NORTHERN GRAPES PROJECT

Viticulture, enology and marketing for cold-hardy grapes

Training systems and Labor: How to Achieve Economically Sustainable Vineyards with Quality Fruit

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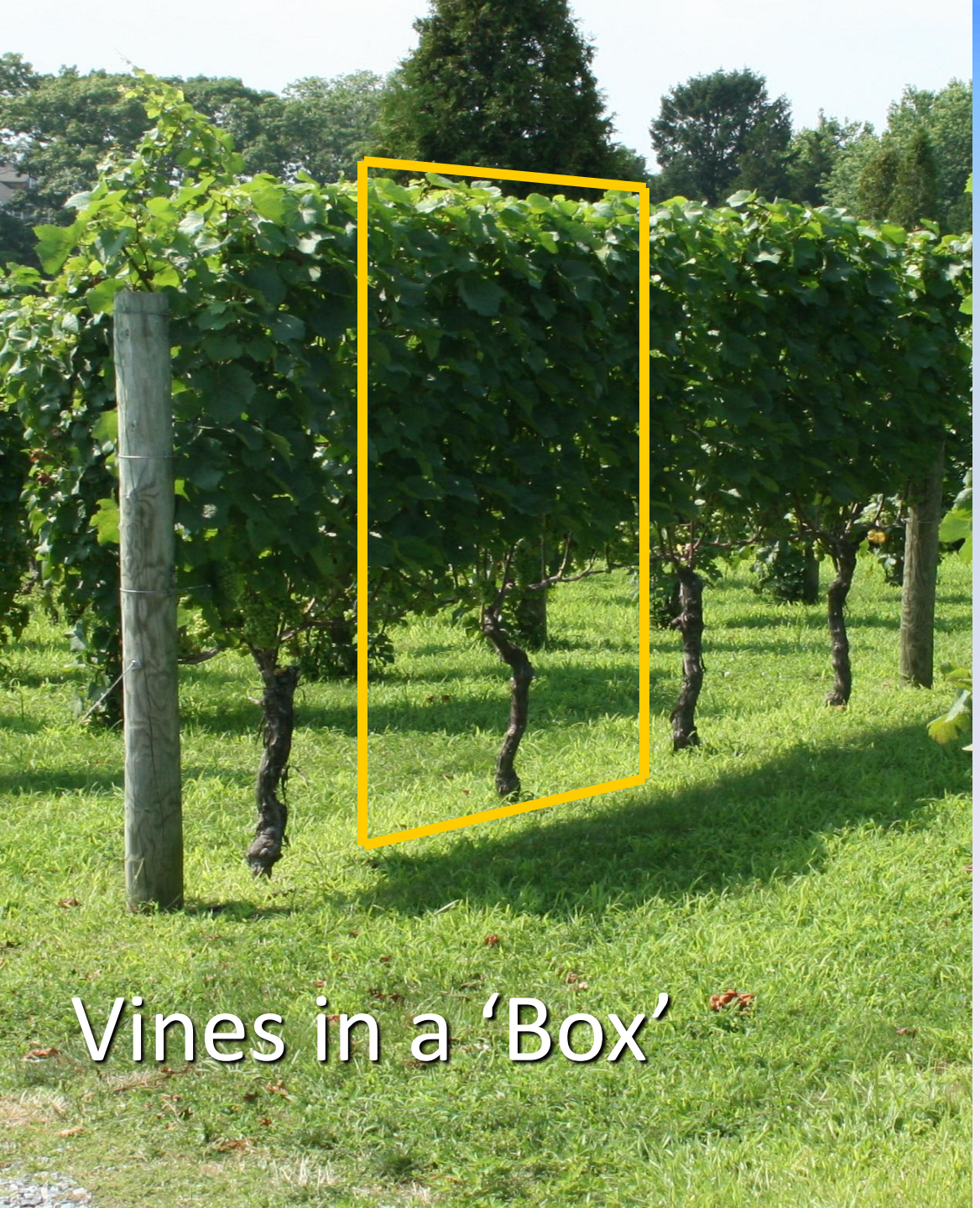
Labor Inputs

Each minute you spend on a vine

=

*13.5 hours labor per acre**

** 6 x 9 ft spacing, 807 vines/acre*



Vines in a ‘Box’

- Space
- Vigor
- Shoot density
- Shading

Tools

- Vine Spacing
- Training system
- Irrigation/Fertility
- Canopy Management
  - Shoot thinning
  - Leaf removal
  - Hedging
- Crop Management
  - Pruning severity
  - Cluster Thinning

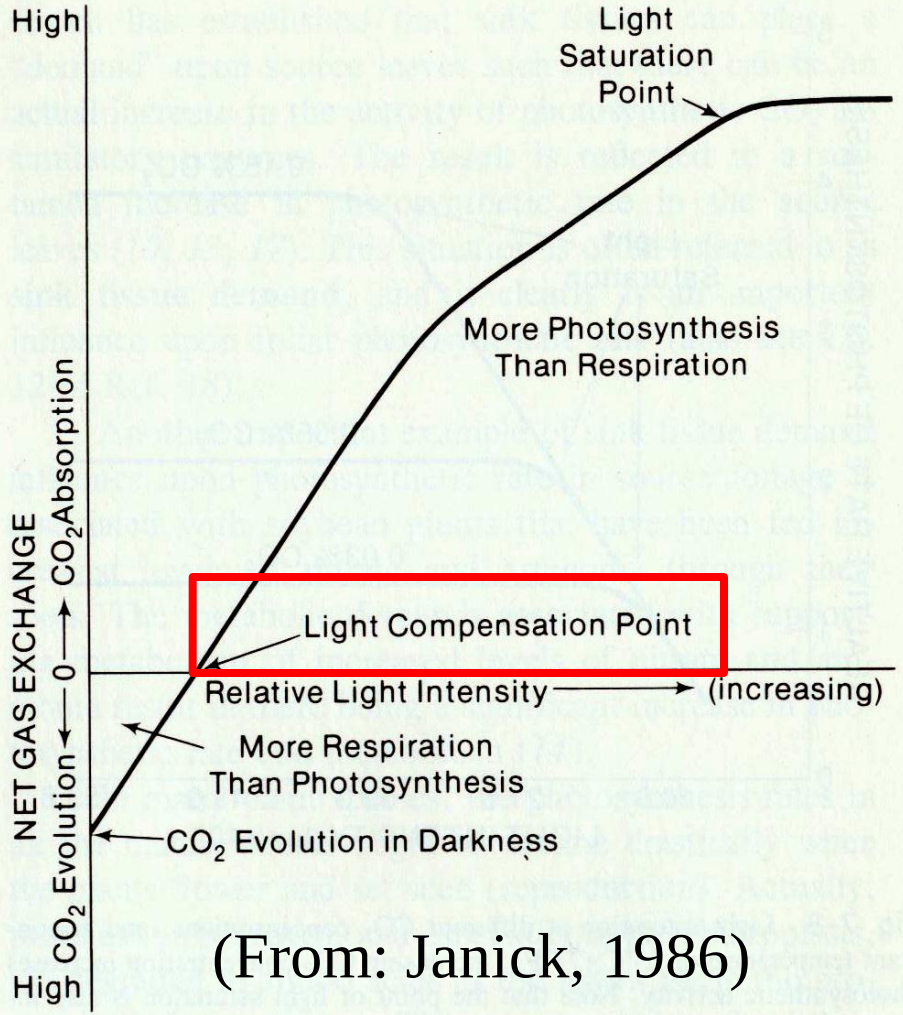
Training Systems

Martin Goffinet ©

iola UMD

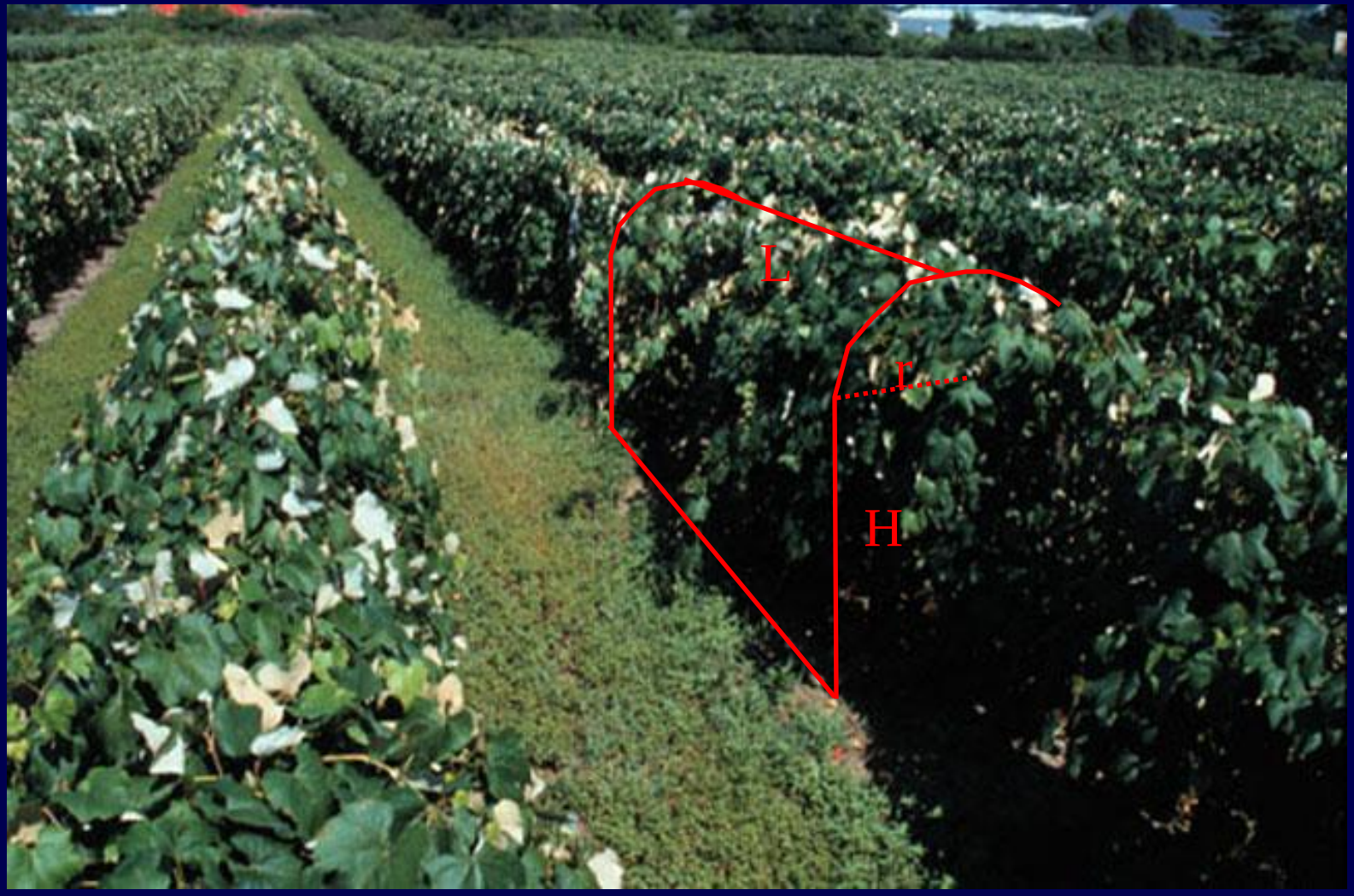
Canopy Microclimate and Shading

Light Compensation Point for Carbon Balance in Leaves

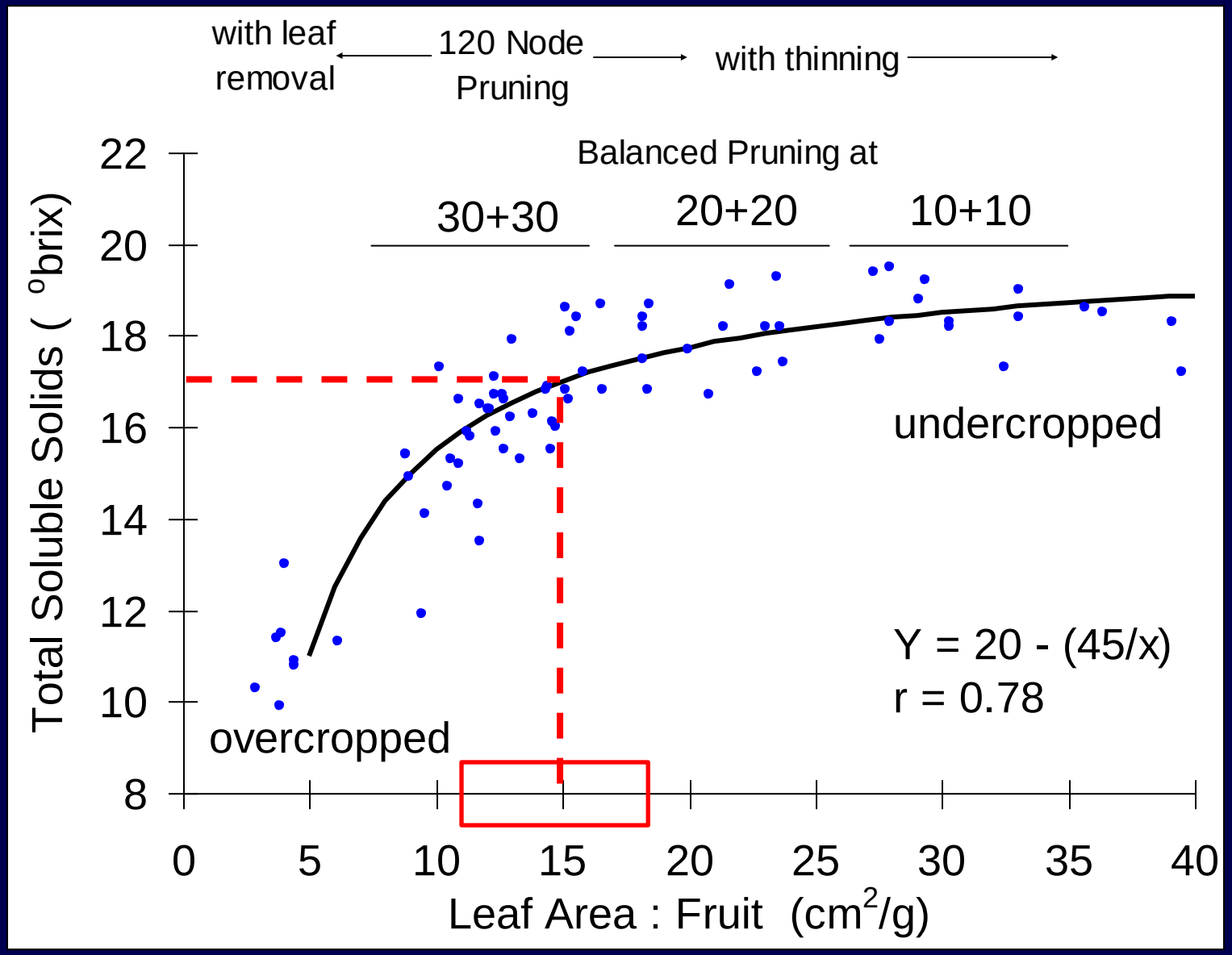


(From: Janick, 1986)

- Leaves need some carbohydrates for their own cellular respiration
- Below compensation point, leaf respiration exceeds photosynthesis
- Shaded leaves do not contribute significantly to vine or fruit carbon requirements



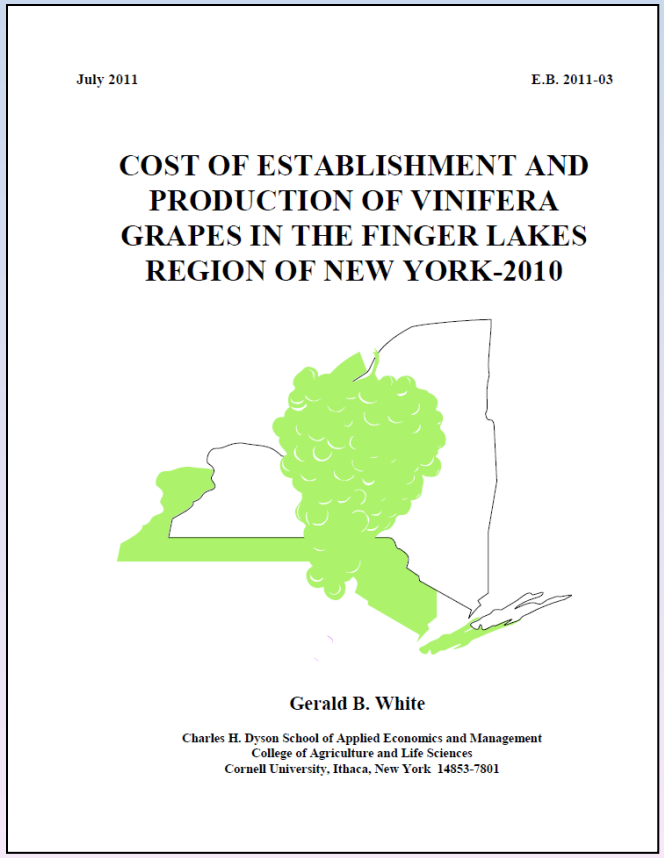
Canopy Surface Area x 1.5 = Maximum Possible Exposed Leaf Area


with leaf removal
120 Node Pruning
with thinning
Balanced Pruning at
30+30
20+20
10+10
Total Soluble Solids (°brix)
22
20
18
16
14
12
10
8
undercropped
overcropped
Y = 20 - (45/x)
r = 0.78
0
5
10
15
20
25
30
35
40
Leaf Area : Fruit (cm²/g)

Outline

- General comments on Cost/Quality/Yield
- Examples
  - Shoot thinning on hybrids
  - Marechal Foch Shoot thinning/Harvest date
  - Cluster thinning on Riesling
  - Vignoles and disease on High Cordon vs VSP

Cost of Establishment of *V. vinifera* in the Finger Lakes Region of NY


July 2011 E.B. 2011-03

COST OF ESTABLISHMENT AND PRODUCTION OF VINIFERA GRAPES IN THE FINGER LAKES REGION OF NEW YORK-2010

Gerald B. White

Charles H. Dyson School of Applied Economics and Management
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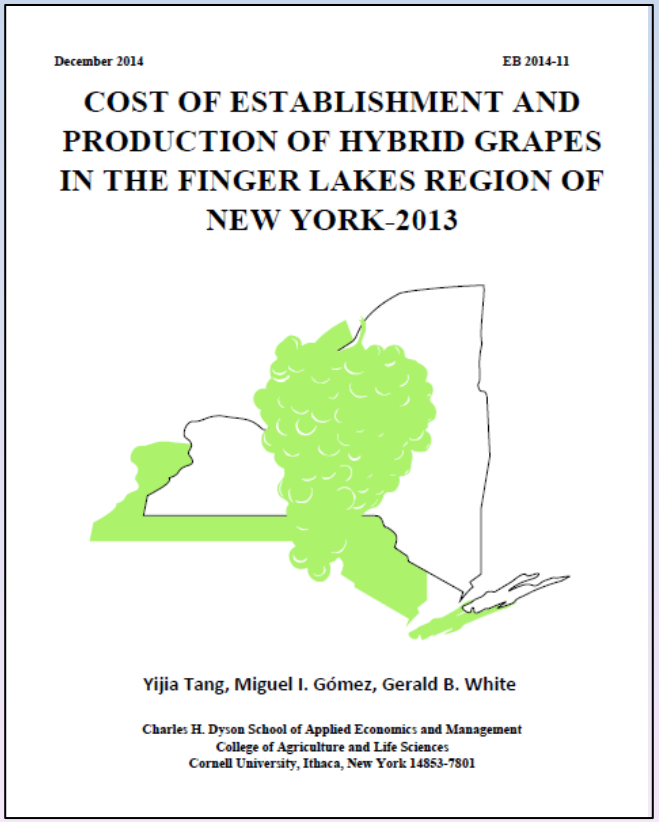
Gerald White


December 2014 EB 2014-11

COST OF ESTABLISHMENT AND PRODUCTION OF HYBRID GRAPES IN THE FINGER LAKES REGION OF NEW YORK-2013

Yijia Tang, Miguel I. Gómez, Gerald B. White

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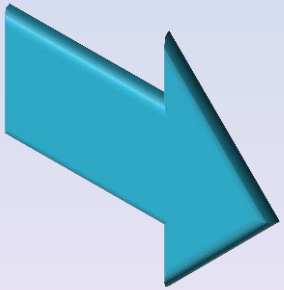
Farming for Flavors

Grapes



"does exhibit cherry and black currant flavors and aromas… but can be much more complex with integrated notes of blackberries, pepper, plum, tobacco, leather, and spice".

$$$?

From One Acre to Twenty

One Acre

- Backpack sprayer
- Weekend work
- Hand labor not limiting
- Modest equipment needs
- Tonnage less important?
- Quality variable?
- Management informal

Twenty acres

- Commercial Sprayer
- Timely management
- Labor efficiency important
- Machinery investments
- Tonnage important
- Quality imperative
- Management crucial

Different businesses

Vineyard + Winery

- Can capture ‘value added’ in wine
- Ratio: Wine > 5x multiplier in revenue
- Can make a lot of wine on a small acreage
- (2,000 cases = 10 acres)
- Can use specialized vineyard practices and recoup cost in premium wines

Stand-alone vineyard

- Needs to be profitable growing grapes
- Tonnage matters
- Labor efficiency important
- Needs more acres of grapes to support equipment investments
- Buyers generally pay more for ‘quantity’ than ‘quality’

Commercial Viticulture

- What growing practices measurably contribute to quality?
- What growing practices measurably contribute to yield?
- At what point do higher yields compromise quality?
- What are buyers willing to pay for ‘extra’ practices that increase quality or reduce yield?

Labor becomes significant

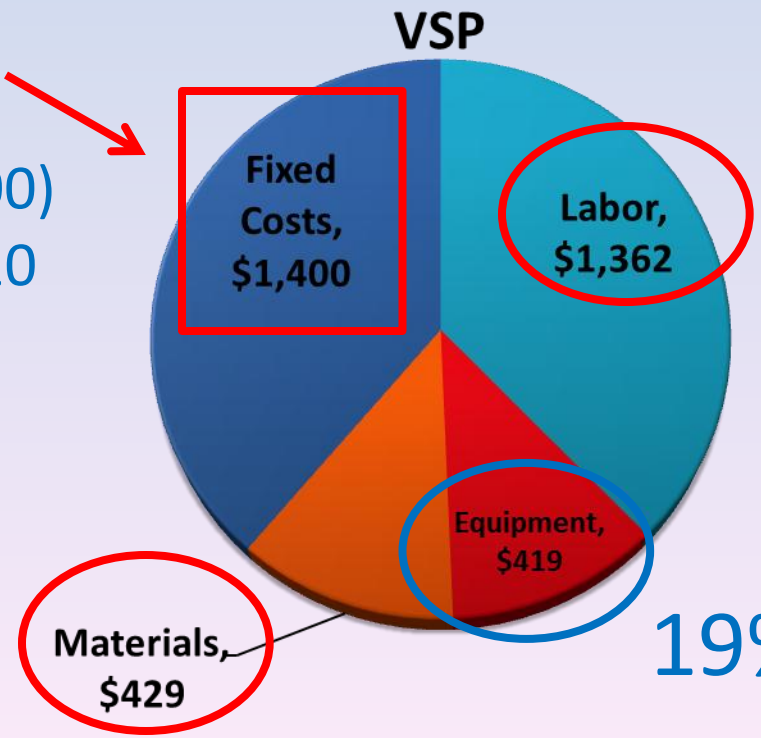
Time spent per vine

- At 9x6 vine spacing: 807 vines per acre
- Each 1 minute per vine = 13 ½ hours of time/acre.
- Pruning: @0.40 per vine = $322.00, about 27 h per acre.
- Tying @ 0.20 per vine = 14 h labor/acre
- Canopy management: each pass 6 h (Shoot Pos, Leaf removal, shoot tipping)

Annual Growing Costs/Acre

40%
(50 AC.)

(25 ac: $2800)
Total = $5,010



Total = $3,610

Variable = $2,210

62%

19%

19%

Source: Gerald White 'Cost of Establishment of *V. vinifera* in Finger Lakes 2010'

Cost Per Ton ($3610/acre)

Yield (T/Acre)	Cost Per Ton	At $2210/Acre
1.5	$2,407	1,473
2.0	$1,805	1,105
2.5	$1,444	884
3.0	$1,203	737
3.5	$1,031	631
4.0	$903	553
5.0	$722	442

Variable Costs Covered

$1000/Ton

10' lb/vine
(6x9 ft spacing)

Source: Gerald White 'Cost of Establishment of *V. vinifera* in Finger Lakes 2010'

What is quality?

- Clean, disease free fruit
- Ripe fruit
- Enough fruit (Yield) to pay the bills
- Vine reserves to maintain production next year

Beyond these basics:

Quality is what the customer wants and is willing to pay for.

Achieving Ripeness

- Enough exposed leaf area to ripen fruit.

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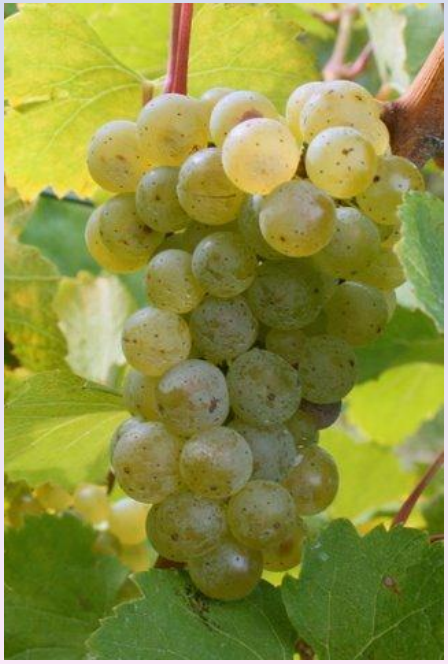

= cm^2/ g

15-20

Pruning and Vine Balance

- Ravaz Index

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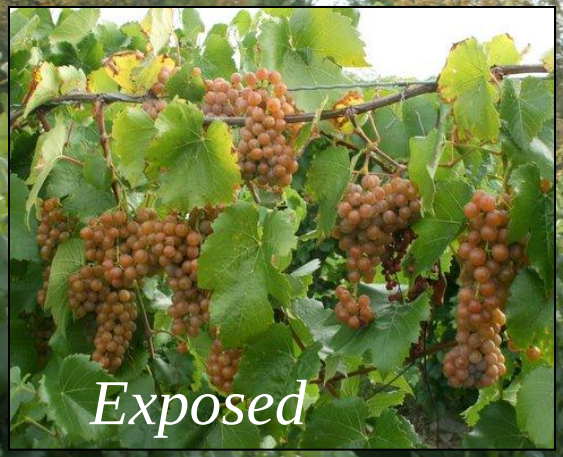
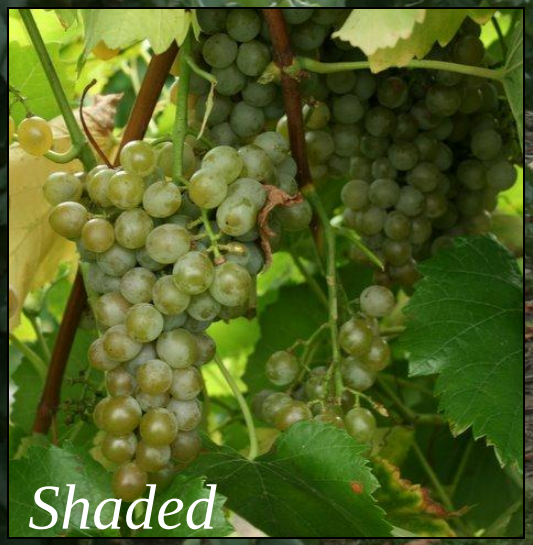
Ravaz Index

5 to 10

Traminette 2007

Excess Vigor

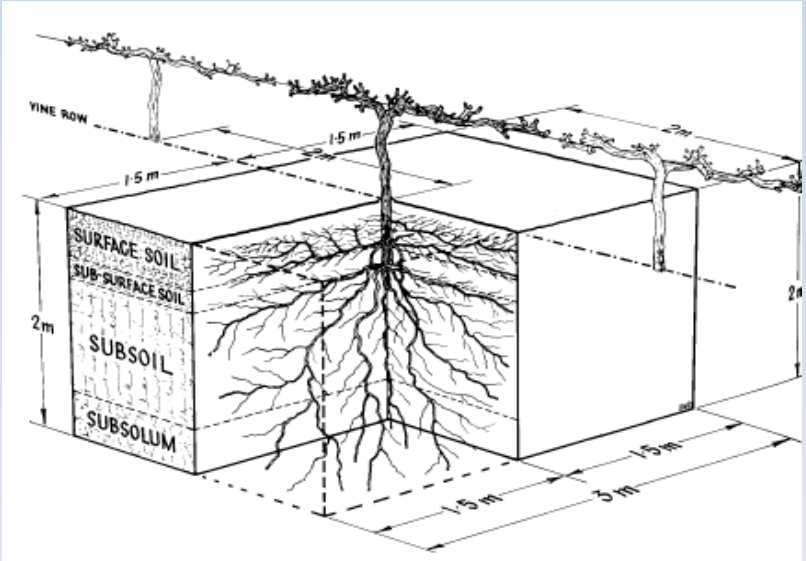




Excessive Vigor


Drought Stress 2005
Inadequate Vigor

Vine Capacity and Vigor



- Soil depth, texture
- Water Holding Capacity
- Organic matter/Fertility

Vigor

= Rate of shoot growth

Vine Capacity

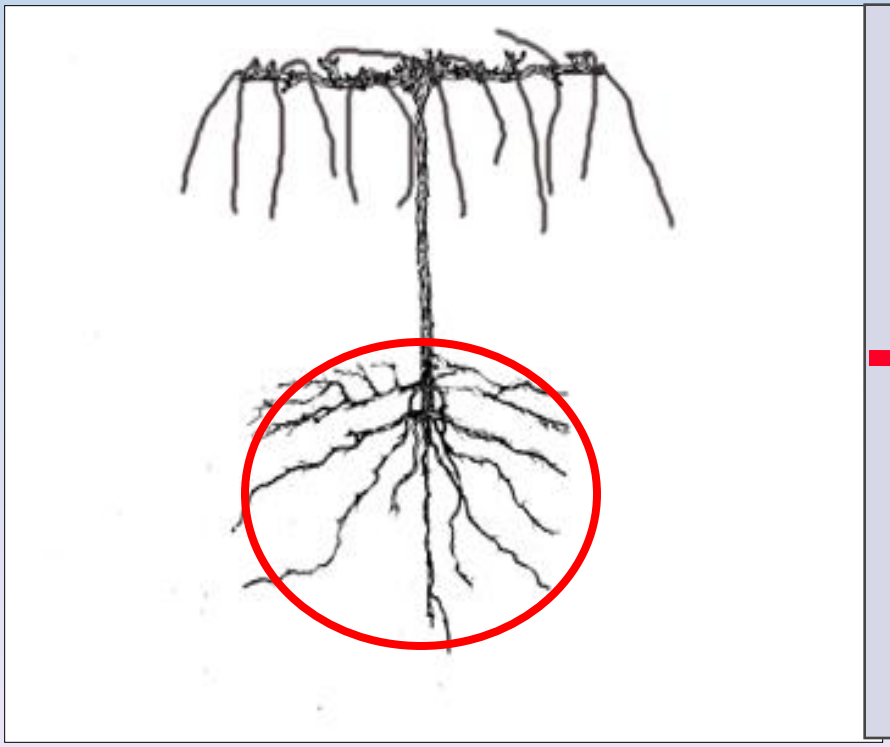
= Sustainable cropping level

Crop Load

= Ratio of exposed leaf area to crop

Diagram courtesy Terry Bates, Viticulture Research Associate
Cornell Lake Erie Research and Extension Laboratory, Portland, NY

Dormant Vine



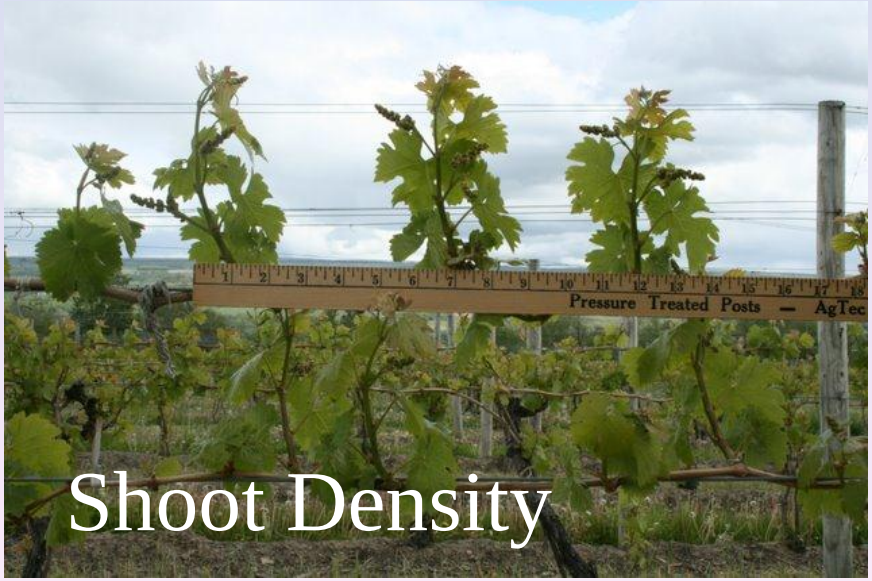
Dry Weight	Starch	N	P
41%	16%	25%	23%
59%	84%	75%	77%

Roots are the Dominant Storage Organ

Shoot Vigor

Shoot Vigor

Pruning Weight



Shoot Density


The Goal:
Balance
The
Challenge:
$$$


Long Island Merlot
2-3 T/acre $1800-2400/Ton
$25 -$40 Bottle Price
2-3 T = $3600 - $7200/acre
Growing costs: $3-4,000/acre


Finger Lakes
Cayuga White
7-8 T/acre ($500-600/T)
$10 Bottle Price
7-8 T = $3500 - $4800
Growing costs: $1,500-1,800/acre

Concord – Geneva Double Curtain

The baseline

- Weed and floor management for productivity
- Clean, disease-free grapes for quality
- Balanced cropping and fruit exposure

Weed control during Vineyard Establishment


Excellent Site Preparation


Grow Tubes


Seeded Cover Crop


Cultivation

Weeds during Establishment

Cost of delaying crop by 1 year

Actual Year	Income	Accumulated Income or (Expense)	Income	Accumulated Income or (Expense)
0	$0.00	**($547.47)**	**$0.00**	**($547.47)**
1	$0.00	($5,749.07)	$0.00	($5,749.07)
2	$0.00	($7,279.56)	$0.00	($7,279.56)
3	$1,500.00	($8,670.64)	$0.00	($10,170.64)
4	$3,000.00	($8,399.80)	$1,500.00	($11,399.80)
5	$3,500.00	($7,318.68)	$3,500.00	($10,318.68)
6	$3,500.00	($6,172.97)	$3,500.00	($9,172.97)
7	$3,500.00	($4,935.96)	$3,500.00	($7,935.96)
8	$3,500.00	($3,647.29)	$3,500.00	($6,647.29)
9	$3,500.00	($2,258.75)	$3,500.00	($5,258.75)
10	$3,500.00	($809.44)	$3,500.00	($3,809.44)
11	$3,500.00	$749.37	$3,500.00	($2,250.63)
12	$3,500.00	$2,389.98	$3,500.00	($610.02)

Adapted from Domoto 2007, *Cost of Establishing A Vineyard – High Cordon, Iowa State University.*
http://www.agmrc.org/agmrc/commodity/fruits/wine/wineryfeasibility.htm

2. Be timely with disease management

- You need to produce clean fruit to produce quality wine.

- You need healthy foliage to ripen grapes and create vine reserves to carry your vines into the next growing season.

Cluster Infections

- Total crop loss on infected clusters
- Small amounts reduce wine quality

  Powdery mildew < 2% detectable in wines

Remedy:

- Fungicide coverage through 4-6 wk after bloom
- Most critical: immediate prebloom and postbloom.
- Timely spray intervals!
- Good Canopy Management – Exposed Clusters

Disease Management- Foliage

Late Season Downy Mildew Defoliation

Canopy Management:

One Component of Cropping System

- Vineyard design (spacing, rootstocks, etc)
- Choice of Training System
- Pruning intensity
- Canopy and Crop Management
  - Shoot Number
  - Cluster Number
  - Berry Number
  - Leaf Removal
  - Shoot Tipping
  - Shoot Positioning

Yield components

Leaf Area/Light Environ.

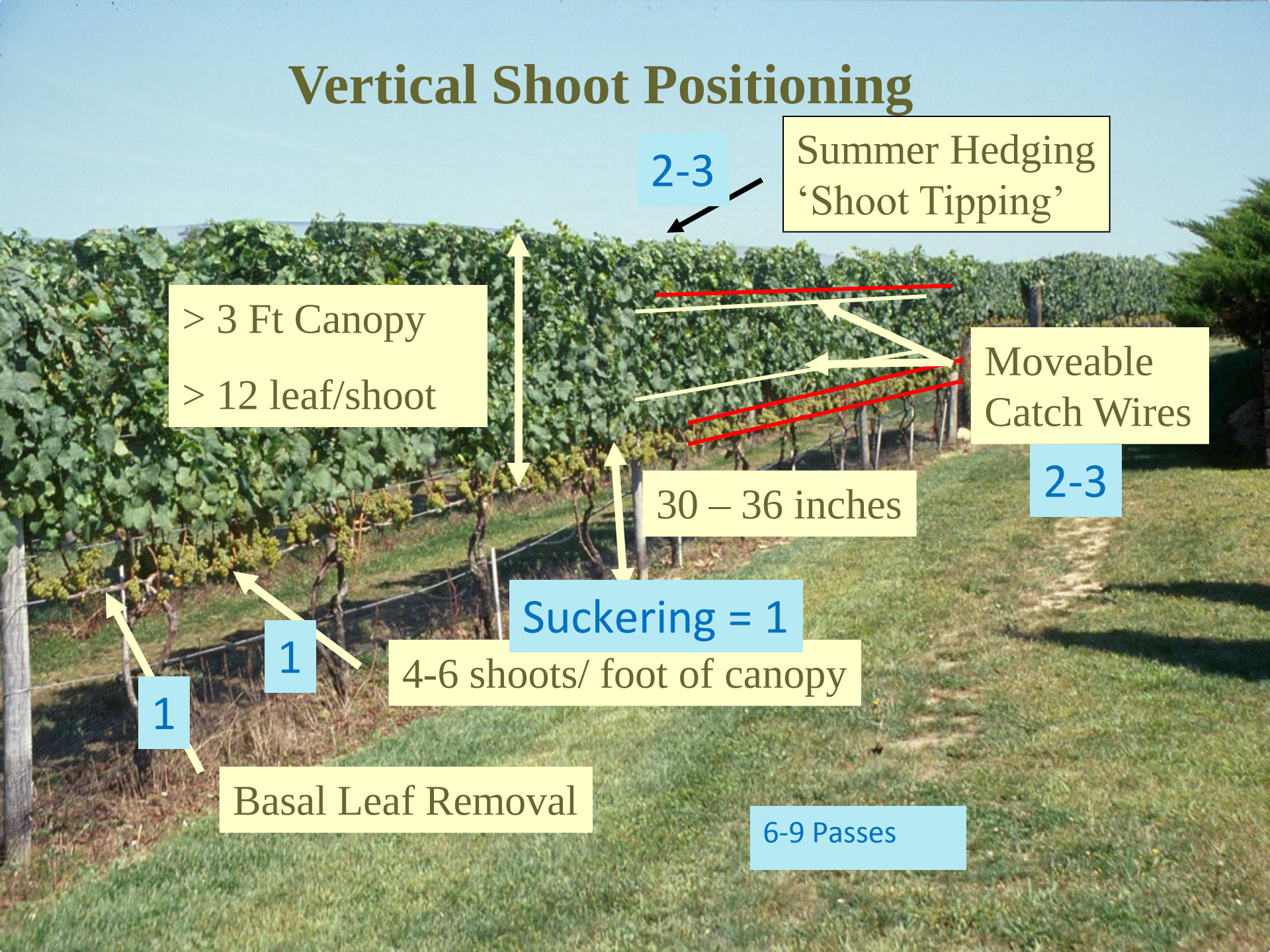
The best canopy management is no canopy management

When possible

- Canopy management costs money
- Canopy management often reduces yield
- Payoff: increased quality or marketability

Inputs:	Output:
Labor	Riper Fruit, Better Wine
Potential Crop	'Willingness to Pay'

Vertical Shoot Positioning

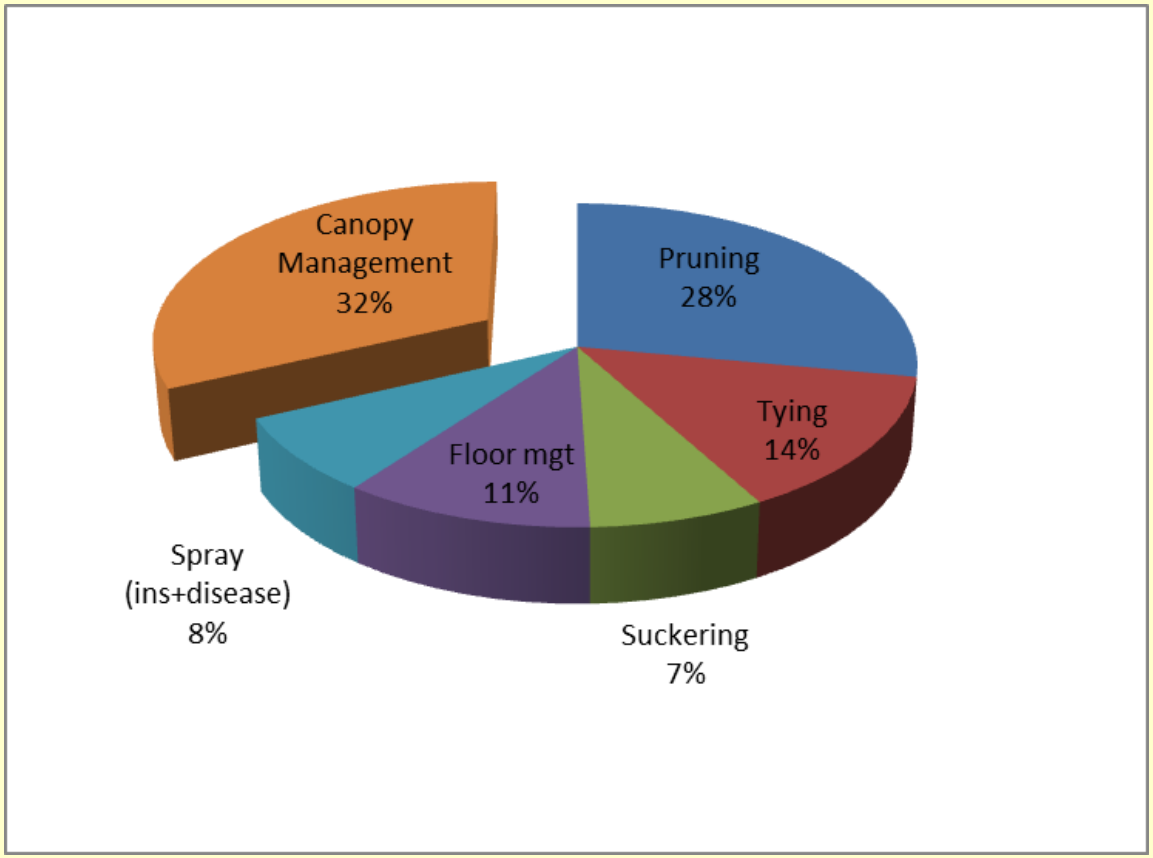


Labor Hours /Acre

Total = 93

Canopy Management
- Shoot thinning
- Shoot positioning
- Cluster thinning
- Leaf removal (mech)
- Summer hedging

Harvest not included
- Machine = 240/acre



Shoot and cluster thinning for hybrids

Foch - unthinned

Foch - thinned

- How much does it cost?
  - Time
  - Crop
- What are the benefits?
  - Ripeness
  - WTP

Grower Demo Blocks

Leon Millot
Vignoles
Traminette
Vidal blanc
Noiret

Shoot thinning Costs

TIME

15 sec/vine

6x9 spacing = 806 vines/acre

202 min/acre = 3.35 hours/acre

X $15/hour = $50.38

CROP

Cabernet Franc @ $1500/T

0.5 T/acre removed

$750 lower receipts

Need: $800.38/acre more in 'quality'

Shoot thinning Costs

Vineyard Layout		Labor time and Cost (@$15/h) for Shoot thinning							
		15 sec/vine		20 sec/vine		30 sec/vine		40 Sec/vine	
Vine spacing	Vines per acre	Hr	$	Hr	$	Hr	$	Hr	$
4x9	1210	5.0	$76	6.7	$101	10.1	$151	13.4	$202
5x9	968	4.0	$61	5.4	$81	8.1	$121	10.8	$161
6x9	807	3.4	$50	4.5	$67	6.7	$101	9.0	$134
7x9	691	2.9	$43	3.8	$58	5.8	$86	7.7	$115
8x9	605	2.5	$38	3.4	$50	5.0	$76	6.7	$101

Other hand labor operations

Pruning/brush pulling: 27H

Tying: 13H

Suckering: 7 H

Cluster thin: 10 H

Other Canopy Mgt (VSP)

Shoot Positioning 2x = 12 H

Leaf removal = 4.5 H

Source: J. White 'Cost of Establishment of *V. vinifera* in Finger Lakes 2010'

Late Shoot Thinning

Grower Demos -Shoot Thinning

0.5-3.3 T/acre

18-42 sec/vine

$450 - $1650

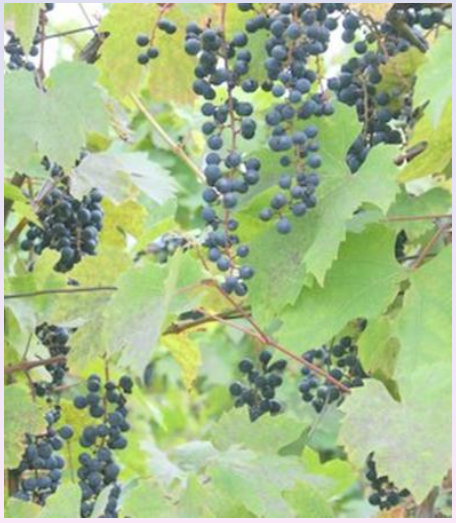
Variety	Yield (T/acre)			Shoots/foot of Row		Hand Thinning Time cost			Gross Receipts to Grower				Extra revenues needed to compensate for Thinning	
	No Thin	Thin	Diff.	No Thin	Thin	Sec per vine	Hr per Acre	$ per Acre @$15	Price per Ton	No thin	Thin	Difference	Extra price/ton	Extra cost per bottle
Chardonnay	3.8	3.2	-0.6	4.4	3.6	-	-	-	$1,200	$4,554	$3,825	-$729	$229	$0.32
Vignoles	11.5	8.2	-3.3	8.5	6.1	22	4.9	$74	$500	$5,770	$4,116	-$1,654	$210	$0.29
Leon Millot	3.5	2.5	-1.0	11.0	7.0	37	6.8	$102	$500	$1,735	$1,235	-$500	$244	$0.34
Traminette	7.3	6.4	-0.9	4.4	3.6	18	4	$61	$500	$3,636	$3,178	-$458	$82	$0.11
Noiret	-	-	-	5.8	4.8	18	3	$45	$500	-	-	-	-	-
Riesling	4.7	3.9	-0.8	5.5	4.8	-	-	-	$1300	$6,110	$5,057	-$1,053	$271	$0.38
Vidal blanc	11	9.9	-1.1	7.1	4.6	-	-	-	$500	$5,481	$4,943	-$538	$54	$0.08
Riesling (ST and LR)	6.8	6.3	-0.5	7.6	6.0	42	11.2	$169		340	$8,190	-$650	$130	$0.18

0.5-1.3 brix

Fruit Quality

Variety	Berry Weight			Brix			TA		pH	
	Unth	Th	Dif	Unth	Th	Dif	unth	thin	unth	th
Chardonnay	1.63	1.64	0.01	19.9	20.0	0.1	9.7	10.6	3.25	3.16
Vignoles	1.51	1.59	0.08	19.9	20.9	1.0	6.7	6.9	3.30	3.27
Leon Millot	0.87	0.94	0.07	22.2	22.2	0.0	15.9	15.0	3.10	3.13
Traminette	1.90	1.85	-0.05	17.0	18.0	1.0	6.5	6.3	3.06	3.07
Noiret	2.22	2.30	0.08	15.1	15.6	0.5	9.7	9.6	3.16	3.23
Riesling	1.74	1.75	0.01	17.7	19.0	1.3	7.1	7.1	3.18	3.15
Vidal blanc	1.54	1.58	0.04	14.4	15.0	0.6	5.7	5.9	3.22	3.20

Leon Millot Shoot Thinning



Leon Millot Shoot Thinning

Thinned vs Unthinned 'Leon Millot' at Goldman Vineyards

Treatment	Unthinned	Thinned	% reduction or increase
Shoots per vine	44.7	28.6	-37%
Clusters per vine	105	56	-47%
Crop wt per vine(lb)	5.10	3.63	-29%
Tons per acre	4.0	2.8	-29%
Cluster Weight (g)	22.9	30.0	+31%
Berry weight (g)	0.78	0.91	+17%
Berries per cluster	29.4	32.8	+11%

Fruit Chemistry

treatment	Berry Weight (g)	Brix	pH	TA
Thinned	0.914	22.6	3.26	15.1
Unthinned	0.779	21.1	3.28	15.3

Shoot thinning Time: 18 second/vine
968 vines per acre

Grower's costs and returns

Leon Millot

At $800 per ton:

Treatment	Yield	Crop value
Unthinned	4	$3,200.00
Thinned	2.8	$2,240.00
Difference	1.2	$ 960.00
Cost of thinning		$53.24
Total cost		$1,013.24

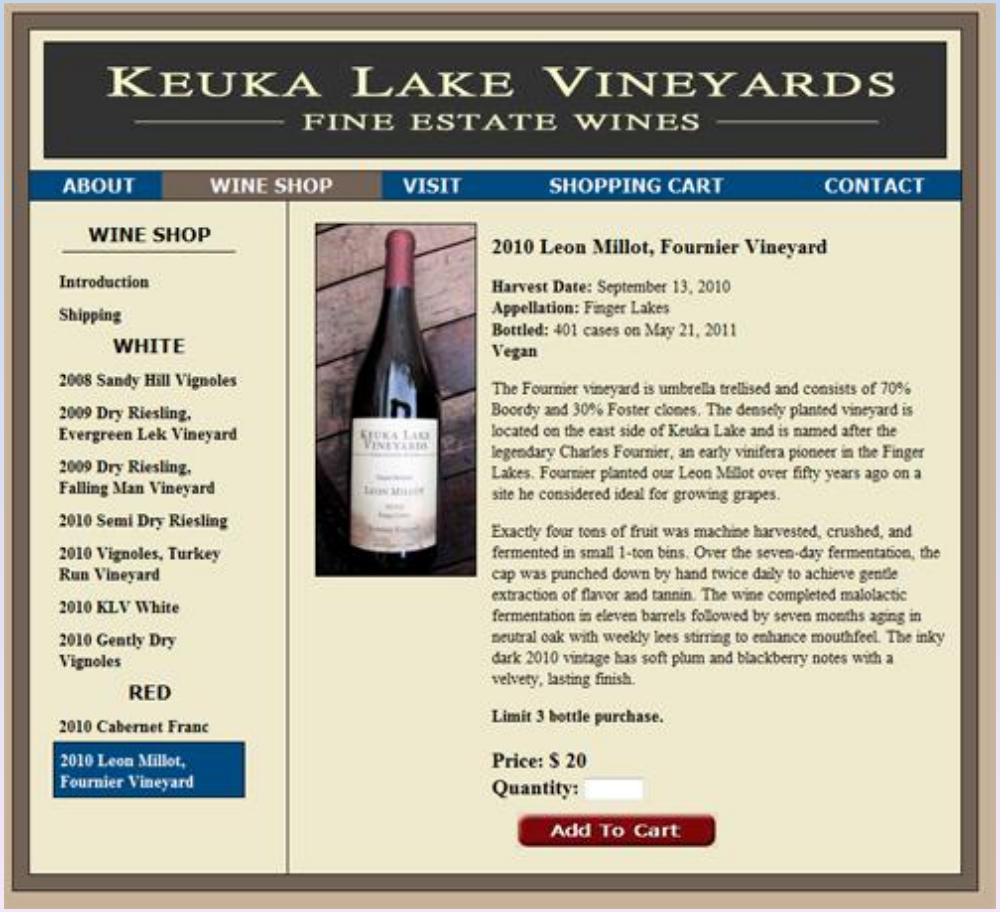
Cost of thinning	
Vines per acre	968
Seconds/vine	18
Time thin hr	4.8
Cost at $11/hour	$53

To maintain net returns, Grower needs to be paid $1162/ton

To maintain net returns, Winery needs to add $0.50/bottle to price

Dollars (Unthinned)

$20/bottle retail



1.1 T less fruit/acre
X 63 cases/ton
X 12 bottles
= 831 bottles

= $16,620 lower gross receipts

Thinned price = $27.50/bottle (approx)

Traminette Shoot Thinning

Treatment	Thinned	Unthinned	% change
Shoots	36.85	51.2	-28%
Clusters	45.8	63.3	-28%
Cluster wt	155.9	129.2	21%
Tons/acre	6.3	7.3	-13%

Grower's costs and returns

At $600 per ton:

Treatment	Yield	Value @$600
Unthinned	7.3	$ 4,351
Thinned	6.3	$ 3,804
Difference	1	$ 547
Cost of thinning		$ 42
Loss		$ 589

Cost of thinning	
Vines per acre	805
Seconds/vine	17
Time thin hr	3.8
Cost at $11/hour	$42

To maintain net returns, Grower needs to be paid $691/ton

To maintain net returns, Winery needs to add $0.13/bottle to price

Cornell University

Shoot thinning, harvest date Marechal Foch 2007

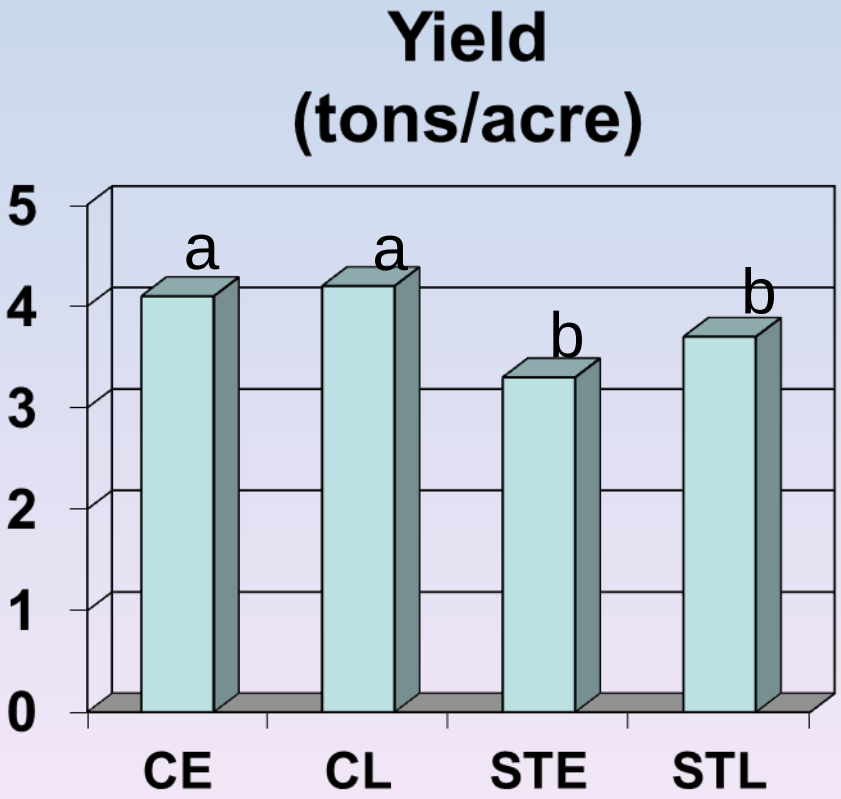
Control

Shoot-thinned

Early harvest: Sept. 11

Late harvest: Sept. 18

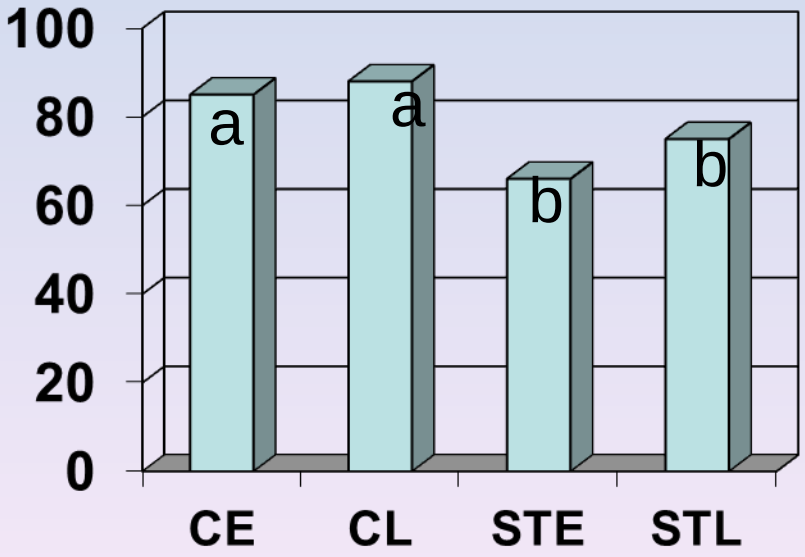
Foch



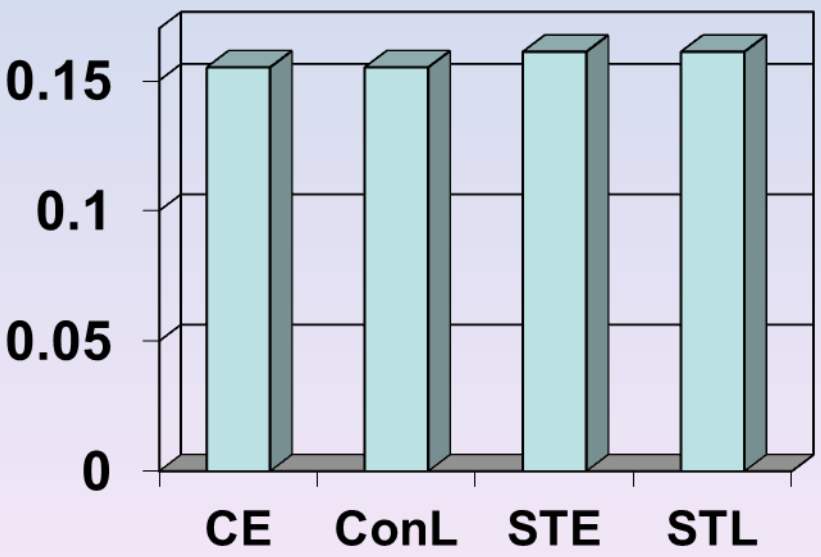
CE = control, early harvest, CL = control, late harvest
STE = shoot thinned, early harvest, STL = shoot thinned, late harvest

Foch

Cluster number (clusters/vine)



Cluster weight (lbs)

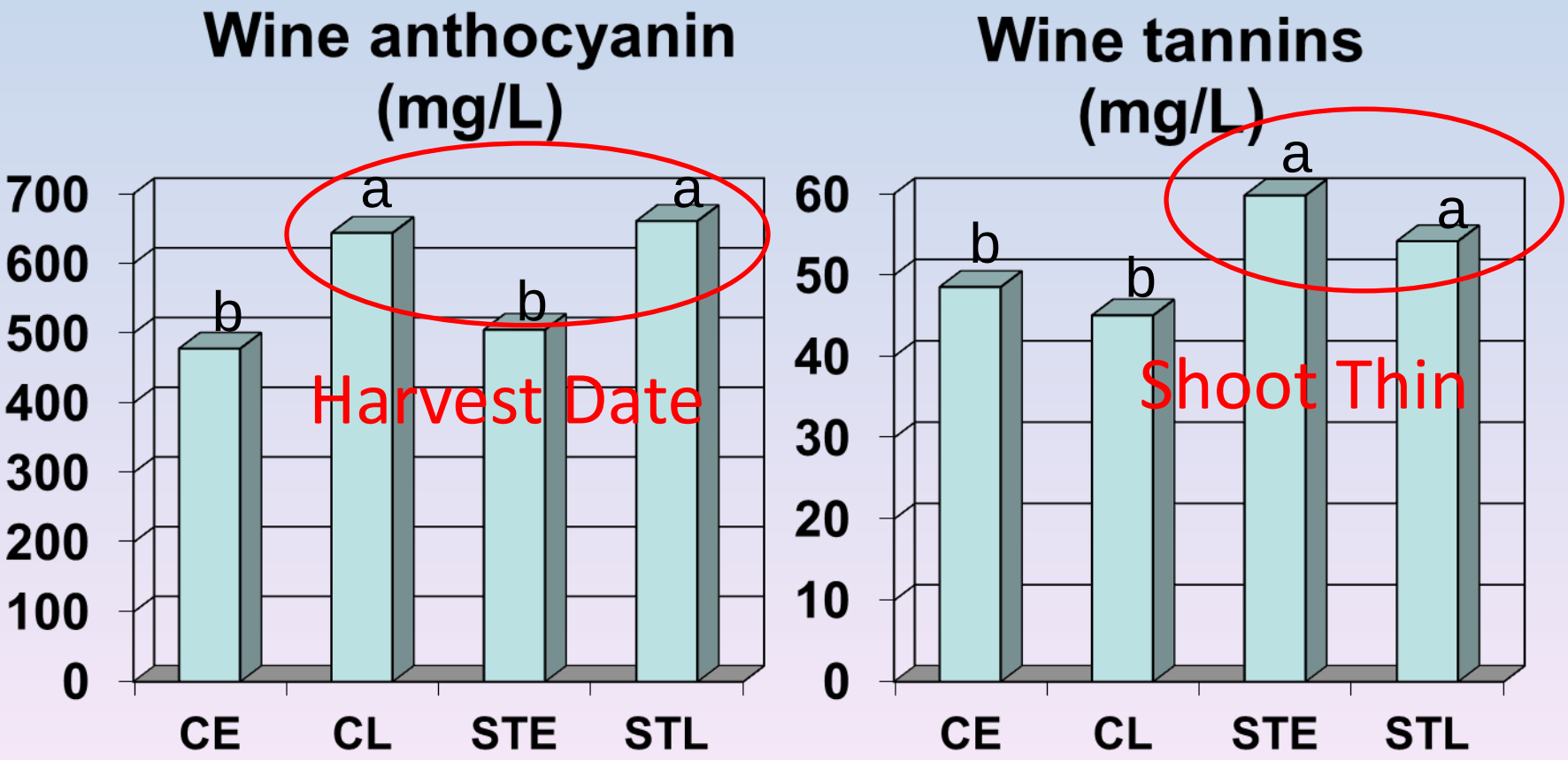


CE = control, early harvest, CL = control, late harvest
STE = shoot thinned, early harvest, STL = shoot thinned, late harvest

Foch

- Brix: 22.7 - 24.3 (harvest date only)
- pH: 3.62 - 3.70 (harvest date only)
- TA: 8.67 – 9.50 g/L (ST and harvest date)

Foch



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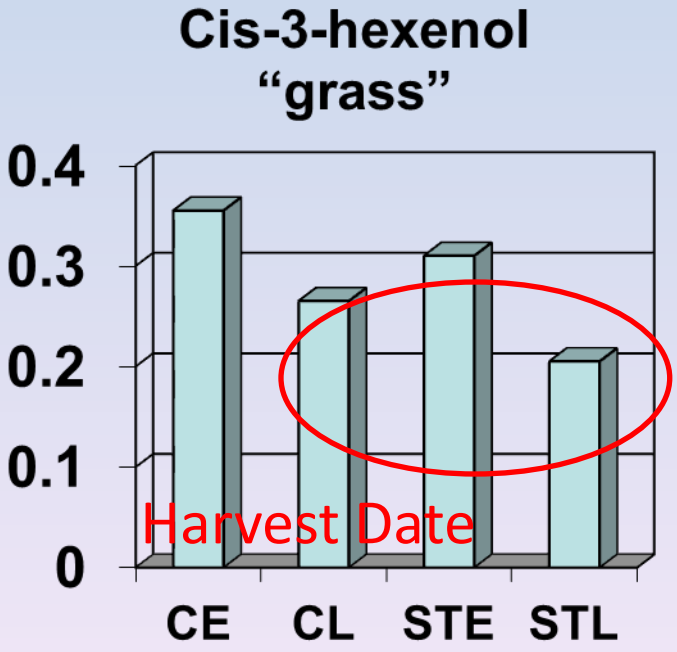
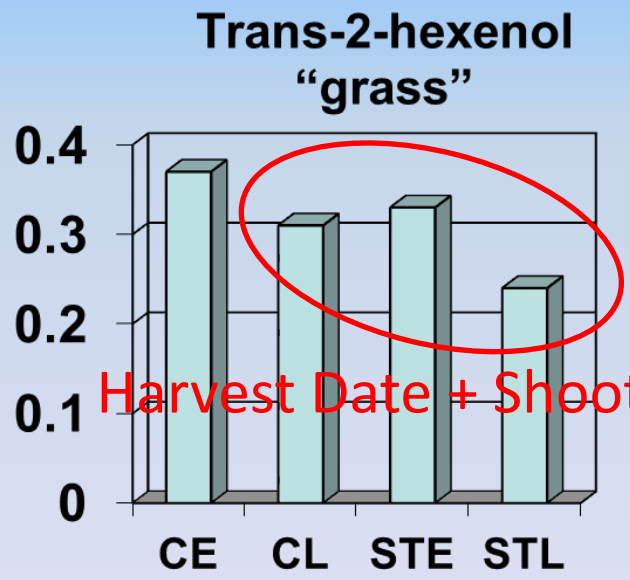
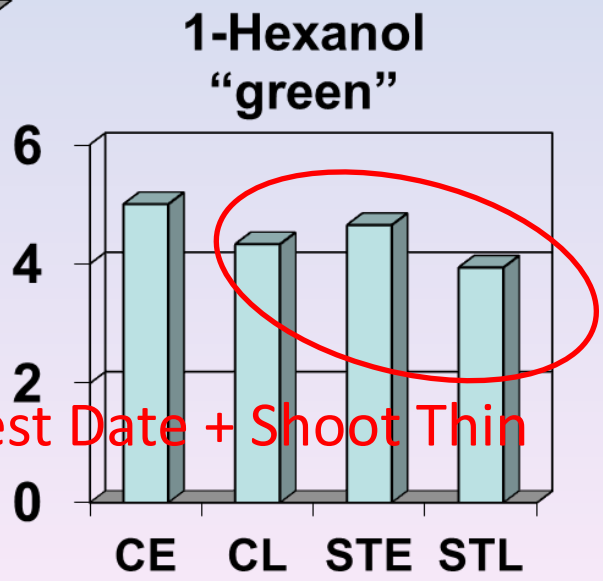
Foch



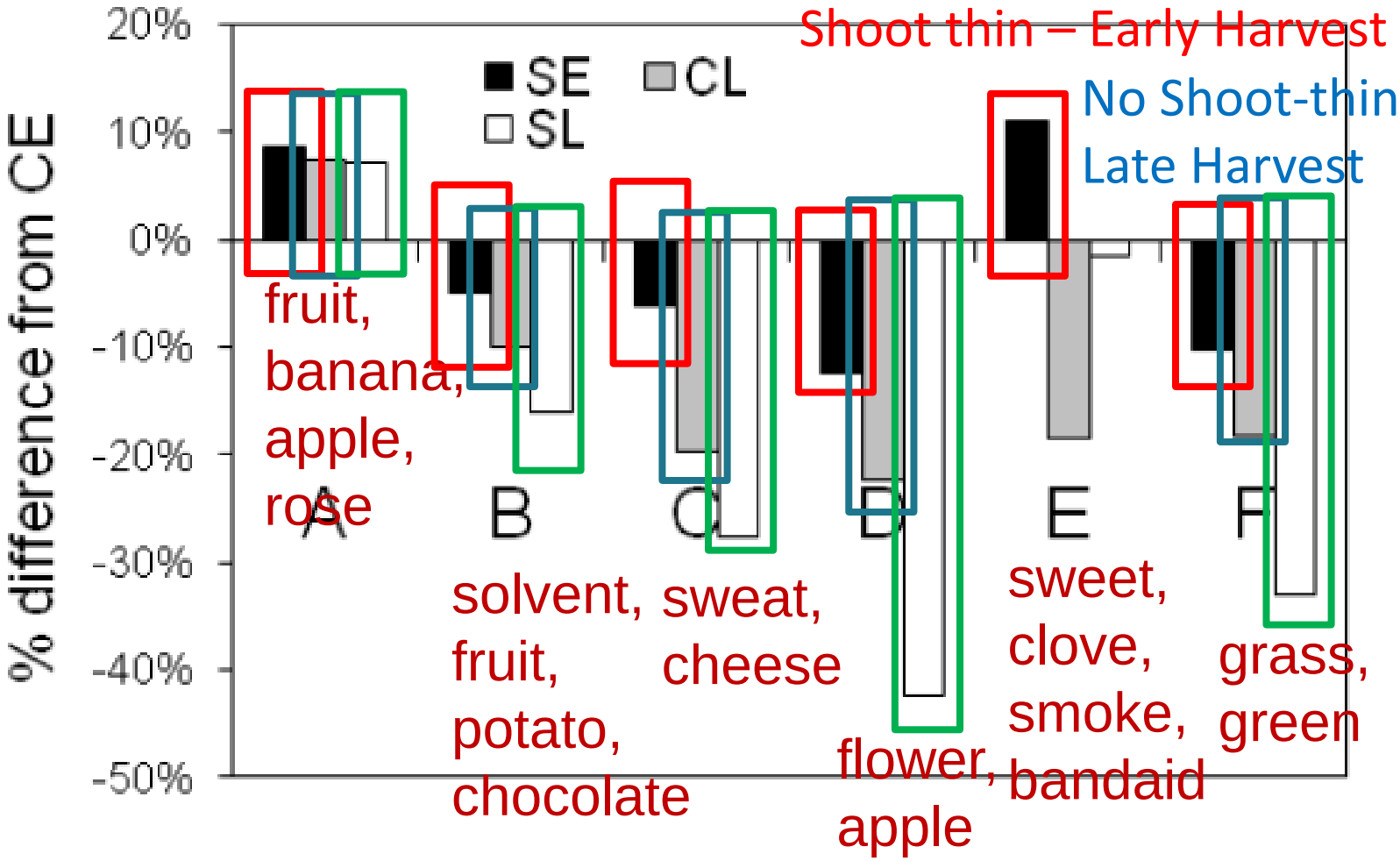




Ratio of compound peak to IS peak area

CE = control, early harvest, CL = control, late harvest
STE = shoot thinned, early harvest, STL = shoot thinned, late harvest

ST and harvest date impact Foch aroma compounds



Y-axis: Average % change in compared to the CE treatment (normalized to 0%).
A: Esters; B: Fusel alcohols; C: Fatty acids; D: Terpenoids; E: Shikimic acid derivatives; F: C_6 alcohols.

Foch
Triangle Tests

Foch Triangle Tests

- Shoot thinned late harvest preferred over Control late harvest
- Shoot thinned late harvest preferred over Shoot thinned early harvest

Maintaining revenue per acre in Foch vineyard:

	Control (2007)	ST (2007)	Control (2008)	ST (2008)
Yield (t/a)	4.1	3.3	7.0	5.3
Rev. per acre	$2,460	-	$4,662	-
Add. prod. costs/acre	$0	$54	$0	$54
Add. prod. costs/ton	$0	$16.36	$0	$10.18
Req. price/ton	$600	$761	$666	$890
Add'l Cost/Btl *(can make 60cs/ton)*	$0	$0.22	$0	0.31

Cornell University

Riesling Cluster Thinning

Cluster Thinning Affects Fruit Composition and Economic Sustainability of Riesling

(Questioning Yield/Quality Folklore with Science)

Trent Preszler & Justine Vanden Heuvel

Control: 2.5+ clusters/shoot
High: 2.0 clusters/shoot
Medium: 1.5 clusters/shoot
Low: 1.0 clusters/shoot

Low crop treatment (1CPS)

Table 2. Economic break-even analysis of cluster thinning in Riesling, 2008.

Clusters /shoot	Control (2.5+)	High (2.0)	Medium (1.5)	Low (1.0)
Cost/acre	$2,400	$2,563	$2,580	$2,595
Yield (T/A)	5.5	4.4	3.3	2.3
Price/ton	$1,750	$2,223	$2,964	$4,275
Net revenue/acre	$7,225 $7225	$7,225 (*constant welfare*) $5137	$7,225 $3195	$7,225 $1430
Add'l $/bottle *(60cs/ton)*		$0.66	$1.69	$3.51

Benefits:
Cluster and Shoot thin Flavors

J. Vanden Heuvel Sensory Evaluations

- Marechal Foch:
  - ST wine significantly different than control in 2007 by 24-member sensory panel
- Riesling Cluster Thinning
  - Sommeliers: Wines different, preference varied.
- Leon Millot (shoot thin) (side by side, informal):
  - Shoot thin + No ST 'different'
  - 60% preferred ST, 40% preferred No ST

How does this relate to $$$??

Measureable Benefits

shoot and cluster thinning

GROWER:

1. I can meet buyer (winery) specs and sell my crop (Y/N)
2. I can better control diseases
3. Easier to harvest fruit
4. Charge more for grapes (grower)

QUALITY :

1. Higher brix (= better quality?)
2. Better color, structure, tannins?
3. Reduce variability in fruit
4. Flavors better (varietal character, etc.)

Winery: I can:

1) charge more
2) Sell more
3) Market better
4) Repeat sales

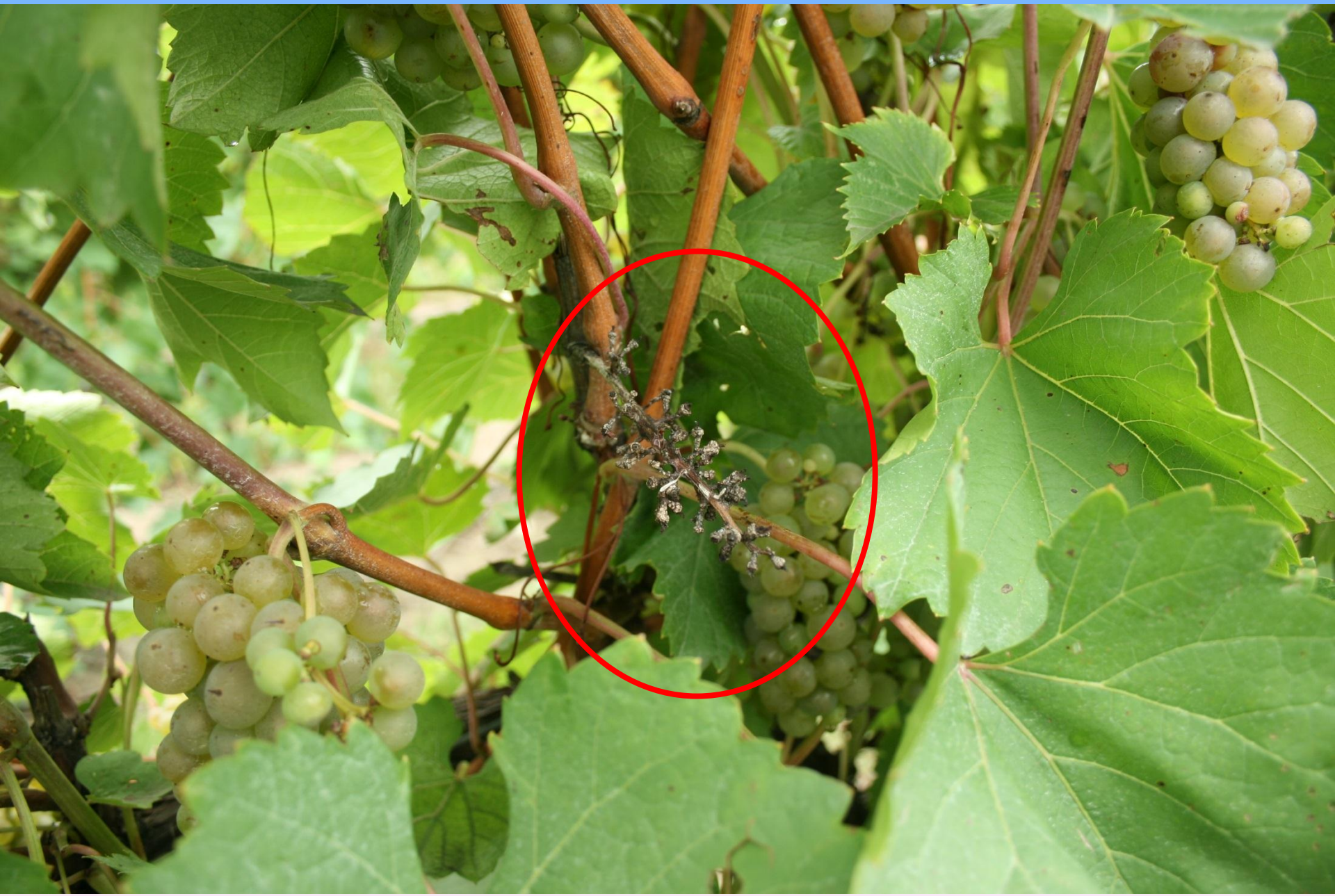
Vignoles – VSP vs Top Wire Cordon

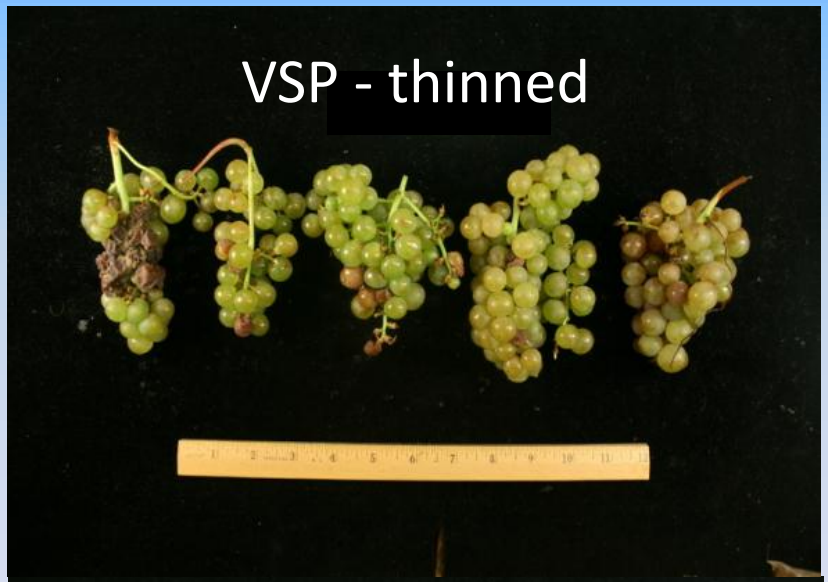
VSP – Shoot thin

VSP – No shoot thin

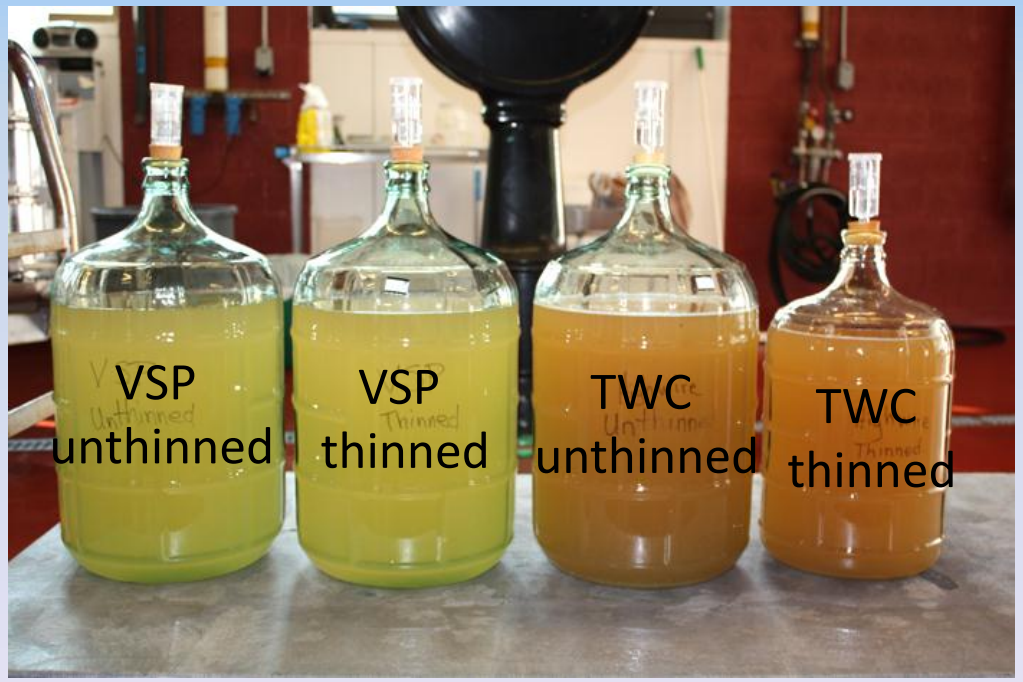
TWC – shoot thin

TWC – no shoot thin

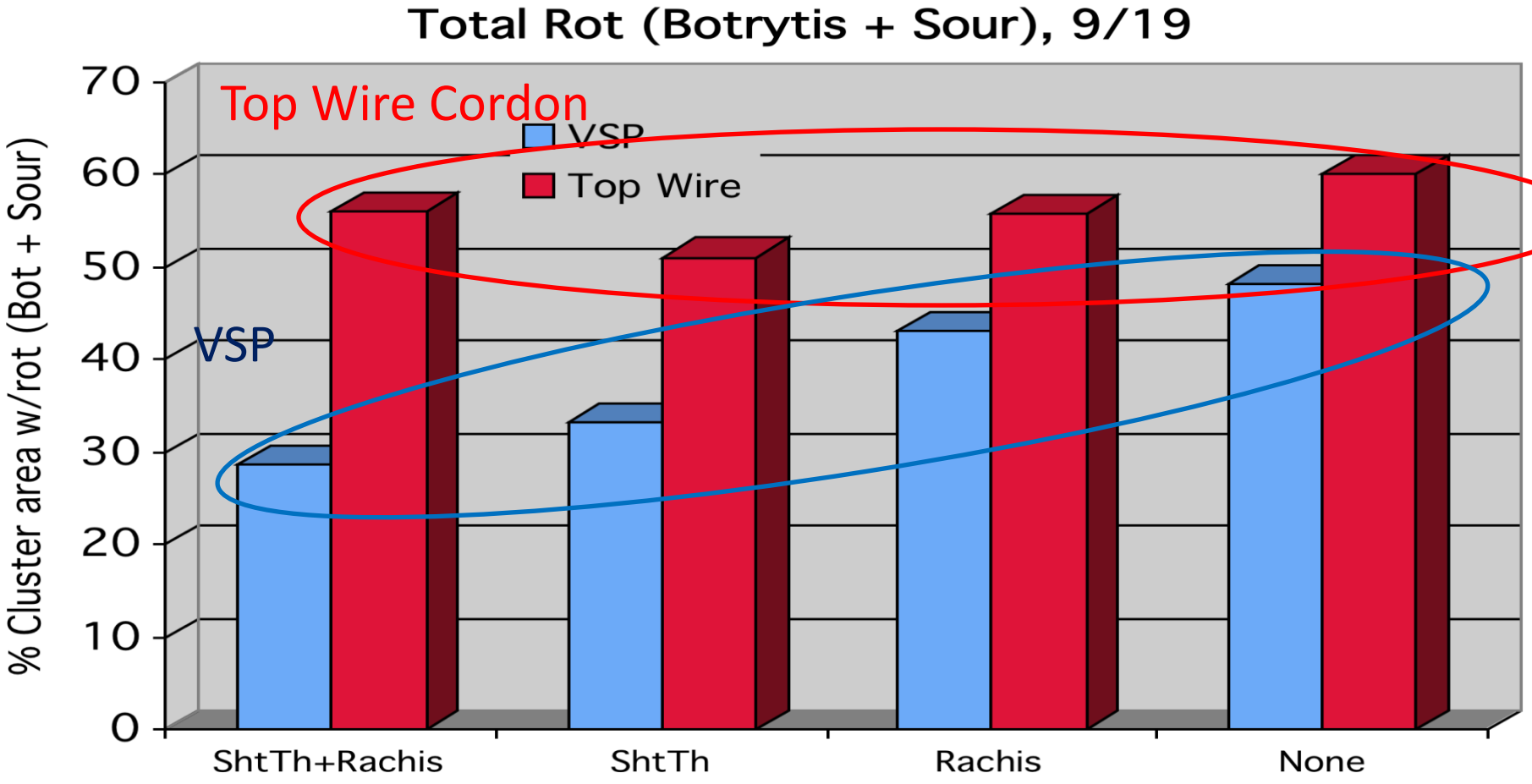



VSP - thinned


TWC - unthinned


VSP unthinned
VSP thinned
TWC unthinned
TWC thinned

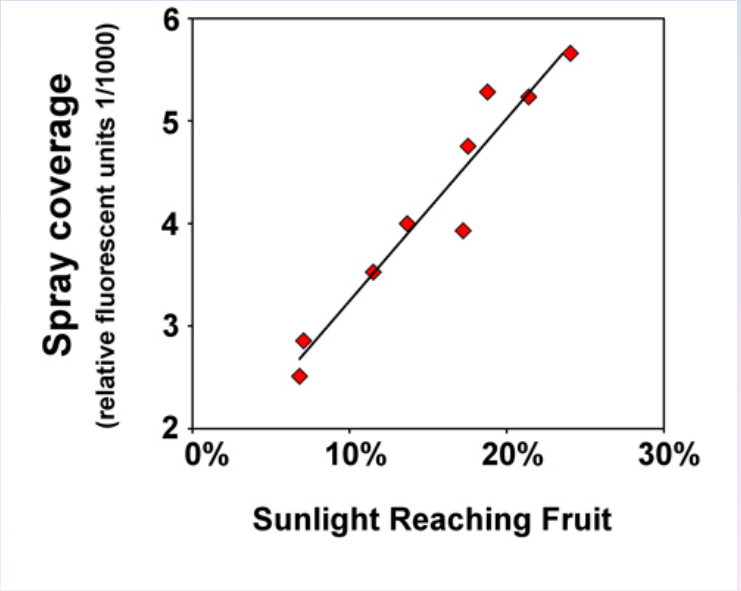
Training system and Fruit Rots



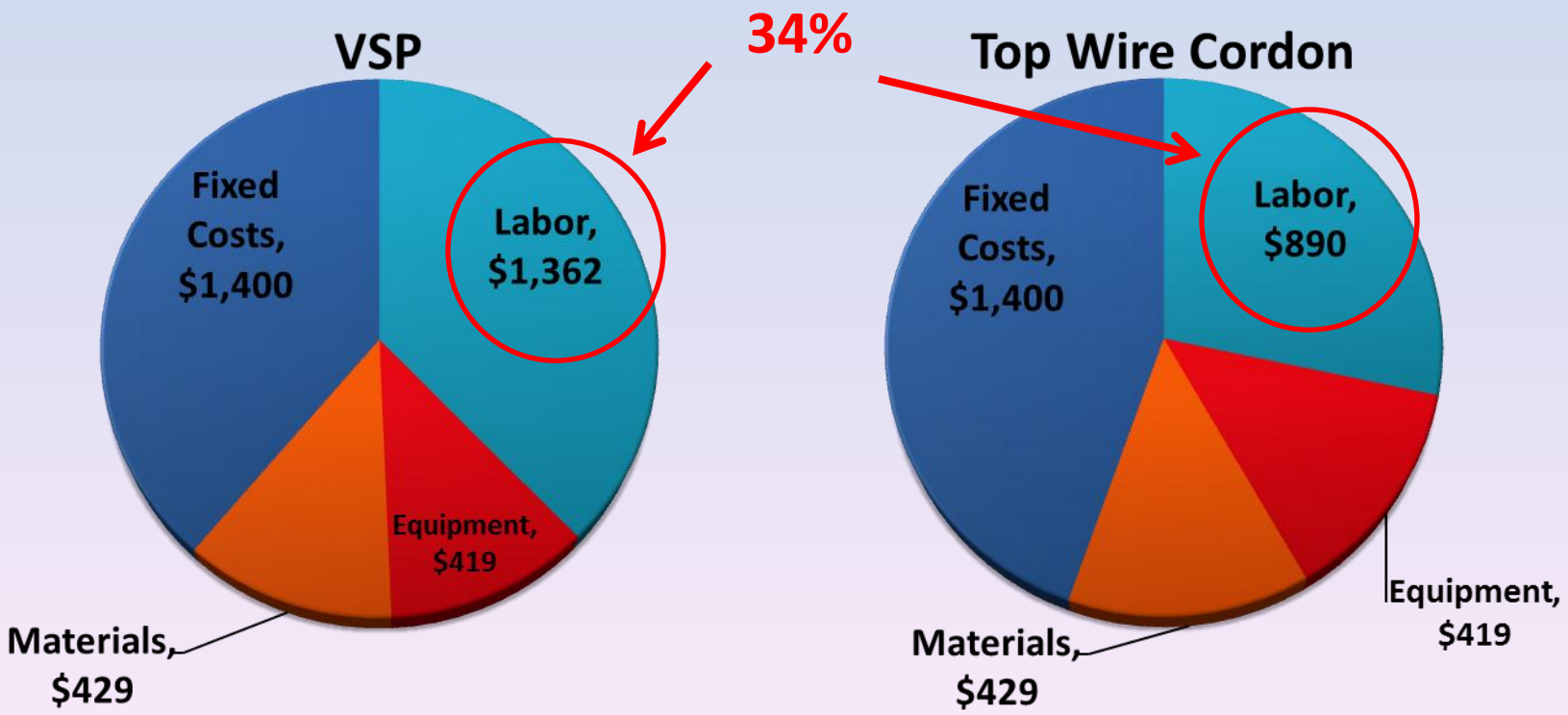
- Effects of training system and canopy manipulation were additive:
  - With no canopy manipulation (check), effect of going from TW to VSP was modest: 20% reduction in average % rot.
  - Within VSP, thinning shoots and removing rachises reduced rot by 40% relative to the check
  - Going from TW to VSP and thinning shoots + removing rachises reduced rot by 52% relative to the TW check

Spray Coverage & Cluster Exposure

- Air movement
- Drying
- Better Spray Coverage



Annual Growing Costs/Acre



Source: Gerald White 'Cost of Establishment of *V. vinifera* in Finger Lakes 2010'

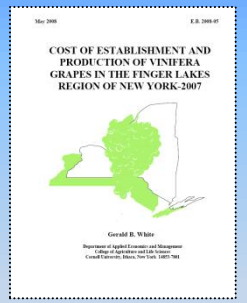
Training System and Canopy Management Costs

Cost of Establishment of V. vinifera in the Finger Lakes

Activity	Cost/acre	H/acre	Rate	Time/vine	VSP	Top Wire Cordon	Umbrella
Pruning & Brush Pulling	$ 323	27	(.40/vine)	2:00 min	x	x	x
Tying	$ 162	13	(.20/vine)	1:00 min	x		x
Suckering	$ 84	7	$12/h	0:50 min	x	x	x
Cluster/Shoot thin	$ 129	10	$12/h	1:15 min	x		
Shoot positioning #1	$ 72	6	12/h	0:45 min	x		
Shoot positioning #2	$ 72	6	12/h	0:45 min	x		
Total	$ 842	69		5:55 min	$ 842 (69h)	$ 407 (34 h)	$ 569 (57 h)

Yield and Gross Receipts

Vertical Shoot Positioning


COST OF ESTABLISHMENT AND PRODUCTION OF VINIFERA GRAPES IN THE FINGER LAKES REGION OF NEW YORK-2007

Gerald B. White

	Gross Receipts at different prices/ton						
Tons	$ 500	$ 600	$ 700	$ 800	$ 900	$ 1,000	$ 1,200
2.0	1000	1200	1400	1600	1800	2000	2400
2.5	1250	1500	1750	2000	2250	2500	3000
3.0	1500	1800	2100	2400	2700	3000	3600
3.5	1750	2100	2450	2800	3150	3500	4200
4.0	2000	2400	2800	3200	3600	4000	4800
4.5	2250	2700	3150	3600	4050	4500	5400
5.0	2500	3000	3500	4000	4500	5000	6000
5.5	2750	3300	3850	4400	4950	5500	6600
6.0	3000	3600	4200	4800	5400	6000	7200
6.5	3250	3900	4550	5200	5850	6500	7800
7.0	3500	4200	4900	5600	6300	7000	8400

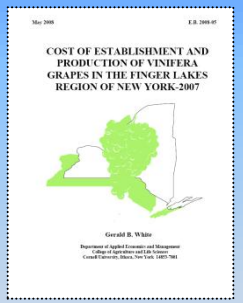
Annual Growing Costs = $2200

Fixed Costs = $1400/ Acre

Total Costs = $3600/ Acre

Yield and Gross Receipts

Top Wire Cordon



	Gross Receipts at different prices/ton						
Tons	$ 500	$ 600	$ 700	$ 800	$ 900	$ 1,000	$ 1,200
2.0	1000	1200	1400	1600	1800	2000	2400
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3.0	1500	1800	2100	2400	2700	3000	3600
3.5	1750	2100	2450	2800	3150	3500	4200
4.0	2000	2400	2800	3200	3600	4000	4800
4.5	2250	2700	3150	3600	4050	4500	5400
5.0	2500	3000	3500	4000	4500	5000	6000
5.5	2750	3300	3850	4400	4950	5500	6600
6.0	3000	3600	4200	4800	5400	6000	7200
6.5	3250	3900	4550	5200	5850	6500	7800
7.0	3500	4200	4900	5600	6300	7000	8400

Annual Growing Costs = $1750

Fixed Costs = $1400/ Acre

Total Costs = $3150/ Acre

Mechanized leaf removal

Mechanization

Canopy Management Within Crop Management

- Consider Costs and Benefits
- Undercropping as common as overcropping
- Tonnage sometimes 'trumps' 'quality gain'
- Hang as much crop as you think you can ripen
- Other practices may have equivalent impact
  - Harvest date, winemaking practices

The Northern Grapes Project is funded by the USDA's Specialty Crops Research Initiative Program of the National Institute for Food and Agriculture, Project #2011-51181-30850

USDA NIFA