Ciência Téc. Vitiv. 28(2) 43-50.2013

ANALYSIS OF THE LOSSES DUE TO GRAPEVINE LEAFROLL DISEASE IN ALBARIÑO VINEYARDS IN RÍAS BAIXAS (SPAIN)

ANÁLISE DAS PERDAS DEVIDO O ENROLAMENTO DA VIDEIRA EM VINHAS DE ALVARINHO NAS RIAS BAIXAS (ESPANHA)

Cristina Cabaleiro[1]*, Ana M. Pesqueira[1], Martín Barrasa[2] and Julian J. Garcia-Berrios[1]

[1]Departamentos de Producción Vegetal and [2]Ingeniería Agroforestal, Escola Politécnica Superior, Universidad de Santiago de Compostela, Campus Universitario s/n 27002 Lugo. Spain.
*corresponding author: Tel.: 34982823101. Fax: 34982285926. E-mail address: cristina.cabaleiro@usc.es

(Manuscrito recebido em 20.01.2014. Aceite para publicação em 18.02.2014)

SUMMARY

Leafroll disease symptoms in grapevine white varieties are milder than in red ones and producers do not regard leafroll to be economically significant especially when yield is not consistently affected. However, the potential alcoholic degree (PAD) of Albariño grapes from Grapevine leafroll associated virus 3 (GLRaV-3) infected plants in two vineyards in Rías Baixas (Spain), was found to be an average of 1º lower than the virus free ones. To analyse the economic losses, two price scales and six vintages for each location were used: A) Grape Purchase Agreements (GPA) and B) bonuses or penalties depending on mean PADs of each year. Income was 8.7% lower with (A) and 13% lower with (B), that is more than 2000 €•ha^{-1} per year. Annual and accumulated losses during the 30 years of vineyard lifespan, with 5% discount rate, and an average yield of 10 t•ha^{-1} were calculated for three scenarios: leafroll free vineyard (E1), 25% GLRaV-3 infected vineyard (E2) and vineyard leafroll free at planting and with mealybug vectors spreading GLRaV-3 up to 100% in 15 years (E3). In the E2 scenario the total income losses amounted to be in A) of 12.9% and in B) of 19.6% when compared to E1. In the E3 scenario the losses will be in A) 24.1% and in B) of 35.1% when compared with E1. These decreases in income in E3 could amount to 74,000 €•ha^{-1}. This study confirms the need to stress the importance of taking GLRaV into consideration also in white varieties with no visible damages.

RESUMO

Os sintomas da doença do enrolamento foliar da videira em castas brancas são menos pronunciados do que nas castas tintas levando os produtores a não considerar as perdas devidas ao enrolamento como economicamente importantes. O grau alcoólico potencial (PAD) do mosto de uvas de plantas da casta Albariño (Alvarinho) com o vírus GLRaV3 foi em média um grau menor que o proveniente de plantas isentas em duas vinhas da região DOC Rías Baixas na Galiza (Espanha). Para calcular as perdas económicas causadas pelo enrolamento foram utilizadas duas tabelas de preços e seis vindimas por local usando dois critérios: A) contratos fixos de compra de uva (GPA) e B) bónus ou penalizações no preço pago em função da média de PAD de cada ano. O rendimento foi em média 8.5% inferior em A) e 13% inferior em B) o que equivale a mais de 2000 € ha^{-1} por ano. Foram calculadas as perdas anuais acumuladas durante os 30 anos de vida útil das vinhas, com um desconto de 5%, e um rendimento anual médio de 10t ha^{-1}, para três cenários respetivamente: (E1) vinha isenta de enrolamento foliar; (E2) vinha com 25% de cepas infetadas com GLRaV3; e (E3) vinha isenta de GLRaV3 à instalação, mas com cochonilhas transmitindo o GLRaV 3 até atingir os 100% de cepas infetadas em 15 anos. Em E2 o rendimento é 12,9% inferior a E1 usando A) e 19,6% usando B). Em E3 o rendimento é 24,1% inferior a E1 usando A) e 35,1% usando B). Estas reduções de rendimento em E3 podem atingir os 74000€ ha^{-1}. Este estudo confirma a necessidade de tomar em linha de conta o GLRaV também em castas brancas onde os danos não são aparentemente visíveis.

Key words: GLRaV; virus; losses; sugar; grapevine.
Palavras-chave: GLRaV; vírus; perdas; açúcar; videira.

INTRODUCTION

The aetiology of leafroll disease is complex and several Grapevine leafroll associated viruses, (GLRaVs) belonging to the *Closteroviridae* family have been identified, most of them ampeloviruses (Martelli *et al*., 2013). It is well documented that the physiological changes induced by the GLRaVs, give place to alterations, mainly delays in the maturation of the grapes of the infected stocks. The musts of infected vines are often more acidic and with lower sugar content than those free of leafroll at the optimal date of harvest expected for healthy plants (Goheen and Cook, 1959; Lider *et al.*, 1975; Woodham *et al.*, 1984; Walter and Martelli, 1996; Guidoni *et al.*, 1997; Cabaleiro *et al.*, 1999; Mannini, 2003; Moutinho-Pereira *et al.*, 2012). However, it is also well documented by most of the cited authors that the damages induced by the leafroll viruses vary based on factors such as cultivars and clones, locations, age of the plants, crop management, virus or combination of viruses infecting the plants, and environmental conditions. It is common that producers do not regard leafroll to be economically significant because grapes are not destroyed and infected vines do not suffer rapid decline or early death, so there is no direct evidence of yield loss (Freeborough and Burger, 2008).

When virus infected plants do not show clear symptoms and are randomly spread all over the vineyard,

which is most common (Cabaleiro *et al.*, 2008), it becomes impossible to carry out a selective delayed harvest to reduce the losses. Therefore, the quality of the harvest from vineyards with high leafroll incidence will be lower, irregular, more affected by environmental conditions and there will be higher risk of fungi attacks during delayed ripening (Garau *et al.*, 1997). Leafroll viruses are "quality" pathogens that affect grapevine, but also an industrial final product, like wine, which depends very much on the quality of the fruit processed. The losses due to leafroll viruses are expected to be higher in cultivars and areas producing premium wines, as it is the case of the Albariño white wines in Galicia. This is because the price of the grapes is calculated according to sugar content and heavy penalties are given when the musts are under certain standards which may change every year depending on the current average potential alcoholic degree (PAD). The cultivar Albariño - the most representative of Rías Baixas wine industry - is a good example of some grapevine cultivars that adapt to the cool and humid conditions of the vineyards close to the Atlantic Ocean. Although Albariño is a traditional cultivar in Rías Baixas region, modern viticulture did not start there until the last quarter of the 20th century. Most plant material used in the new vineyards came from few centenary plants or small plots; about 30% of these plants were leafroll infected (Segura *et al*., 1993). Certified virus-free Albariño became available only recently after a long process of sanitary and clonal selection from the old plants in traditional orchards (Bosso *et al.*, 2004, 2005). Since the ripening conditions may be quite variable, more problems with leafroll infected plants are expected in cool climates than in warmer ones (Garau *et al.*, 1997; Charles *et al.*, 2006). In the last decade, several studies have been published on the economic impact of leafroll disease in different grape growing regions in the world, mostly from cool climate areas in New Zealand, South Africa, Switzerland or USA (Walker *et al.*, 2004; Freeboorough and Burger, 2006; Besse *et al.*, 2009; Atallah *et al.*, 2012; Fuller *et al.*, 2013). However, it is in Mediterranean areas and climates, that the prevalence and spread of Grapevine leafroll associated virus 3 (GLRaV-3) is maximum, especially in table grapes (Bertolini *et al.*, 2010) because mealybugs are common pests (Golino *et al.*, 2008; Daane *et al.*, 2012). Despite the high incidence of the virus, leafroll disease is not so often mentioned as a problem in table grape cultivars as it is in wine ones, probably because the symptoms of the disease in some table grape varieties are less evident than in wine cultivars (Freeboorough and Burger, 2006).

Since 1992, the effects of GLRaV on the cultivar Albariño in the "Denominación de Origen Controlada" (DOC) "Rías Baixas" (Quality wine produced in Rías Baixas) have been evaluated (Cabaleiro and Segura, 1996; Cabaleiro *et al.*, 1999; García-Berrios *et al.*, 2007; Pereira *et al.*, 2012). The first data collected (1992 - 1994) showed that in years without favourable environmental conditions the musts might not reach the minimum PAD in the DOC. This prompted us to compare sugar content data from several more years and from two locations (Meaño in the North and Goián in the South of Rías Baixas) in the same region (Galicia-Spain) to obtain a good estimate for different ripening conditions according to vineyard, location and year. With the overall data, the income reduction expected from the leafroll disease in the region was estimated on the basis of leafroll disease incidence in the vineyard at planting either as a fixed factor or considering its increment in case of virus spread by mealybugs.

MATERIAL AND METHODS

The field studies were carried out in two vineyards planted with the Albariño white variety in the Rías Baixas described in previous papers (Cabaleiro *et al.*, 1999; García-Berrios *et al.*, 2007; Pereira *et al.*, 2012). PADs from six vintages in each vineyard are available: 1992 - 1994 and 2003 - 2005 for the vineyard in the North (N) and 2000 - 2005 for the vineyard in the South (S) (Table I). The average reduction in PAD in the musts from GLRaV-3 infected plants is 0.92° in the N vineyard and 1.07º in the S vineyard; and in both cases they are statistically significant for the whole period and most of the years (García-Berrios *et al.*, 2007). The differences in the PAD among years are significant both for infected and virus free plants, indicating the changing annual environmental conditions and therefore, the heterogeneity of the harvest quality in this particular grape growing region. The N vineyard has an incidence of 33.3% GLRaV-3 and the S, about 23%. In these vineyards, no mealybugs or scale insects have been found, but in N a very slow and unexplained increase of infected plants (<1% per year) has been observed from 1991 to 2006 (Cabaleiro and Segura, 1997, 2006; Cabaleiro *et al.*, 2008).

In these vineyards, there were no significant differences between the harvest weight of GLRaV-3 free and the infected plants; in other older vineyard, lower yield was quantified (Cabaleiro and Segura, 1996), but yield drops are irregular and likely to be location and season dependent. So for the purpose of the general study, no yield drops were taken into account and the basis for the calculation of losses was only the PAD which is the factor more significantly affected by leafroll and the only one used to assign premium prices or penalties.

The two price scales, both using PAD of the musts at harvest as a quality criterion, are as follows:

A) Price scale depending on PAD as in the Grape Purchase Agreements (GPA) with a fix value agreed for three campaigns which assigns a base price per kg to each PAD from 11 to 13º; during the years included in this study prices varied from 1.06 €•kg^{-1} for 11º to 1.43 €•kg^{-1} for 13º and higher PAD; grapes

under 11º were out of the agreement and must be sent to "table wine" at lower prices (<0.7 €•kg^{-1}), which hardly covered the production costs of traditional Albariño vineyards at that time.

did not reach 11º, there was an additional penalty of 0.30 €•kg^{-1} per 0.5º interval; nowadays, grapes under 11º are not allowed in the cellar and growers must delay harvest or sell the grapes out of the DOC as

Table I

Potential alcoholic degree (PAD) of Albariño grapes from GLRaV-3 free and infected plants in the North (N) and South (S) vineyards in Rías Baixas DOC. Drop of earnisgns due to the current infenction rate with GLRaV-3 in each vineyard (33.3% N; 23% S) according to grape purchase agreements (A) and according to the bonus and penalties for PAD established by the cooperative winery (B).

Grau alcoólico potencial (PAD) de uvas de Alvarinho isentas ou infetadas com GLRaV3em vinhas do Norte (N) e do Sul (S) da DOC Rías Baixas. Perdas segundo a incidência real de GLRaV 3 em cada vinha (33.3% no N e23.0% no S) de acordo com os preços estabelecidos em (A) - contrato fixo de compra de uvas e em (B) - bónus e penalizações conforme o PAD estabelecido pela adega

	N						S								
	1992	**1993**	**1994**	**2003**	**2004**	**2005**	**N**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**S**	**mean**
PAD (º) GLRaV-3 (+)	11.0	10.5	10.3	9.8	10.2	11.9	10.6	11	10.9	9.9	11.4	9.8	13.1	11.0	11.5
PAD (º) GLRaV-3 (-)	11.6	11.4	10.8	11.1	11.4	12.9	11.5	11.1	12.2	11	12.8	11.1	14.1	12.1	12.5
ΔPAD (º)	0.6	0.9	0.5	1.3	1.2	1.0	0.9	0.1	1.3	1.1	1.4	1.3	1.0	1.0	1.0
PAD (º) with actual levels of[a] GLRaV-3	11.4	11.1	10.6	10.7	11.0	12.6	11.2	11.1	11.9	10.7	12.5	10.8	13.9	11.8	12.2
€·kg^{-1} (A)[b] with actual levels of GLRaV-3	1.11	1.08	0.7	0.7	1.06	1.34	1.0	1.08	1.16	0.7	1.32	0.7	1.43	1.1	1.2
€·kg^{-1} (A) without GLRaV-3	1.13	1.11	0.7	1.08	1.11	1.41	1.1	1.08	1.22	1.06	1.38	1.08	1.43	1.2	1.3
% loss·kg-^{1} (A)	1.8	2.7	0.0	35.2	4.5	5.0	8.4	0.0	4.9	34.0	4.3	35.2	0.0	13.1	9.0
Losses (€·ha-^{1})[c] (A) for actual levels of GLRaV-3	200	300	0	3,800	500	700	917	0	600	3,600	600	3,800	0	1,433	1,067
Mean PAD(º)[d]	**11.7**	**11.7**	**11.7**	**12**	**12.6**	**12.9**		**11.4**	**11.7**	**11.7**	**12**	**12.6**	**12.9**		
€·kg^{-1} (B)[b] with actual levels of GLRaV-3	1.94	1.86	0.7	0.7	1.34	1.94	1.4	1.94	2.04	0.7	2.10	0.7	2.26	1.62	1.8
€·kg^{-1} (B) without GLRaV-3	1.98	1.94	0.7	1.74	1.58	2	1.7	1.94	2.1	1.82	2.22	1.4	2.42	1.98	2.0
% Loss·kg-^{1} (B)	2.0	4.1	0.0	59.8	15.2	3.0	14.0	0.0	2.9	61.5	5.4	50.0	6.6	21.1	12.0
Losses (€·ha^{-1})[c] (B) for actual levels of GLRaV-3	400	800	0	10,400	2,400	600	2,433	0	600	11,200	1,200	7,000	1,600	3,600	2,100

[a]33.3% North vineyard; 23% South vineyard.
[b]A) Grape Purchase Agreement; b) Prices according to winery criteria.
[c]with an average harvest of 10,000 kg•ha^{-1}.
[d]PAD calculated with the overall PAD of all grapes entering the cellar each particular year (Data from Martin Codax winery).

B) Price scale as in one of the main cooperative wineries in the DOC, with grapes with the average PAD of each vintage getting 2 €•kg^{-1}, a price that was maintained during all the years of this study; the price of the grapes over or under the average is increased or decreased using intervals of 0.5º: the first interval of 0.5º gets a bonus or penalty of 0.02 € per each 0.1º; in the second interval (0.5 to 1º over or under), it is 0.04 € per each 0.1º and in the third (1 to 1,5º over or under) 0.06 € per each 0.1º. Initially, when the grapes

table wine, getting lower prizes as seen above.

The harvest starting dates (between the 2nd and the 24th of September) in one of the main areas of "Rías Baixas" for a ten years period (1994-2004) are shown in Figure 1 together with the average PAD for each year in the same area which was the base for the price of grapes in Case B; it varied from 11.3º in 1998 and 1999 to 12.6º in 2004 (Data from Martín Codax winery).

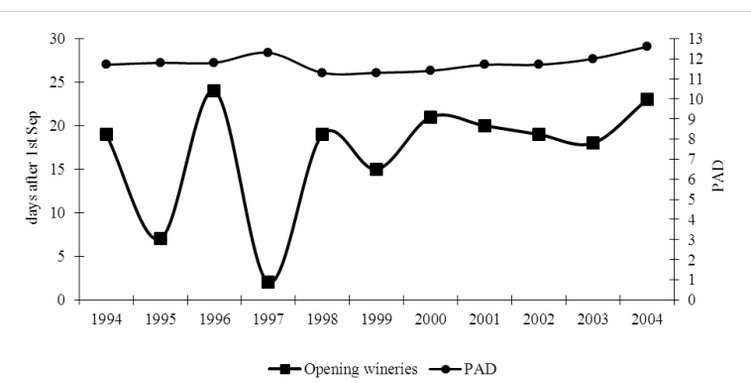

Figure 1 - Mean Potential alcoholic degree (PAD) of the musts from grapes of Albariño variety and harvest starting dates from 1994 to 2004 (data from Martín Codax winery).

Grau alcoólico potencial (PAD) dos mostos de uvas da casta Alvarinho e datas de início da vindima entre 1994 e 2004 (dados da adega Martín Codax)

For both vineyards with known GLRaV-3 incidence actual losses, compared to an ideal situation with all plants leafroll-free, were calculated on the basis of the two price scales.

In order to make an estimation of losses due to GLRaV-3 in Albariño in the region, the mean prices given to the grapes from the 12 vintages available were considered as 12 different situations which summarize most of the possible cases to be found in the region in a long period of time. These data were used to carry out the economic study of a vineyard with 30 years lifespan taking into account two price scales and three scenarios:

1) E1 vineyard GLRaV-3 free and without mealybug infestation.

2) E2 vineyard with 25% GLRaV-3 incidence, random distribution and without mealybug infestation.

3) E3 Vineyard GLRaV-3 free at planting, close to older vineyards with GLRaV-3, and with medium mealybug infestation. The rate of spread of the virus adopted was the one measured after ELISA analysis of test plants in a commercial plot: healthy at planting and with 81.1% GLRaV-3 after 14 years (Cabaleiro and Segura, 2006; Cabaleiro, 2009). For practical purpose, 100% incidence is adopted from 15th year onwards. The rate of spread and the disease progress curve of grapevine leafroll in this vineyard in Rías Baixas was similar to others described worldwide and reviewed by Cabaleiro (2009).

In Rías Baixas DOC, the maximum yield allowed is 12000 kg•ha^{-1}. An average of 10000 kg•ha^{-1} will be considered for Albariño vineyards in full production. At the start of production, the yield used for the calculations was as follows: 1000 kg•ha^{-1} for the 3rd year, 3000, 6000, 8000 and 9000 kg•ha^{-1} for the 4th, 5th, 6th and 7th years and 10000 kg•ha^{-1} for the 8th year ahead.

The income was quantified in scenarios E1, E2 and E3, expressed as constant Euros, with a discount rate of 5%. When losses are expressed as percentage it is referred to E1 data. Fixed and operating costs vary significantly among vineyards due to different factors (size of vineyard, number of plants per ha, trellis system, soil and pest management) not related to virus infection and therefore only differences in the income were used to compare scenarios.

RESULTS AND DISCUSSION

In Rías Baixas, contrary to what has been reported in other grape growing regions due to climatic change (Duchêne and Schneider, 2005; Jones *et al*., 2005), it seems to be a trend to delay the harvest date (Fig. 1) to get the same or higher PAD in the musts. That is the outcome of the wineries quality improvement programmes through bonuses and penalties according to PAD; whether the delay is due to high leafroll prevalence in the region or not, it seems that growers understood that they cannot afford to sell their grapes out of the DOC or risk getting low prices because of low PAD.

Table I summarizes the effect of GLRaV-3 on the PAD of the musts, the differences with the leafroll free ones, the actual PAD when applying the incidence of GLRaV-3 in the vineyard, the price got by the musts of Albariño from the mixed grapes with respect to that which would get a vineyard with only leafroll free plants and the resulting decrease in income (in €•ha^{-1}) due to the lower prices of the musts (an average of 10.5% lower). Growers belonging to cooperative wineries could get higher prices than those signing GPA, but their penalties were higher when they had leafroll disease/lower PAD in their vineyards. The economic impact of leafroll was similar in both vineyards despite the lower incidence of the virus and better ripening conditions in the S vineyard. In years with poor environmental conditions during summer, the risk of musts being under 11º would be high in both areas; and these would be years with higher losses because the price of the grapes could be 35 to 61% lower than the healthy ones, as occurred in 2003 in N and 2002 and 2004 in S. In 2004, the low PAD was not due to weather conditions but to mismanagement (excess of bunches not removed) which affected more the infected plants. The field data from other cultivars, locations and climates support the importance of the leafroll disease as a factor affecting must quality (Charles *et al.*, 2006) and recently several reports confirmed that it prevents the achievement of maximum benefits from a vineyard (Freeborough and Burger, 2008; Atallah *et al.*, 2012; Fuller *et al*., 2013); The benefits from using certified virus-free stock were evaluated in California by Fuller *et al*. (2013). The present study confirms that it applies also to Albariño, even when using a conservative model that did not consider yield losses and despite not being one of the most affected white varieties.

Figures 2 and 3 show the annual and accumulated income for E1, E2 and E3 scenarios with current prices according to (A) and (B) criteria, respectively. The total income during a productive lifespan of 30 years of a vineyard with 25% GLRaV-3 infection is 12.9% (A) or 19.6% (B) lower than a healthy one. If GLRaV-3 would spread to a 100% infection after only 15 years, the decrease in income could be as much as 24.1% (A) or 35.1% (B) compared to the a healthy vineyard. In these conditions the decreases in income could be, in the worst scenario, about 74,000 €•ha^{-1} (Fig. 4). The prices of the Albariño grapes were high when compared to other regions and varieties but the production costs are also high. They are 0.7 €•kg^{-1} or even higher in small plots or in rainy years because of the extra cost of fungicide spraying. Taking into account that in cool years poorer PADs are expected, the cash flow could be negative not only when grapes are under 11º but also when they are only slightly over, which is more probable in highly leafroll infected vineyards.

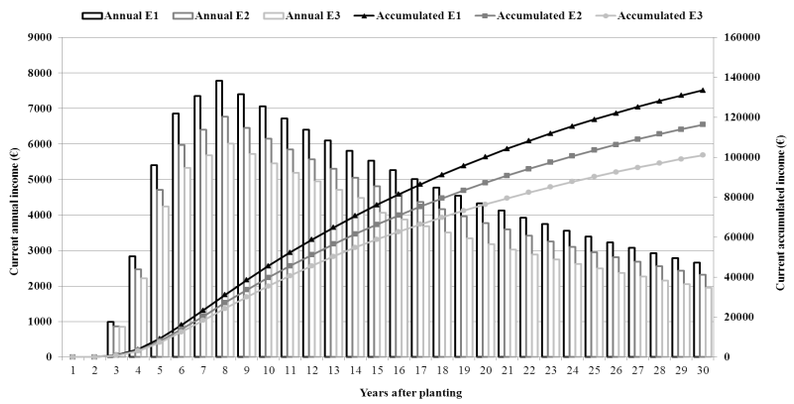

Figure 2. Present annual and accumulated income over a 30 years lifespan of a hectare of Albariño in Rías Baixas DOC using the (A) criterion of prices (grape purchase agreement), with a 5% discount, in scenarios E1 (virus free), E2 (25% GLRaV 3infected vines) and E3 (GLRaV3 spreading until 100% at the 15th year onward).

Rendimentos anuais e acumulados durante a vida útil de 30 anos de um hectare de vinha da casta Alvarinho na DOC Rías Baixas, calculados usando os preços do critério (A) (contrato fixo de compra de uvas) com 5% de desconto, nos cenários E1 (isenta de vírus), E2 (com 25% de infeção com GLRaV3) e E3 (com o aumento progressivo de GLRaV3 até atingir 100% a partir dos 15 anos).

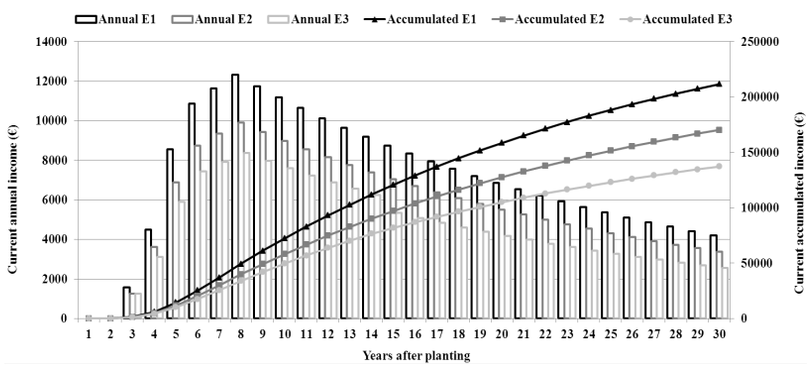

Figure 3. Present annual and accumulated income over a 30 years lifespan of a hectare of Albariño in Rías Baixas DOC, using the (B) criterion of prices (bonus and penalties for PAD), with a 5% discount, in scenarios E1 (virus free), E2 (25% GLRaV 3 infected vines) and E3 (GLRaV3 spreading until 100% at the 15th year onward).

Rendimentos anuais e acumulados durante a vida útil de 30 anos de um hectare de vinha da casta Alvarinho na DOC Rías Baixas, calculados usando os preços do critério (B) (bónus e penalizações conforme o PAD) com 5% de desconto, nos cenários E1 (isenta de vírus), E2 (com 25% de infeção com GLRaV3) e E3 (com o aumento progressivo de GLRaV3 até atingir 100% a partir dos 15 anos).

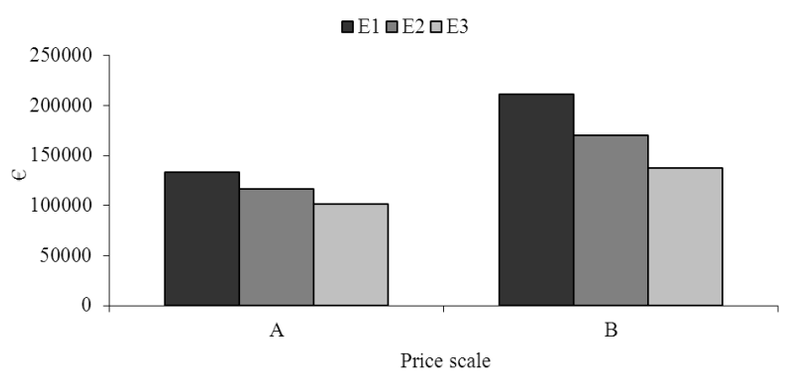

Figure 4. Present accumulated income of a hectare of an Albariño vineyard in Rías Baixas DOC in tree scenarios: E1 (virus free), E2 (25% GLRaV 3infected vines) and E3 (GLRaV3 spreading until 100% at the 15th year onward) using two price scales (A) - grape purchase agreements and (B) - bonus and penalties for PAD established by the cooperative winery.

Rendimentos acumulados de um hectare de vinha da casta Alvarinho na DOC Rías Baixas, comparando três cenários: E1 (isenta de vírus), E2 (com 25% de infeção com GLRaV3) e E3 (com o aumento progressivo de GLRaV3 até atingir 100% a partir dos 15 anos) e usando os preços estabelecidos em (A) - contrato fixo de compra de uvas e em (B) - bónus e penalizações conforme o PAD estabelecido pela adega cooperativa.

As it was mentioned above, producers do not regard leafroll to be economically significant because the decline of the vine is progressive and many factors affect the performance of leafroll infected plants. Yield loss is the most common factor studied as it most clearly affects income. In this work, yield was not taken into account because field data for Albariño as other white cultivars (Wolpert and Vilas, 1992) did not show a clear drop, at least in the two vineyards used as model; in an older one, losses up to 30% were registered but not always statistically significant (Cabaleiro and Segura, 1996). In the literature at least a 10% decrease is always reported and in extreme cases it can go up to 85% (Charles *et al*., 2006). Obviously, in such cases, no further economic study is needed for recommending uprooting. In most studies, the effect on the sugar content of the musts is considered, but as a fixed percentage of price drop (Freeborough and Burger, 2008; Atallah *et al.*, 2012). In this study actual variable decreases in price for Albariño grapes according to PAD were used because that is how the industry works. The losses would be higher if other factors, as the cost of delayed harvest, were taken into consideration; but they are difficult to measure because the level of risk increases as grapes are left longer on the vine, especially in cool climates with high probability of rainfall at the end of September or beginning of October. Furthermore, in good years, delaying the harvest is risky because the cellars could not take any more grapes once they occupy their facilities.

The losses are particularly clear and easier to understand by owners of big vineyards with high technology, where most factors are supposed to be under control after high investments are done. In any case, the main problem is that there is not much to be done to improve the quality of virus infected plants: partial defoliation (Pereira *et al.*, 2012) or thinning of bunches (Lider *et al.*, 1975, Kliewer and Lider, 1976) will increase sugar content but the cost of such actions could be also high and the improvements may not be enough to counteract the damages. Therefore, the main point is: once a vineyard is known to be leafroll infected, the grower should determine whether or not the losses are affordable and when the vineyard has to be partially or completely uprooted and replanted. The need of roguing or an early total uprooting and replanting in areas with well-known varieties that are much affected has been studied by several authors under different scenarios in several countries (Walker *et al*., 2004; Freeborough and Burger, 2008; Atallah *et al.*, 2012). Roguing has been proposed as an effective control measure in red cultivars before the vineyard is 20 years old, where infection rates are under 27 to 30%, the primary source of infection is within the vineyard and there are no neighbouring sources of virus and vectors (Atallah *et al.*, 2012). To those authors "no control" can be economically optimal when an incidence level greater than 25% causes a yield reduction less than 30% and there is no quality penalty. In Albariño there are quality penalties but, like in other white cultivars, roguing is not viable, due to the difficulties in the identification of leafroll infected plants. The use of quick and cheap diagnosis methods as direct immunoprinting-enzyme linked immunosorbent assay (DIP-ELISA) (Couceiro *et al.*, 2006) could help to confirm positives but both in white and red cultivars the delay in detection of infected foci enhances the risk of spread of the virus by vectors. To reduce that risk, the removal of several plants around the symptomatic one has been proposed in several studies (Freeborough and Burger, 2008; Atallah *et al.*, 2012).

Economic losses become really important when the virus spreads and reaches 100%. In this study 15 years were supposed to be necessary to reach that incidence but it could be earlier depending on the mealybug infestation level and the distance to the infected plants (Cabaleiro, 2009). In Rías Baixas, leafroll vectors are not common pests and heavy infestations which are obliged to control are rare; although it seems that they are increasing in the last decade, especially in the south (unpublished data). Without vectors, leafroll incidence in a vineyard will not increase or it will do so very slowly (Cabaleiro *et al.*, 2008). But even if that is the most common case, when leafroll prevalence in a region is high, with average incidences of 30% or higher, economic losses due to the disease could be significant. In Rías Baixas and other regions in Europe, many vineyards are small and properties are sub-divided a great deal. The biggest enterprises are often cooperative ones with hundreds of growers with no more than 1 ha each, and sometimes divided in several plots. Add to this that in traditional vineyards the heterogeneity is an important part in getting the typicality of wines: different ages and rootstocks and many clones of unknown sanitary status. In these conditions, a disease like leafroll is easily not taken into consideration as cause of important losses. When at the end of the 20th century the biggest modern vineyards were planted, especially in the south of the region, no certified virus free plant material was available and that was the reason why the prevalence of several GLRaV is high.

The knowledge of the actual and future economic impact of this disease, also in white varieties, will help to stress the absolute need of using virus free plant material and watching for the presence of mealybugs which are rare nowadays but seem to be much more common than 30 years ago (unpublished data). This study confirms the importance of taking GLRaV into consideration for the future. It has been more than 30 years since the beginning of the expansion of Albariño which in that time had to be done with standard plant material. When those vineyards are replanted, the use of certified virus-free Albariño, would be the guarantee that, in the absence of vectors, the yield and must quality will be maintained throughout the lifespan of the vineyard.

CONCLUSIONS

The leafroll disease is a factor which prevents the achievement of maximum benefits from Albariño vineyards in Rías Baixas even when yield is not significantly affected. The best control measurement to be taken is the use of certificate virus free plants.

There is no way to avoid the estimated losses for the majority of vineyards with leafroll incidence around 25%, but the early detection and control of vectors would avoid the spread of the virus and therefore the strong increase of the losses and reduction of lifespan that has been estimated for vineyards 100% infected.

ACKNOWLEDGMENTS

This work was partly funded by grants from the INIA (VIN00-030), Xunta de Galicia (XUGA200074A93 and PGIDITO3PXIC20001PN), the Ministerio de Ciencia y Tecnología (AGL2002-02438) and the European Commission INTERREG program (AL-VIRUS/SP1.P7). The authors want to thank "Adegas Galegas" (Grupo Galiciano) and Gerardo Mendez (Albariño do Ferreiro) for their collaboration to carry out the field work and to Francisco Tubío for the information and data from Martín Codax winery.

REFERENCES

Atallah S.S., Gómez M.I., Fuchs M.F., Martinson T.D., 2012. Economic Impact of Grapevine Leafroll Disease on *Vitis vinifera* cv. Cabernet franc in Finger Lakes Vineyards of New York. *Am. J. Enol. Viticult.*, **63** (1), 73-79.

Bertolini E., García J., Yuste A., Olmos A., 2010. High prevalence of viruses in table grape from Spain detected by real-time RT-PCR. *Eur. J. Plant Pathol.,* **128**, 283-287.

Besse S., Rütsche C., Gugerli P., 2009. Tentative analysis of the economic impact of grapevine leafroll disease in the vineyard of Valais (Switzerland). *Proceedings of the 16th Congress of the International Council for the Study of Virus and Virus-like Diseases of the Grapevine (ICVG):* Dijon, France, 31 Aug-4 Sept, pp. 232-233.

Boso S., Santiago J.L., Martínez-Rodríguez M.C., 2004. Intravarietal agronomic variability in *Vitis vinifera* L. cv. Albariño. *Am. J. Enol. Viticult.*, **55** (3), 279-282.

Boso, S., Santiago, J.L., Vilanova, M., Martínez, M.C., 2005. Caractéristiques ampélographiques et agronomiques de différents clones du cultivar Albariño (*Vitis vinifera* L.). *Bull de L´OIV,* **889-890**, 143-158.

Cabaleiro C., 2009. Current advances on the epidemiology of leafroll disease. *Proceedings of the 16th Congress of the International Council for the Study of Virus and Virus-like Diseases of the Grapevine (ICVG)*: Dijon, France, 31 Aug-4 Sept, pp. 264-268.

Cabaleiro, C., Segura, A., 1996. Efecto del enrollado de la vid .GLRaV-3 en un viñedo en plena producción del cultivar "Albariño". Invest Agrar: Producción y Protección Vegetal., 11, 451-463.

Cabaleiro C., Segura A., 1997. Some characteristics of the transmission of grapevine leafroll associated virus 3 (GLRaV-3) by *Planococcus citri* Risso. *Eur. J. Plant Pathol.*, **103**, 373-378.

Cabaleiro C., Segura A., 2006. Temporal analysis of grapevine leafroll associated virus 3 (GLRaV-3) epidemics. *Eur. J. Plant Pathol.*, **114**, 441-446.

Cabaleiro C., García-Berrios J., Segura A., 1999. Effect of grapevine leafroll associated virus 3 on the physiology and must of *Vitis vinifera* L. Cv. Albariño following contamination in the field. *Am. J. Enol. Viticult.*, **50**, 40-44.

Cabaleiro C., Couceiro C., Pereira S., Cid M., Barrasa M., Segura A., 2008. Spatial analysis of epidemics of Grapevine leafroll associated virus-3. *Eur. J. Plant Pathol.*, **121**, 121-130.

Charles J.G., Cohen D., Walker J.T.S., Forgie S.A., Bell V.A., Breen K.C., 2006. A review of Grapevine Leafroll associated Virus type 3 (GLRaV-3) for the New Zealand wine industry. Report to New Zealand wine growers, HortResearch. Accessed February 17, 2014 at http://www.nzwine.com/assets/sm/upload/we/Oc/ob/lyNZW_06-105_GLRaV-3_Review_Final_Rpt.pdf

Couceiro C., Cid M., Pereira S., Segura A., Cabaleiro C., 2006. Use of direct immunoprinting (DIP)-ELISA for the detection of grapevine leafroll viruses. Extended abstracts 15th Meeting of ICVG, Stellenbosch, South Africa, pp. 180-181.

Daane K.M., Almeida R.P., Bell V.A., Walker J.T.S., Botton M., Fallahzadeh M., Mani M., Miano J.L., Sforza R., Walton V.L., Zaviezo T., 2012. Biology and management of mealybugs in vineyards. In: N.J Bostanian, C Vincent and R Isaack (Eds.) *Arthropod Management in Vineyards: Pests, Approaches, and Future Directions*. Springer Science+Business Media B.V. Chapter 12, pages 271-307.

Duchêne E., Schneider C., 2005. Grapevine and climatic changes: A glance at the situation in Alsace. *Agron. Sustain. Dev.*, **25**, 93-99.

Fuller K.B., Alston J.M., Golino D.A., 2013. The benefits form certified virus-free stock: A case study of grapevine leafroll-3 in the North coast region of California. Robert Mondavi Institute. Center for wine economics. Accessed February 17, 2014 at: http://vinecon.ucdavis.edu/publications/cwe1306.pdf.

Freeborough M.J., Burger J., 2008. Leafroll: Economic implications. Wynboer. Accessed January 13, 2013 at http://www.wynboer.co.za/recentarticles/200812-leafroll.php3

Garau R., Fiori P.P., Prota V.A., Tolu G., Fiori M., Prota, U., 1997. Effect of virus infection on own-rooted clones of different wine grapes cultivars from Sardinia. *Extended Abstracts 12th Meeting ICVG,* Lisbon (Portugal): pp. 169-170.

García-Berrios J., Pereira S., Enriquez M., Segura A., Cabaleiro C., 2007. Climatic change and effects of the leafroll viruses on the must characteristics of the cv Albariño. *Proceedings of the CONCLIVIT,* Zaragoza, 5-9 April.

Goheen A.C., Cook J.A., 1959. Leafroll (red-leaf or rougeau) and its effects on vine growth, fruit quality and yields. *Am. J. Enol. Viticult.,* **10,** 173-181.

Golino D.A., Weber E., Sim S.T., Rowhani A., 2008. Leafroll disease is spreading rapidly in a Napa Valley vineyard. *California Agric.*, **62** (4), 156-160.

Guidoni S., Mannini F., Ferrandino A., Argamante N., Di Stefano R., 1997. The effect of grapevine leafroll and rugose wood sanitation on agronomic performance and berry and leaf phenolic contento f a Nebbiolo clone (*Vitis vinifera* L.). *Am. J. Enol. Viticult.*, **48** (4), 438-442.

Jones G.V., Duchene E., Tomasi D., Yuste J., Braslavska O., Shultz H., Martinez M.C., Boso S., Langellier F., Perruchot C., Guimberteau G., 2005. Changes in European winegrape phenology and relationships with climate. *Comptes Rendus Proceedings GESCO*, Geisenheim, Germany, **I**, 55-61.

Kliever W.M., Lider L.A., 1976. Influence of leafroll viruses on the composition of Burger fruits. *Am. J. Enol. Viticult.*, **27**, 118-124.

Lider L.A., Goheen A.C., Ferrari N.L., 1975. A comparison between healthy and leafroll affected grapevine planting stocks. *Am. J. Enol. Viticult.*, **26** (3), 144-147.

Manini F., 2003. Virus elimination in grapevine and crop performance. *Extended Abstracts 14th Meeting ICVG*, Locorotondo, Italy, September 12-17.

Martelli G.P., Ghanem-Sabanadzovic A., Agranovsky A.A., Al Rwahnih M., Dolja V.V., Dovas C.I., Fuchs M., Gugerli P. Hu J. S., Jelkmann W, Katis N.I., Maliogka V.I., Melzer M.J., Menzel W., Minafra A., Rott M.E., Rowhani A., Sabanadzovic S., Saldarelli P., 2012. Taxonomic revision of the family *Closteroviridae* with special reference to the grapevine leafroll-associated members of the genus *Ampelovirus* and the putative species unassigned to the family. *J. Plant Path.*, **94** (1): 7-19.

Moutinho-Pereira J., Correia C.M. , Gonçalves B., Bacelar E.A., Coutinho J.F., Ferreira H.F., Lousada J.L., Cortez M.I., 2012. Impacts of leafroll-associated viruses (GLRaV-1 and -3) on the physiology of the Portuguese grapevine cultivar 'Touriga Nacional' growing under field conditions. *Ann. Appl. Biol.*, **160**, 237-249

Pereira S., García-Berrios J.J., Segura A., Cabaleiro C., 2012. Effects of partial defoliation on must quality of cv. Albariño infected by Grapevine leafroll associated virus 3. *Phytopath. Medit.*, **51** (2), 383-389.

Segura A., González M.L., Cabaleiro C., 1993. Presence of grapevine leafroll in North West of Spain. *In:* Gugerli, P. (ed) *Extended Abstracts 11th Meeting ICVG*, Montreux, Switzerland.

Walker J.T.S., Charles J.G., Froud K.J., Connolly P., 2004. *Leafroll virus in vineyards: Modelling the spread and economic impact*. Report to New Zealand Winegrowers Limited, 19 pp.

Walter B., Martelli G.P., 1996. Sélection clonal de la vigne: Sélection sanitaire et sélection pomologique. Influences des viroses et qualité. Effets des viroses sur la culture de la vigne et ses produits. *Bulletin de l´O.I.V.*, **69**, 945-971.

Wolpert J.A., Vilas E.P., 1992. Effect of mild leafroll disease on growth, yield and fruit maturity indices of Riesling and Zinfandel. *Am. J. Enol. Viticult*., **43** (4), 367-369.

Woodham R.C., Emmet L.W., Fletcher G.C., 1984. Effects of thermotherapy and virus status in Sultana. *Vitis,* **23**, 268-273.