal of shoot tips decreased total leaf area by 47%, mainly because of reduced main leaf area (Table 3). Main leaf area, lateral leaf area and total leaf area per vine were not significantly reduced by cluster zone leaf removal. There was no compensatory increase in the main leaf area per vine in response to lateral shoot removal. Vines with un-hedged lateral shoots had 25% more lateral leaf area than vines with laterals cut back to four leaves but there was no difference in total leaf area between these treatments. Shoot tip removal increased the proportion of leaf area arising from lateral shoots but leaf removal did not change this ratio. Surprisingly, shoot diameter during mid-ripening did not respond to shoot tip removal, even though the hedged shoots were 76% shorter. On the other hand, cluster zone leaf removal reduced shoot diameter. Vines with short laterals had the highest shoot diameter at mid ripening. Trunk volume measured in the winter following the first season was not affected by any of the treatments. Pruning weights were not affected by lateral shoot length or leaf removal but decreased greatly with shoot tipping during both seasons. Pruning weights and average cane weight were lower after the second season, in response to balance pruning. In the winter of 1997, mean cane weight ranged from 40 to 51 g, still higher than the desirable 30-40g. This is the result of some of the nodes left at pruning in 1995 failing to produce viable shoots (data not shown). Vines without lateral shoots had the lowest cane weights because of the absence of woody laterals (cane weight includes laterals).

Carbohydrate reserves in the wood

Non-structural carbohydrate concentration in the trunk during the winter following the first season was not changed by any of the treatments (Table 3). However, total carbohydrate reserves stored in the trunk increased with lateral shoot length, demonstrating the importance of having a canopy with a higher proportion of fully expanded young leaves during the period of downward translocation for reserve replenishment.

Table 3: Effect of canopy management practices on vegetative growth and carbohydrate reserves in the wood of Pinot noir grapevines

		Tipping Main Shoots			Lateral Length				Leaf Removal			Significant Interactions
		No	Yes	F	Absent	Short	Long	F	No	Yes	F	
Main leaf size (cm^2)	96	99	113	**[1]	98	109	112	ns	109	103	ns	ns
Lateral leaf size (cm^2)	96	31	38	**	—	33	35	ns	37	32	ns	ns
Main leaf area / vine (m^2)	96	5.69	2.47	***	4.17	4.24	3.80	ns	4.50	3.64	ns	ns
Lateral leaf area / vine (m^2)	96	2.13	1.73	ns	—	2.57 b	3.22 a	***	2.19	1.68	ns	ns
Total leaf area / vine (m^2)	96	7.82	4.18	***	3.89 b	6.81 a	7.02 a	**	6.68	5.32	ns	ns
Percent lateral leaf area	96	24	32	*	0	39 b	46 a	***	29	28	ns	ns
Shoot length, bloom[2] (cm)	96	99	107	*	103	101	106	ns	101	106	ns	ns
Cane length, mid-ripening (cm)	96	175	99	***	137	142	132	ns	141	134	ns	ns
Cane diameter, mid-ripening (mm)	96	9.3	9.5	ns	9.3 b	9.7a	9.2 b	*	9.6	9.2	*	ns
Trunk volume, February (cm^3)	96	2543	2372	ns	2409	2424	2541	ns	2500	2415	ns	ns
Pruning weight, mid-winter (kg/vine)	95-96	1.39	0.77	***	1.00	1.10	1.15	ns	1.05	1.11	ns	ns
	96-97	1.03	0.58	***	0.68	0.81	0.93	ns	0.80	0.81	ns	ns
Cane weight, mid-winter (g)	95-96	73	42	***	53	59	61	ns	56	59	ns	ns
	96-97	49	43	*	40 b	47 a	51 a	**	48	44	ns	ns
Reserve carbohydrates in the wood, mid-winter (% dry wt)	95-96	15.6	15.7	ns	14.8	15.5	16.7	ns	15.0	16.4	ns	ns
(g/Trunk)	95-96	304	281	ns	256 b	294 ab	327 a	*	280	305	ns	ns

[1] ns, *, ** and *** indicate not significant, and statistically significant at the 0.05, 0.01, and 0.001 levels of probability, respectively.
Values followed by the same letter within row sections do not differ significantly.
[2] Measurement just prior to shoot tipping treatment