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Economic analysis of the financial impact of the grape leafroll virus (GLRV) in the Finger Lakes region of New York

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1. Executive summary

Leafroll is one of the most important virus diseases of grapevines worldwide, reducing the yield and quality of grapes. The present study is aimed at quantifying the cost impact of the grape leafroll virus (GLRV) and identifying the best disease management options under several scenarios of reduced yield and quality.

The costs associated with the absence of response to the GLRV ranged from $9,695 (for a 30% reduction in yield and no quality penalty) to $16,014 per acre (case of 50% reduction in yield and 10% penalty). This cost impact was lowered to a range of $547-$9,336 (for GLRV incidences 1- 27%) through roguing[1] and $9,384 through vineyard replacement (GLRV incidences above 27%). Using certified vines at planting limited the costs of vine-transmitted GLRV to $740.

Roguing turned out to be the appropriate management method if the GLRV incidence is below 27%. Above that level, replacement was found to be the best option. However, there were two cases where 'no intervention' was the best management practice. The first is the case where yield reduction is less than 30%, GLRV incidences greater than 27% and no price penalty is enforced. The second is a situation of a vector transmitted infection happening beyond year 19. Beyond that age, roguing did not have a positive impact on the Net Present Value (NPV), suggesting no intervention in that case as well.

[1] Roguing consists of removing infected vines and replacing them with new ones

2. Introduction

This study was undertaken with the objective to assist grape growers and wine makers of the Finger Lakes region of New York in their decision making process for the optimal management of leafroll disease, through net present value scenarios.

Specifically, it is aimed at comparing the NPV of not managing the disease at all, roguing (removing infected vines and replacing them with new vines) and replacing the vineyard in order to (1) quantify the costs involved under several scenarios and (2) identify the economically most appropriate options given the GLRV incidence, the level of fruit yield reduction, the penalty imposed on low grape quality, and the vineyard age.

3. Project background

Leafroll is one of the most important virus diseases of grapevines worldwide because of its capability of affecting all cultivars and rootstocks (Martelli and Boudon-Padieu, 2006). Affected vines are less vigorous than healthy ones and have a marked reduction in fruit yield (up to 30 to 50% or more) and quality (reduced sugar content and increased acidity in fruit juice). This effect is well documented in Finger Lakes vineyards (Martinson et al., 2008) but no information on the budgeted costs of leafroll disease is available. The aim of the present study is to complement available information on the biology and physiology of the disease by assessing the economic impact it has on growing *Vinifera* grapes in the Finger Lakes.

4. Methodology

The study consisted of a questionnaire administered to the vineyard managers in the Finger Lakes and aimed at identifying the range of GLRV incidence and magnitudes of yield reduction, the management options adopted, and the quality penalties incurred. This information is then used in the financial analysis to construct disease response scenarios.

a. Questionnaire

A guided questionnaire was conducted in 2009-2010 with ten vertically integrated[2] wineries of the Finger Lakes region of New York State, located around Cayuga and Seneca lakes. Those wineries were identified previously as having leafroll-like symptoms in their vineyards. Vineyard managers were interviewed either personally or by phone. They were mainly asked about the incidence of GLRV, the impact the virus had on their yield and the quality of their grapes and wines and finally whether and how they reacted to the virus infection (see the questionnaire in appendix 1).

Their answers were used to identify the parameters to be analyzed in the present study. The *first* is the GLRV incidence; the surveyed vineyards reported approximately 1, 5 and 40% levels of infection introduced through infected vines at the time of planting.

[2] Wineries that source their grapes partially or completely from their own vineyards

However, disease transmission could have also been mediated by insect vectors (soft scale and mealy bug species) that were reported to be present in vineyards of the Finger Lakes and capable of transmitting the virus (Fuchs, 2009). The *second* parameter identified in the questionnaire and used to formulate scenarios for the study is the management response to the infection. Vineyard managers either did not respond to the GLRV, or responded by roguing (removing and replacing the infected vines), or by replacing the vineyard. The *third* parameter is the impact of the GLRV on the yield and the quality of grapes and ultimately the price paid for those grapes. None of the interviewed wineries perceived or measured a reduction in yield. Only two out of the ten perceived a decrease in the grape quality measured as a reduction in the sugar level and an increase in the acidity. One winery reported imposing a 10% penalty on grapes having a low sugar level. Another winery reported having had to pay such a penalty when the harvested GLRV affected grapes had a low sugar level. For the other wineries, grapes were only inspected visually at the time of buying/selling and none reported rejection upon inspection.

Those parameters and their interactions were used to identify the scenarios evaluated in the study. Literature related to the spread and damages of the GLRV was reviewed in order to compare information and to obtain this information whenever it was not available.

b. *Financial analysis*

A net present value (NPV) was calculated for the scenarios identified through the guided questionnaire. Since fixed costs are unchanged under GLRV incidence and disease management, they were omitted when comparing the different scenarios. The cost incurred by the GLRV in today's dollar terms was computed under the different scenarios as the difference between each scenario's NPV per acre and the one of the baseline scenario (no GLRV). The NPV calculations used primary data from White (2007) summarized in Table 1 below, collected guided questionnaire data and reports from the literature. Using this methodology, the analysis looked at the economics of each disease management option identified in order to compare the economic impact of the virus under these scenarios and recommend the management options that are economically sound under the different scenarios.

5. Assumptions

The assumptions of the analysis are inspired directly from the questionnaire results and the related literature. Those include the baseline data, the disease incidence, its spread pattern, and impact on yield and on the price paid for grapes.

a. Baseline data

Baseline data on planting, costs, revenues and financial assumptions from White (2007) were used to compute the NPVs. They are summarized in Table 1.

Table 1: Assumptions of the report on the Cost of Establishment and Production of *Vinifera* Grapes in the Finger Lakes region of New York (White, 2007)

General assumptions	
Row spacing	9 ft
Vine spacing	6 ft
Vines per acre	807 vines
Vine replacement without GLRV	2%
Cost assumptions	
Skilled labor wage	$16.6/hr
Unskilled labor wage	$11.60/hr
Gasoline	$ 2.90/gallon
Diesel	$3.32/gallon
Vines	$3.25vine
Revenue assumptions (Cabernet Franc**)**	
Price	$1,700/ton
Yield (years 4 and above)	3.3 tons/acre
Financial assumptions	
Discount rate	7.37%
Project life cycle	25 years

b. GLRV incidence

GLRV incidences reported by respondents were approximately 1, 5, and 40% of the vineyard. Those were considered first and then other key rates were identified such as the break even incidence and the incidence that determines switching from one management option to the other.

c. Virus spread

Unlike virus incidence, virus spread was not as easily identified by vineyard managers. The pattern of virus spread used is the one suggested by a model of GLRaV-3 infection that was used by Walker et al (2004) to predict levels of virus infection under the presence of vectors, over a 20 year period based on the observed changes in the distribution of the virus for the period 1998-2003. In that model, virus infection was predicted to spread within the vineyard with 50% infection occurring in years 6, 8 and 11 for the three plots studied. Those plots were predicted to reach 90% vine infection in years 11, 12 and 15. This information on the predicted spread virus in the vineyard was used as the basis for the following economic analysis. As shown in figure 1, the model predicts the typical S-shaped curve of disease diffusion.

In the roguing scenarios, it was assumed that the spread is controlled by individual vine removal, but not eradicated immediately. Under these scenarios, infection continues to spread for a number of years, however, at a substantially reduced rate. The annual levels of GLRV under no control were reproduced from figure 1 and are provided in Table 2 along with the disease incidence under major roguing scenarios. Those were computed assuming symptoms become visible in year 4 in all scenarios. In addition, the following assumptions were made for the scenarios of 1, 5, 40 and 60% GLRV incidences (assumptions similar in nature are made to the other levels of infection considered).

- Roguing at 1% incidence (T1): the level of infection stays at 1% every year. It is assumed that, once the disease is present, it can only be controlled but never eradicated unless entire vineyard is replanted and vectors are controlled.
- Roguing at 5% incidence (T5): roguing lowers infection level down to 3% in year 5, then 1% thereafter
- Roguing at 40% incidence (T40): roguing lowers infection level down to 20% in year 5, then 10% in year 6, then 5% in year 7, 3% in year 8, and 1% thereafter
- Roguing at 60% incidence (T60): roguing lowers the incidence down to 40% in year 5, then 20% in year 6, then 10% in year 7, 5% in year 8, 3% in year 9 and 1% thereafter.

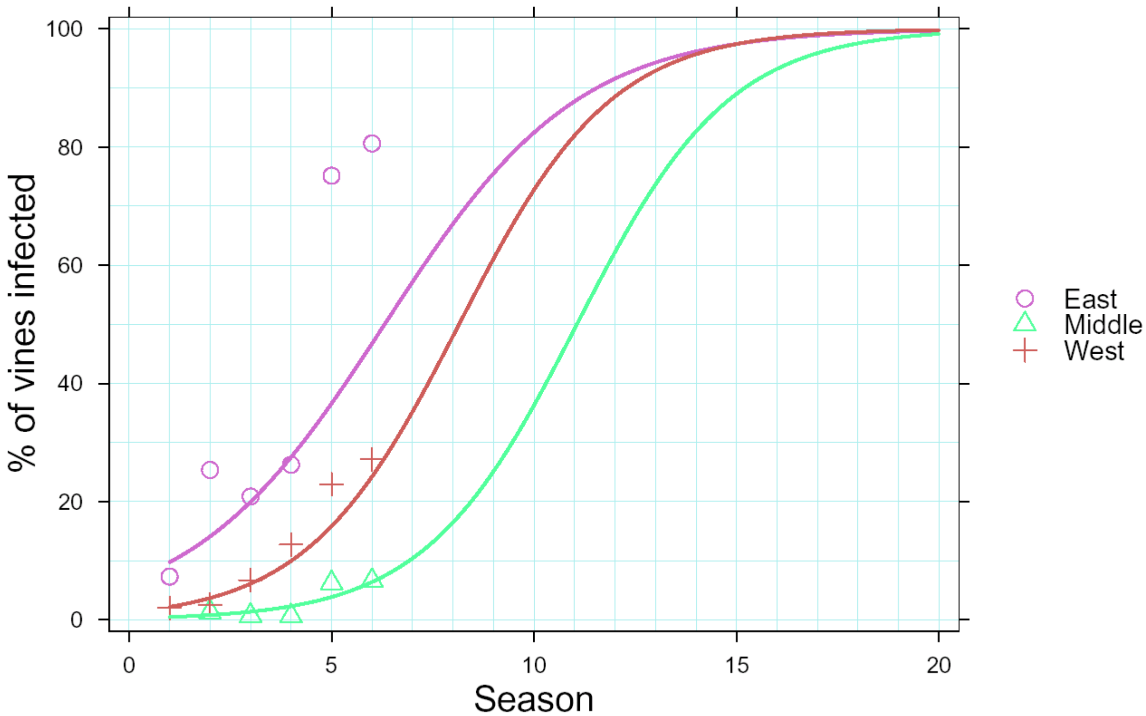

Figure 1. The predicted levels of virus infection over a 20 year period based on the relationship between the percentages of infected vines each season over the assessment period 1998-2003 (Walker et al., 2004).

Table 2. Evolution of GLRV incidence under the five roguing scenarios (T1, T5, T40, T60, and N). Yield of healthy and infected vineyards.

Years	Roguing scenarios				
	N*	T1	T5	T40	T60
0	0	0	0	0	0
1	1	0	0	0	0
2	2	0	0	0	0
3	8	0	0	0	0
4	12	1	5	40	60
5	22	1	3	20	40
6	28	1	1	10	20
7	36	1	1	5	10
8	48	1	1	3	5
9	60	1	1	1	3
10	70	1	1	1	1
11	80	1	1	1	1
12	88	1	1	1	1
13	92	1	1	1	1
14	95	1	1	1	1
15	98	1	1	1	1
16	98	1	1	1	1
17	98	1	1	1	1
18	98	1	1	1	1
19	98	1	1	1	1
20	100	1	1	1	1
21	100	1	1	1	1
22	100	1	1	1	1
23	100	1	1	1	1
24	100	1	1	1	1
25	100	1	1	1	1

*N is the scenario of no GLRV control; percent infection from model of Walker et al (2004) T1, T5, T40 and T60 are roguing scenarios at 1, 5, 40 and 60% incidence. Assumptions are explained in Section 5.c *d. Yield reduction due to infection*

For the most part, surveyed vineyard managers did not measure the reduction in yield due to the GLRV. Literature reviewed suggests a range from zero to over 70% yield reduction. It has been estimated that in the absence of leaf roll virus German wine sector production might increase by up to 60% (Scheu, cited by Over de Linden and Chamberlain, 1970). Given the results of the guided questionnaire, a yield reduction of 30% was considered and, given that crop reductions of 40-60% are commonly reported in the literature, a yield reduction of 50% was considered as well.

Table 3. Yield (tons per acre) of healthy vs. infected vineyards (with 30% vs. 50% yield reduction).

Years	Yield		
	Healthy vineyards	Affected vineyard with 50%yield reduction	Affected vineyard with 30%yield reduction
0-2	0.00	0.00	0.00
3	1.00	0.96	0.97
4	3.30	3.10*	3.18
5	3.30	2.94	3.08
6	3.30	2.84	3.02
7	3.30	2.71	2.94
8	3.30	2.51	2.82
9	3.30	2.31	2.71
10	3.30	2.15	2.61
11	3.30	1.98	2.51
12	3.30	1.85	2.43
13	3.30	1.78	2.39
14	3.30	1.73	2.36
15-19	3.30	1.68	2.33
20-25	3.30	1.65	2.31

*Yield with GRLV=%vines infected*yield of infected vines + % healthy* yield of healthy vines where yield reduction due to virus is assumed to be 50% and 30%

e. Quality reduction due to infection and grape prices

The guided questionnaire sought the quantification of quality reduction through increase of acidity and decrease of sugars and the identification of contractual mechanisms to penalize or poor quality grapes. However, vineyard managers did not measure the acidity and sugar level of their grapes. For the most part, the practice was that the buyer would visually inspect the vineyard before buying. There was however one buyer who imposed a 10% price penalty for grapes that did not meet the minimum sugar level required. For that reason, the N30 and N50 scenarios were modified to compare scenarios without the 10% penalty, NN30 and NN50, respectively in order to identify any effect the penalty incentive has or ought to have on the management decisions of the vineyard manager.

6. Scenarios considered

The scenarios considered reflect the information collected from the guided questionnaire: the management interventions (no intervention, roguing at different incidences, or total replacement), the modes of disease transmission (at planting, through infected vines or later on, through insect vectors), and the impact of grape quality reduction on price (10% penalty, no penalty). Other scenarios consider hypothetical situations such as a late onset of the symptoms and the use of certified vines.

a. Baseline (T0)

This is the baseline scenario depicting the cash flow of one acre over 25 years, without GLRV incidence. It is used to calculate the cost impact of GLRV by computing the difference between the baseline NPV and the NPV of different management options scenarios.

b. No intervention (VN)

This scenario depicts a situation where the GLRV is introduced in year one through insect vectors or at planting through infected vines (1%) and spreads following the sigmoid model of Walker (2004), the vineyard manager chooses not to do anything. The evolution of GLRV incidence under that scenario is presented in Table 2 under column N. This scenario is evaluated under two values of the GLRV-led yield reduction: 30 and 50% (VN30 and VN50) and under the two circumstances of no penalty and 10% penalty on lower quality grapes. This scenario is used to compute the cost impact of ignoring GLRV.

c. Roguing scenarios (T1-T60)

In these scenarios, the GLRV is introduced at planting time through infected vines at different levels, those vines show GLRVG-like symptoms after the fourth year and are immediately removed every year (roguing). The virus does not spread following the model of Walker (2004) since the infected plants are removed every year. Instead, the level of infection decreases gradually as described in Table 2 for different roguing scenarios labeled T1 to T160 depicting infection levels from 1 to 60%. These scenarios help identify the infection levels where roguing would be advisable.

d. Replacement

This is a scenario where the vineyard manager decides to replant the entire vineyard at the onset of symptoms in year 4. The NPV of this scenario is used as a benchmark to identify which of roguing and replacement is a better option at different intervals of GLRV incidence.

e. Late vector mediated infection (LV)

In this scenario, late vector mediated infections in years 12, 16 and 20 are considered in order to identify a vineyard age beyond which any intervention is not economically justified.

f. Prevention through certified vines (C)

This scenario simulates a situation where the planted vines are certified virus free and cost 25% more than conventional vines. The NPV of this scenario is used to demonstrate the cost and benefit of procuring certified vines at the time of planting.

7. Results of the analysis

Q1. Is it better to rogue, replant?

Roguing is the better solution if infection level is less than 27% and replant otherwise (whether yield reduction is 50% or 30%). As shown in Fig.2 by the difference between the blue dots and the red dot, the advantage of roguing over replacement decreases as the level of infection increases. Beyond an infection level of 27%, replacing the whole vineyard is economically justified. This is consistent with the finding of the questionnaire where the winery with a GLRV incidence of 40% had their vineyard replanted whereas the wineries with infection levels of 1% and 5% practiced roguing. Fig. 2 and Table 1 show that roguing in a vineyard with a GLRV incidence of 40% drives the NPV to negative values, making the operation economically not feasible.

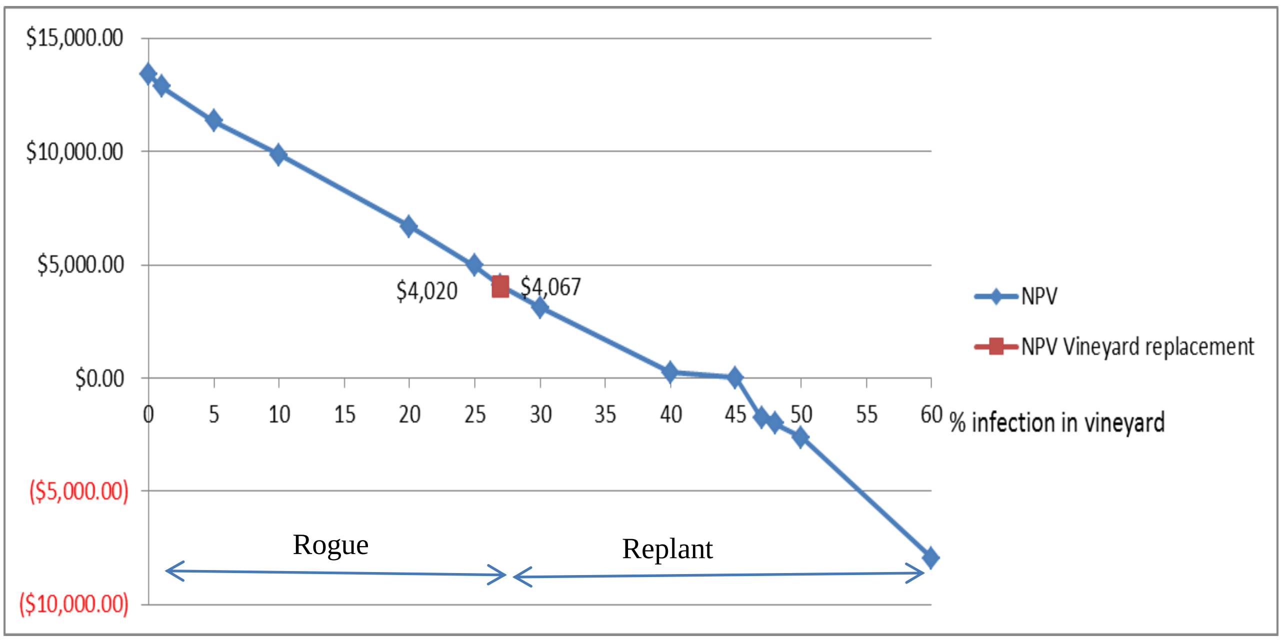

Fig.2 NPV/acre of roguing scenarios under increasing incidence (blue) compared to the NPV of replacement (red)

Q2. What is the *cost* involved by introducing GLRV through infected vines at planting?

The GLRV has the lowest cost impact if it occurs at a 1% incidence and roguing is practiced. At any higher incidence, the preventative method of planting certified plants is the preferred way to cope with GLRV as it limits its impact to $740.14/acre, assuming a price markup of 25% for the certified vines.

Table 4. NPV/acre of roguing scenarios under increasing GLRV incidence compared to the NPV of replacing the vineyard and planting certified vines

Intervention scenarios	NPV	GLRV cost impact*
Baseline scenario (no GLRV)	$13,403.85	
Roguing at increasing GLRV incidence (%)		
1	$12,857	$547
5	$11,328	$2,076
10	$9,857	$3,547
20	$6,671	$6,733
25	$4,945	$8,459
27	**$4,067**	$9,337
30	$3,124	$10,280
40	$253	$13,150
45	$0.00	$13,404
47	($1,782)	$15,186
48	($2,019)	$15,423
50	($2,611)	$16,015
60	($7,962)	$21,366
Replacing the vineyard at onset of symptoms in year 4	**$4,020**	$9,384
Planting certified vines in year 1	$12,663	$740

***** The GLRV cost impact is computed as the difference between the NPV of roguing and the baseline NPV (no infection).

Q3. What if GRLV is introduced through *vectors* in the midlife of the vineyard rather than through infected vines at the time of planting? Is roguing still advisable, even if the vineyard is old? Is there a vineyard age breaking point?

Beyond year 19, if the vineyard gets infected, it is better not to rogue. This can be seen in the third column of Table 5 where the impact of roguing on the NPV becomes negative in year 20. This is due to the old age of the vineyard: investing in planting new vines five years before the end of the lifecycle is not economically justified. This means that any time before the age of 19 years, roguing is economically beneficial.

Table 5. NPV of late vector mediated infection scenarios with and without roguing

Late vector mediated infection scenarios	**NPV**	**Impact of roguing***
Year 12, no roguing	$10,099**	
Year 12, roguing	$13,263	$3,164
Year 16, no roguing	$7,986	
Year 16, roguing	$12,819	$4,833
Year 20, no roguing	$13,180	
Year 20, roguing	$12,889	($290)

* The impact of roguing is computed as the difference between the NPV of 'roguing' and the NPV of 'no roguing'
** The NPVs are computed using infection levels in Table 2, column N

Q4. Is there any situation where *doing nothing* is the best response?

Yes, ‘doing nothing’ is the best response if yield reduction is less than 30%, incidence greater than 27% and there is no quality penalty.

Table 6 depicts a decision matrix incorporating three key parameters: the level of infection (less or greater than 27%), the magnitude of yield loss caused by infection (30% and 50%) and whether there is a penalty for lower quality grapes or not. It is clear that in the presence of the quality incentive, the recommendation is still as in Fig. 1 and Table 2: rogue if infection less than 27% and replant otherwise. However, in the absence of penalty, anytime the incidence is higher than 27% and the yield loss is 30%, there is an indifference point between ‘no intervention’ and replacement. This suggests that, if yield reduction is less than 30%, ‘no intervention’ becomes the best response as its NPV would be higher than its value at 30% infection, consequently higher than the NPV of replacement. Note that roguing is not an option in this case since GLRV incidence is greater than 27% (Tables 8a and 8b in Appendix 2).

Table 6. Decision matrices: rogue, replant or do nothing, depending on the yield loss (30 or 50%), the GLRV incidence (less or more than 27%) and the quality incentive (10% penalty, no penalty).

30% yield loss	**10% penalty**	**No penalty**
< 27% infection	ROGUE	ROGUE
> 27% infection	REPLANT	**INDIFFERENT**
Less than 30% yield loss		
< 27% infection	ROGUE	ROGUE
> 27% infection	REPLANT	**DO NOTHING!**
50% yield loss		
< 27% infection	ROGUE	ROGUE
> 27% infection	REPLANT	REPLANT

There figures leading to the decision matrices in Table 6 are summarized in Table 7 which is based on the NPVs in Tables 8a and 8b (Appendix 2).

Table 7. NPV of no intervention scenarios under different yield reduction (30 and 50%) and quality penalty (0 and 10%) conditions

No intervention scenarios	NPV	GLRV cost impact*
No intervention (VN30), no penalty*	**$3,709**	$9,695
No intervention (VN30), 10% penalty	$3,334	$10,070
No intervention (VN50), no penalty	($2,294)	$15,698
No intervention (VN50), 10% penalty	($2,610)	$16,014
Replacing the vineyard at onset of symptoms in year 4	**$4,020**	$9,384

*VN00 stands for vector mediated infection (V), no intervention (N), 00% reduction in yield

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APPENDIX 1. ***Questionnaire***

1. EXTENT OF INCIDENCE

What percentage of your vineyard is affected by leafroll? (*Highlight one*)

a. 0
b. 0-10
c. 10-25
d. 25-50
e. 50 or more
f. I don't know

2. VARIETIES

What grape varieties were affected by leafroll?

3. SYMPTOMS OF LEAFROLL VIRUS ON CROP

In the following section, please mention whether you noticed a change in **per vine** yield, sugars and/or acidity associated with the leafroll virus infection. If changed occurred, please indicate the degree of change, if measured or estimated (*highlight answer*).

Yield decreased by (%):

a. 0 (no decrease)
b. 0-10
c. 10-25
d. 25-50
e. 50 or more
f. I don't know

Sugars decreased by (º brix):

a. 0 (no decrease)
b. 0-1
c. 1-2
d. 2-3
e. 3-4
f. I don't know

Acidity increased by (g/L):

a. 0 (no decrease)
b. 0-0.5
c. 0.5-1
d. 1-2
e. 2 or more
f. I don't know

4. CHANGES IN AGRICULTURAL PRACTICES IN RESPONSE TO LEAFROLL INCIDENCE

Have you replanted your vineyard in response to leafroll infection? Yes No (*highlight one*)
If not, have you changed any of the following practices as a response to your vineyard leafroll infection? (*Tick the appropriate cell*)
If yes, please mention how many units (of labor or equipment) you had to utilize on each activity as a result of leafroll infection

	yes	no	If yes, how many units (vines replanted, quantity fertilizer/pesticide, etc)
Vine replacement			
Leaf removal			
Fertilization			
Pesticide			
Other:			

5. <u>CONTRACTS WITH VINEYARDS</u>

Do you buy/sell grapes from vineyards other than your own? Yes No (*highlight one*)
If yes, do you have contracts with those vineyards? Yes No (*highlight one*)
If yes, does the contract refer to quality standards related to the sugars and/or the acidity of the grapes? Yes No (*highlight one*)
If yes, what are those standards?

a. Sugars:____ ______
b. Acidity:__________

How do you penalize (get penalized for) lower standards?

a. No penalization for lower standards
b. Batch is refused
c. There is a penalty of:

APPENDIX 2. Tables 8a and 8b

Table 8a. NPV of 'no intervention' with and without penalty vs. Roguing vs. Replacement at increasing GLRV incidence (assuming 30 % yield reduction due to infection)

NPVs assuming 30% yield reduction			
GLRV incidence (%)	**No intervention + penalty**	**Roguing**	**Replacement**
1	$3,334	$12,857	$4,020
5	$3,334	$11,328	$4,020
10	$3,334	$9,857	$4,020
20	$3,334	$6,671	$4,020
25	$3,334	$4,944	$4,020
27	$3,334	$4,067	$4,020
30	$3,334	$3,124	**$4,020**
40	$3,334	$253	$4,020
45	$3,334	$0.00	$4,020
47	$3,334	($1,782)	$4,020
48	$3,334	($2,019)	$4,020
50	$3,334	($2,611)	$4,020
60	$3,334	($7,962)	$4,020

GLRV incidence (%)	**No intervention + no penalty**	**Roguing**	**Replacement**
1	$3,710	$12,857	$4,020
5	$3,710	$11,329	$4,020
10	$3,710	$9,857	$4,020
20	$3,710	$6,671	$4,020
25	$3,710	$4,945	$4,020
27	$3,710	$4,067	$4,020
30	$3,710	$3,124	**$4,020**
40	$3,710	$253	$4,020
45	$3,710	$0.00	$4,020
47	$3,710	($1,781)	$4,020
48	$3,710	($2,019)	$4,020
50	$3,710	($2,611)	$4,020
60	$3,710	($7,962)	$4,020

Table 8b. NPV of 'no intervention' with and without penalty vs. Roguing vs. Replacement at increasing GLRV incidence (assuming 50 % yield reduction due to infection)

NPVs assuming 50% yield reduction			
GLRV incidence (%)	**No intervention + penalty**	**Roguing**	**Replacement**
1	($2,610)	$12,857	$4,020
5	($2,610)	$11,328	$4,020
10	($2,610)	$9,857	$4,020
20	($2,610)	$6,671	$4,020
25	($2,610)	$4,945	$4,020
27	($2,610)	$4,067	$4,020
30	($2,610)	$3,124	**$4,020**
40	($2,610)	$253	$4,020
45	($2,610)	$0.00	$4,020
47	($2,610)	($1,782)	$4,020
48	($2,610)	($2,0192)	$4,020
50	($2,610)	($2,611)	$4,020
60	($2,610)	($7,962)	$4,020

GLRV incidence (%)	No intervention + no penalty	Roguing	Replacement
1	($2,295)	$12,857	$4,020
5	($2,295)	$11,328	$4,020
10	($2,295)	$9,857	$4,020
20	($2,295)	$6,671	$4,020
25	($2,295)	$4,945	$4,020
27	($2,295)	$4,067	$4,020
30	($2,295)	$3,124	**$4,020**
40	($2,295)	$253	$4,020
45	($2,295)	$0.00	$4,020
47	($2,295)	($1,782)	$4,020
48	($2,295)	($2,0192)	$4,020
50	($2,295)	($2,611)	$4,020
60	($2,295)	($7,962)	$4,020