Mechanization in the Vineyard

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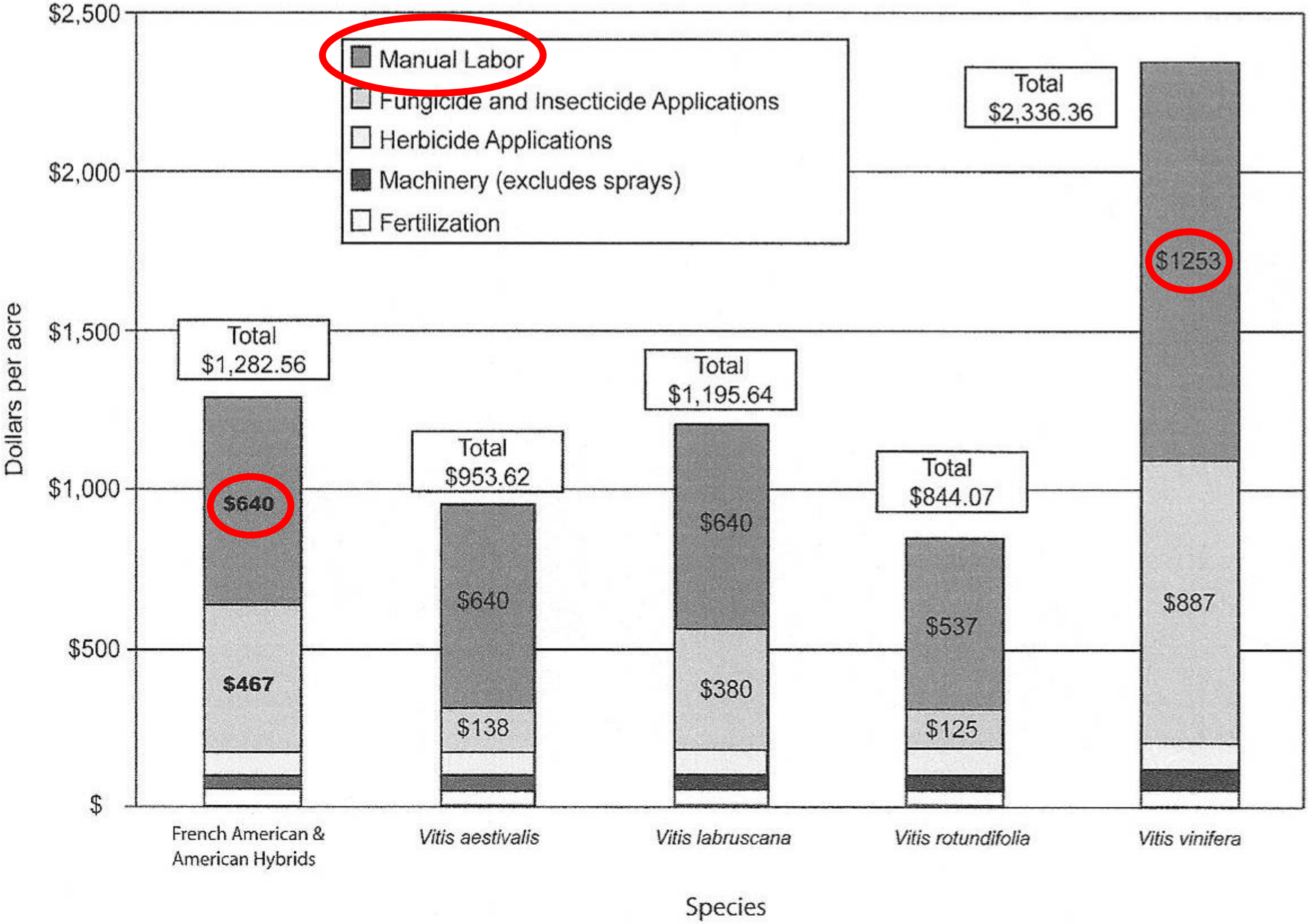
Why do we need to mechanize vineyard operations?

Labor Issues

- High cost of labor
- Availability of labor
- Quality of labor
- Grower liability
- State and Federal regulations

Figure 3. Breakdown of Pre-harvest Operating Costs for Mature Vineyards.[a]



a. Totals include interest on operating capital.

From Noguera et al., 2005

Other Reasons to Mechanize Vineyard Operations

- Increasing competition from international wine imports, with lower labor and production costs
- Lower grape prices, smaller profit margins
- Better control over your own operation

Potential Advantages of Vineyard Mechanization

- Increased yield (balanced cropping)
- Reduced risk of crop loss
- Improved fruit composition, disease incidence and wine quality
- Reduced labor costs through reduced labor requirements
- Less paperwork
- More timely completion of operations
- Improved working conditions for employees

Potential Disadvantages of Vineyard Mechanization

- Initial high investment in equipment
- Increase in management intensity is required
- Need for skilled workers
- Reduced fruit quality and wine quality
- Increased disease incidence and severity
- Loss of vine vigor over time

Efficiency Considerations

- Topography: flat or slight slope
- Rows: uniform width, straight and long
- Turning space: ample
- Trellis system: rigid and high quality
- Vineyard uniformity: High, vine size, age etc.
- Weather conditions: must be able to operate machinery at critical times

Availability of Vineyard Mechanization Implements

- Pruning
  - Mechanical pre-pruner (+ hand follow-up)
  - Fully mechanical pruner
- Trunk/cordon brushing
- Shoot thinning
- Shoot positioning
- Leaf removal
- Wire lifting
- Fruit thinning
- Harvesting

Between Row vs Over the Row Mechanization

- Row spacing
- Equipment type
- Slope
- Trellis system type

Mechanization Status of Selected Trellis Systems

- Non-divided canopy
  - Vertical shoot positioned
  - Single curtain
- Horizontally divided canopy
  - Lyre
  - Geneva double curtain
  - Quadrilateral
- Vertically divided canopy
  - Scott-Henry
  - Smart-Dyson
  - Smart-Dyson Ballerina

BALANCED CROPPING: THEORY AND PRACTICE

CROP LOSS FROM ADVERSE WEATHER CONDITONS

- Winter Injury – acclimation, mid-winter minimum, and deacclimation
- Spring Freeze Injury
- Poor Fruit Set
- Hail, Wind, etc.
- Global Warming = more extreme weather events
- Assumes Good Pest Control

VINE BALANCE

Crop Load

Exposed Leaf Area	:	Fresh Fruit Weight
Vine Size		Yield
Light Interception		Fruit Maturation
Photosynthesis		Respiration
Carbon Assimilation		Carbon Partitioning
Energy In		Energy Out
Source		Sink
Size of Engine		Size of Load

Vineyard productivity and fruit quality are maximized when both sides of the relationship are measured and managed

Mechanized Balanced Cropping

- Balanced pruning
  - Newton Partridge
  - Nelson Shaulis
- Hand balanced cropping
  - Stan Howell
- Mechanized balanced cropping
  - Justin Morris

Balanced Cropping and Risk Management Strategy

1. Precision machine pruning with minimal hand follow-up to retain the number of nodes needed for 200% of the target yield level
2. Mechanical shoot thinning to achieve an estimated 130% of the target yield level

Balanced Cropping and Risk Management Strategy

3. Mechanical fruit thinning at the “lag phase” of berry development to adjust crop to target yield level

Result: final crop reduction is completed mid-summer, allowing the grower to compensate for freeze damage, low crop potential, poor fruit set, etc.

Mechanized Balanced Cropping of Chambourcin/Chardonel Grapevines

Dr. R. Keith Striegler
Eli. A. Bergmeier
Jackie L. Harris

Research conducted at the
University of Missouri

"Effect of Mechanical Pruning and Shoot Thinning on 'Chardonel' Grapevines"

Eli Bergmeier; M.S. candidate in Plant Science, University of Missouri
Vineyard Manager, Crown Valley Winery, Ste. Genevieve, MO

Acknowledgement: financial support for this research has been provided by the Missouri Wine and Grape Board (2007-2010) and the Viticulture Consortium-East (2008-2010)

Experiment Objectives

- Determine if mechanical pruning and shoot thinning control yield as effectively as hand performed treatments in 'Chardonel'
- Determine if mechanical pruning or shoot thinning negatively impact fruit composition or vine performance of 'Chardonel' relative to hand executed controls

Experiment Parameters

- Location: Crawford County, MO
- Soil: Union silt loam; tile drained; drip irrigated
- Spacing: 7′ x 9′ (vine x row)
- Vines: Chardonel/3309C
- Training system: high bilateral cordon with downward shoot positioning
- Experiment area: approximately 5 acres
- Experimental design: incomplete block design comparing hand and mechanical pruning and shoot thinning treatments (4 treatment combinations)
- Experimental vine population: 4 replications of 20 vine plots (80 vines per treatment combination; 320 vines total)

Data Analysis and Interpretation

- Analysis: SAS version 9.1; proc GLM for balanced parameters and proc Mixed for unbalanced parameters with Tukey correction for multiple comparisons and $\alpha=0.05$; Fisher's LSD for 2007 data with $\alpha=0.05$
- N=8 for pruning and thinning factors; N=16 for crop & shoot type factors
- Key:
  - HP: hand prune
  - MP: machine prune with hand follow-up
  - HST: hand shoot thinning
  - MST: machine shoot thinning
  - Means followed by one or more identical letters are not significantly different; n.s. = not significant
- Interactions not common; data not shown

2007 Season Notes

- April 4-8, 2007 “Easter Massacre” after near-record warmth in late March followed by four successive nights of temperatures well below freezing
- Widespread freeze damage to shoots, buds and canes in most cultivars; nearly complete count bud loss in experiment population
- Shoot thinning not performed

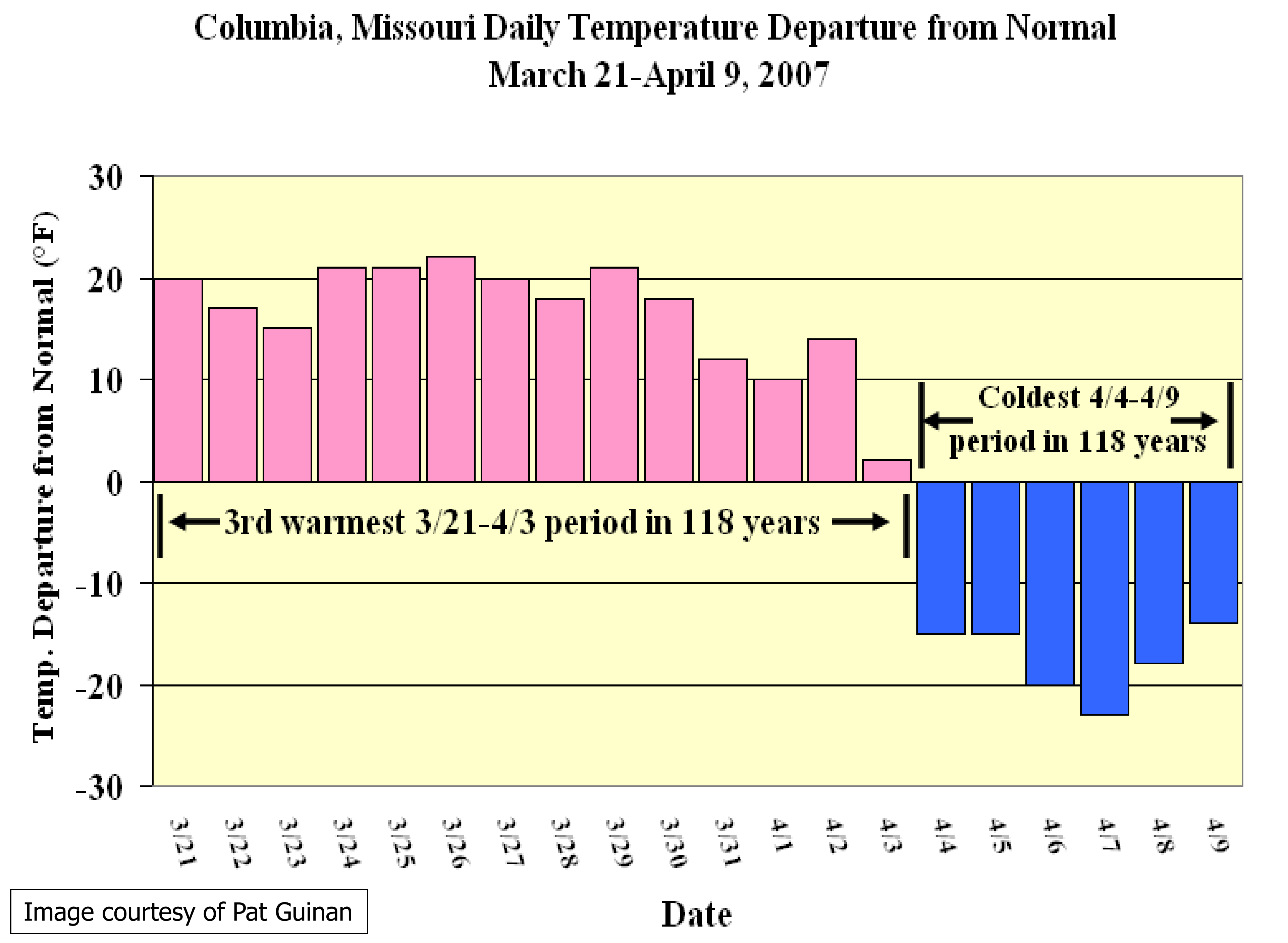

Columbia, Missouri Daily Temperature Departure from Normal
March 21-April 9, 2007
Temp. Departure from Normal (°F)
30
20
10
0
-10
-20
-30
Coldest 4/4-4/9
period in 118 years
3rd warmest 3/21-4/3 period in 118 years
3/21
3/22
3/23
3/24
3/25
3/26
3/27
3/28
3/29
3/30
3/31
4/1
4/2
4/3
4/4
4/5
4/6
4/7
4/8
4/9
Date
Image courtesy of Pat Guinan

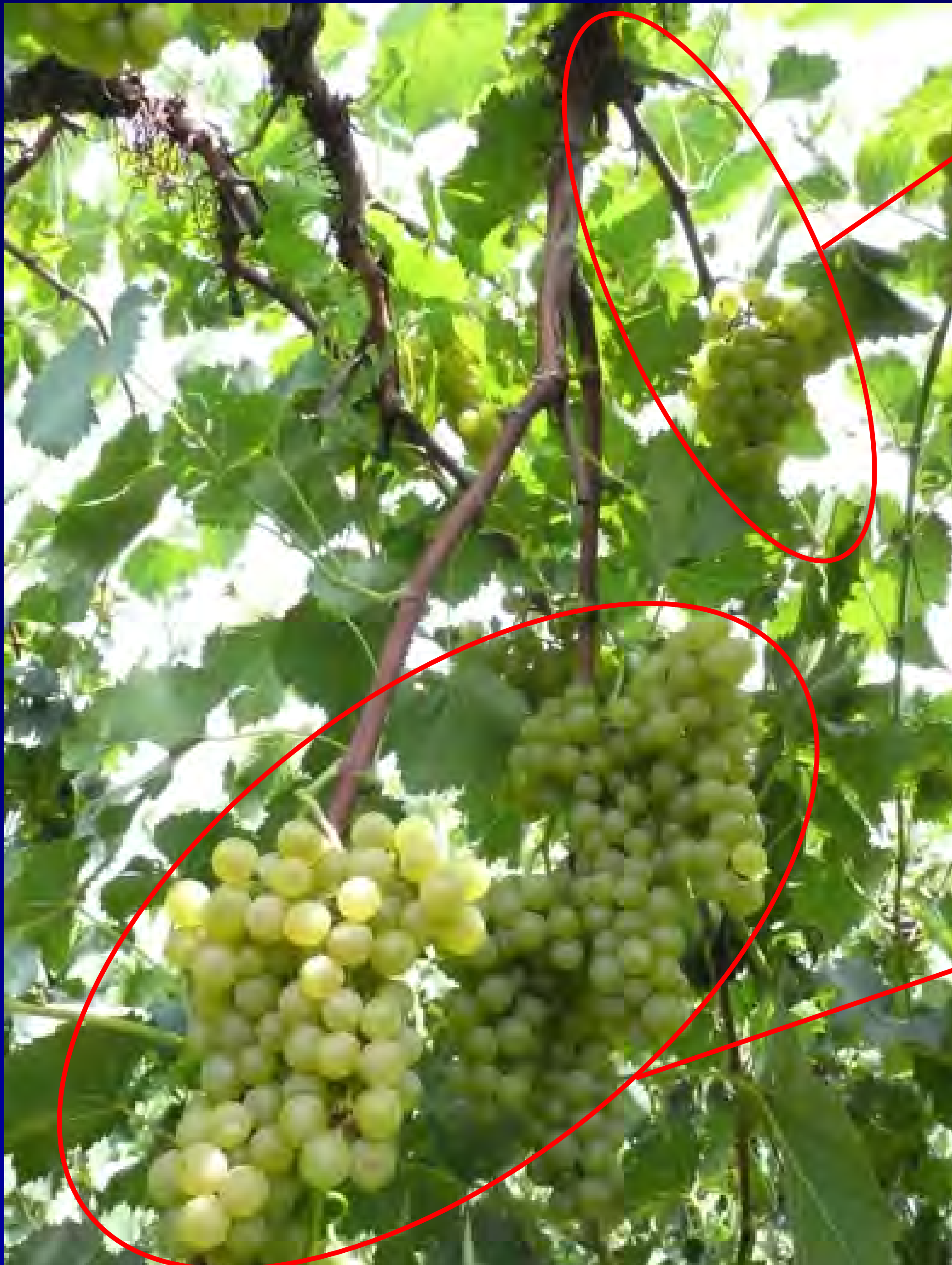
Table 1. Effect of pruning and shoot thinning method on yield and yield components; 2007.

Treatment	'06 Pruning Weight (lb./vine)		'07 Nodes Retained/ Vine		Ripe clusters per vine		Yield (tons/A)	
HP + HST	2.2	a	41	b	20.0	bc	3.0	b
HP + MST	2.0	a	35	b	17.2	c	2.4	b
MP + HST	1.7	b	98	a	33.7	a	4.4	a
MP + MST	1.6	b	98	a	25.0	b	3.0	b

Under “normal” conditions…

Table 2. Effect of hand and mechanical pruning and shoot thinning practices on yield; 2008 & 2009.

Factor	Count Yield (lb./foot)		Non-count Yield (lb./foot)		Second Crop Yield (lb./foot)		Total Yield (tons/A)		Portion of yield from lateral shoots	
2008										
Prune										
Hand	3.7	a	1.7	a	0.1	n.s	13.2	a	0.03	n.s.
Machine	3.1	b	1.2	b	0.1		10.6	b	0.02	
Thin										
Hand	3.7	a	1.6	n.s.	0.0	b	12.8	a	0.01	b
Machine	3.0	b	1.3		0.2	a	11.0	b	0.04	a
2009										
Prune										
Hand	4.0	n.s.	0.6	b	0.04	n.s.	11.4	n.s.	0.0078	n.s.
Machine	3.6		0.8	a	0.03		10.8		0.0066	
Thin										
Hand	3.8	n.s.	0.6	b	0.02	b	10.6	n.s.	0.0042	b
Machine	3.9		0.8	a	0.05	a	11.6		0.010	a



Non-count cluster; 1 cluster/shoot

Count clusters; 2 clusters/shoot


Table 3. Soluble solids (%) of Chardonel grapes farmed using hand and mechanical pruning and shoot thinning practices; 2008 & 2009.

Effect of Pruning Method			Effect of Thinning Method			Effect of Crop Type		
Method	Mean	Sig.	Method	Mean	Sig.	Type	Mean	Sig.
2008								
Hand	20.4	b	Hand	20.3	b	Count	21.1	a
Machine	20.8	a	Machine	20.8	a	Non-count	21.3	a
						Lateral	19.3	b
2009								
Hand	20.2	n.s.	Hand	20.0	n.s.	Count	21.4	a
Machine	19.8		Machine	20.0		Non-count	21.3	a
						Lateral	17.3	b

Table 4. pH of Chardonel grapes farmed using hand and mechanical pruning and shoot thinning practices; 2008 & 2009.

Effect of Pruning Method			Effect of Thinning Method			Effect of Crop Type		
Method	Mean	Sig.	Method	Mean	Sig.	Type	Mean	Sig.
2008								
Hand	3.27	n.s.	Hand	3.26	n.s.	Count	3.36	a
Machine	3.27		Machine	3.28		Non-count	3.31	b
						Lateral	3.13	c
2009								
Hand	3.06	n.s.	Hand	3.06	n.s.	Count	3.18	a
Machine	3.08		Machine	3.08		Non-count	3.14	a
						Lateral	2.90	b

Table 5. Titratable acidity (g/L) of Chardonel grapes farmed using hand and mechanical pruning and shoot thinning practices; 2008 & 2009.

Effect of Pruning Method			Effect of Thinning Method			Effect of Crop Type		
Method	Mean	Sig.	Method	Mean	Sig.	Type	Mean	Sig.
2008								
Hand	8.63	n.s.	Hand	8.88	n.s.	Count	7.64	c
Machine	8.87		Machine	8.63		Non-count	8.17	b
						Lateral	10.44	a
2009								
Hand	10.15	n.s.	Hand	10.39	n.s.	Count	8.75	b
Machine	10.29		Machine	10.05		Non-count	9.04	b
						Lateral	12.88	a

Summary

- Machine pruning produced equivalent or higher yields than hand pruning in 2007 under adverse weather conditions
- Machine pruning and shoot thinning provided yield control equivalent to or better than hand operations in 2008 & 2009
- Second crop was increased with machine shoot thinning in 2008 & 2009
- Basic fruit composition generally more effected by crop type than pruning or thinning method
- Combination of pruning and shoot thinning without fruit thinning may produce inadequate crop control

"Effect of Mechanical Pruning and Shoot Thinning on 'Chambourcin' Grapevines"

Eli Bergmeier

R. Keith Striegler

Acknowledgement: financial support for this research has been provided by the Missouri Wine and Grape Board (2008-2011), the Viticulture Consortium-East (2008-2010), and the Missouri Wine Marketing and Research Council (2010-2011)

Experiment Objectives

- Determine if mechanical pruning and shoot thinning control yield as effectively as hand performed treatments in 'Chambourcin
- Determine if mechanical pruning or shoot thinning negatively impact fruit composition or vine performance of 'Chambourcin' relative to hand executed controls

Experiment Parameters

- Location: Gasconade County, MO
- Soil: Wrengart silt loam, drip irrigated, permanent fescue cover crop
- Spacing: 8′ x 9′ (vine x row)
- Vines: Chambourcin, own-rooted
- Training system: high bilateral cordon with downward shoot positioning
- Experiment area: approximately 2 acres
- Experimental design: incomplete block design comparing hand and mechanical pruning and shoot thinning treatments (4 treatment combinations)
- Experimental vine population: 4 replications of 10 vine plots (40 vines per treatment combination; 160 vines total)

Summary

- Balanced cropping operations
  - Mechanical pre-pruning done in 2009, 2010, and 2011
  - Mechanical shoot thinning not done in 2009; done on mechanically pre-pruned vines in 2010; and done on hand pruned and mechanically pre-pruned vines in 2011.
  - Fruit thinning performed in 2009, 2010, 2011
- Use of balanced cropping allowed for attainment of consistent yield with little impact on fruit composition

BALANCED CROPPING: A CASE STUDY

- Vineyard in Southern Monterey County north of Paso Robles, CA
- Chardonnay, Cabernet Sauvigon, and Merlot
- Trellis System = VSP; 9ft. Rows
- Hand farmed vines were spur-pruned; machine farmed vines were mechanically pruned to a close box around the cordon

CHARACTERISTICS OF FREEZE EVENT

- April 18, 2011
- No inversion
- 26˚F = low temperature
- Viognier (hand farmed) severely impacted
  - 2011 - no crop
  - 2012 - 50% crop
  - 2013 – looking good now

Variety	Farming Method	2011 Tons/Ac	2012 Tons/Ac
Chardonnay	Hand	1.92	7.62
Chardonnay	Machine	3.81	7.71
Cabernet Sauvignon	Hand	1.94	6.36
Cabernet Sauvignon	Machine	5.95	8.29
Merlot	Hand	3.82	7.70
Merlot	Machine	6.43	7.68

Recent Advances in Vineyard Mechanization

Other Vineyard Mechanization Projects

1. Spatial Crop Load Measurement and Management

   Terry Bates and James Taylor: Cornell University
   Sanjiv Singh and Stephen Nuske: Carnegie Mellon University

2. Michigan State University

3. Washington State University

4. Robotic Pruning – Purdue University and Texas Tech University

In Field Sorting


oxbo
6120

MU Extension Publication:

Preparations for Successful Vineyard Mechanization

- **Eli Bergmeier**
  Viticulture Research Specialist
  Institute for Continental Climate Viticulture and Enology

- **R. Keith Striegler**
  Director and Viticulture Program Leader
  Institute for Continental Climate Viticulture and Enology

- http://extension.missouri.edu/p/WG3001

Questions?

Economics of Balanced Cropping with the Oxbo System – A Case Study

Greg T. Berg[1] and R. Keith Striegler[2]

[1]Oxbo International Corp., Kingsburg, CA
[2]University of Missouri

Study Details

- Comparison:
  - hand vs. machine-executed balanced cropping
- Cooperators: Stone Hill Winery; Hermann, MO
  - Jon Held, Owner and Nick Pehle, Vineyard Manager
- Conditions:
  - High bilateral cordon training
  - 8 X 9′ (vine X row) spacing yielding 4,840 ft cordon per planted acre

Assumptions

- All hourly wages calculated at $10.50 plus 40% benefits ($14.70/hr.)
  - Power unit and tool carrier operators, and hand laborers
- Equipment manufactured by Oxbo International Corporation, Inc.
  - Implement use as specified by Morris-Oldridge (M-O) Complete System for Vineyard Mechanization
  - Tractor-towed Oxbo 2220 tool carrier
  - Implements: two 'high-wire sprawl' pruning heads, two VSP shoot thinning heads, two force balanced shakers fruit thinning heads
  - MSRP for new, complete implement package = $121,000

Assumptions (2)

- 20% “up-charge” on mechanized operation labor for equipment set-up and adjustment, headland turns, travel time, etc.
- Power unit expenses:
  - 105 hp power unit
    - Fuel cost = $11.28/hour
    - Lubricant cost = $1.68/hour
    - Rental cost = $17.85/hour
  - 45 hp power unit (touch-up pruning)
    - Fuel cost = $5.94/hour
    - Lubricant cost = $0.89/hour
    - Rental cost = $7.65/hour

Mechanized Operation Parameters

Table 11. Critical assumptions for mechanized vineyard operations

Operation	No. of Machine Operators	No. of Data collectors	Ground-speed (mph)	Rows per Pass
Precision box pruning	3	0	0.70	2.0
Spring crop adjustment	3	2	1.50	2.0
Summer crop adjustment	2	2	1.00	1.0

Pruning Operation Assumptions

- Hand pruning
  - Without pre-pruning, required 32 labor hours per acre @ $14.70/hr = $470/acre
- Mechanical pruning + light hand follow-up
  - Mechanical prune to box 16" wide and 14-18" tall, cut as close to the top of the cordon as possible
  - Mechanical pruning: 0.65 equipment hours + 2.4 labor hours (three person crew) per acre; $65/acre
  - Hand follow-up: 3.4 equipment hours per acre + 18 labor hours (driver + 4 laborers on tractor-towed wagon); $324/acre
  - Total of 21 labor hours per acre
  - Total operation expense: $388/acre


Spring Crop Adjustment Assumptions

- Hand shoot thinning
  - Estimated to be necessary in 6 out of 10 seasons, requiring approximately 1 labor hour per 225 feet of cordon
  - Expense: 21.5 hours/acre X $14.70 = $316 X 0.60 = $190/acre annualized
- Mechanical shoot thinning
  - Required annually: after precision box pruning and hand follow-up, shoot counts averaged 10-15+ shoots per foot of row
  - Shoot counts reduced by 10-50% to reach target yields; performed optimally at 4-8 inches of growth
  - Goals were to reduce canopy density while semi-selectively removing unfruitful shoots and retaining more fruitful shoots
  - Operation expenses: 0.31 equipment hours + 1.8 labor hours for a total of $44/acre


New Holland

Summer Crop Adjustment Assumptions

- Crop reduction by fruit thinning offers a final opportunity to adjust crop load
- Hand cluster thinning
  - Estimated to be necessary in 4 out of 10 seasons, requiring approximately 1 labor hour per 225 feet of cordon
  - Expense: 21.5 hours/acre X $14.70 = $316 X 0.40 = $126/acre annualized
- Mechanical fruit thinning
  - Estimated to be necessary in 6 out of 10 seasons
  - Optimal timing for fruit thinning is during lag phase of berry development (veraison); safely remove 5-25% of crop per pass
  - Operation expense: 0.92 equipment hours + 5.5 labor hours = $61/acre annualized

Hand vs. Machine Labor Costs for this Study

Table 12. Comparison and summary results for labor requirements and variable costs for balanced cropping by hand and mechanical methods

BC Method	Pruning		Spring Crop Adjustment		Summer Crop Adjustment		Partial Budget Totals	
	Time (hours)	Cost ($)	Time (hours)	Cost ($)	Time (hours)	Cost ($)	Time (hours)	Cost ($)
HBC	33.7	470	12.9	190	8.6	126	55.2	787
MBC	20.7	388	1.5	44	2.7	61	24.9	493
Savings	*13*	*82*	*11.4*	*146*	*5.9*	*66*	*30.3*	*294*
Savings (%)	*39%*	*17%*	*89%*	*77%*	*49%*	*52%*	*55%*	*37%*

Summary

- In this study, balanced cropping by machine resulted in:
  - More consistent and predictable yields
  - Improved fruit quality
  - Reduced employee turnover rate
  - Improved employee working conditions
- For this 150 acre mechanized vineyard operation, variable production cost savings was $42,708 annually, in part by reducing seasonal labor by 4,251 hours