CFPA	SAAPPA / SASPA / SAT	DFTS	Winetech
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Indicate (X) client(s) to whom this final report is submitted.
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FINAL REPORT

FOR 2011/12

PROGRAMME & PROJECT LEADER INFORMATION

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PROJECT INFORMATION

Project number	WW 02-19
Project title	The evaluation of different herbicides and herbicide application techniques for total chemical control of leaf-roll infected grapevines, as part of a strategy to prevent the transfer of the virus to newly planted grapevines.
Project Keywords	

Industry programme	**CFPA**	
	Deciduous	
	DFTS	
	Winetech	Soil science
	Other	

Fruit kind(s)	Wine grapes
Start date (dd/mm/yyyy)	01/04/2006
End date (dd/mm/yyyy)	31/03/2012

(Note: adjust footer – insert the project number no, researcher and research institution)

FINAL REPORT

1. Executive summary

None of the treatments applied during the first phase of the trial gave total control of both the scion and rootstock of the 14 year old Chardonnay/Richter 99 vines established on a medium textured soil. These vines were heavily infected with the leaf-roll virus at least four years prior to treatment. Poor vegetative growth might have caused poor translocation of the herbicides to the roots. The most effective treatments were applied to six year old recently infected (two seasons or less) Chardonnay/ Ramsey vines established on a medium textured soil during phase two. Garlon 480 EC applied post-harvest as a basal stem treatment took a full season (from March to March) to kill all roots to a depth of 200 mm or 300 mm. Depending on the season, most roots were controlled in the 300-900 mm soil layer. A post-harvest foliar application of Plenum may also be considered as, within the above-mentioned time frame, the grapevine roots were controlled to a depth of 200 mm and depending on the season, as deep as 500 mm.

The Cabernet/Richter 99 vines planted in the place of the treated grapevines showed no phytotoxic or leaf-roll symptoms for up to two years (end of the trial). These vines were planted four months after the treated grapevines were removed. However, 'normal' grapevines adjacent to the newly planted grapevines only showed leaf-roll symptoms one year later. This probably resulted in one newly planted grapevine out of 36 testing positive with the ELISA test one year after being established and two out of 36 testing positive after two years.

The results will be submitted to the agrochemical company that holds the patent to the above-mentioned two herbicides to help facilitate registration of these chemicals for the control of leaf-roll infected grapevines.

2. Problem identification and objectives

The wine grape industry is currently experiencing a drastic increase in the occurrence of grapevines infected with leaf-roll virus. As the virus has a pronounced negative effect on grape quality and the productive lifespan of the vines, it is important to research methods by which the spread of the virus can be stopped and its occurrence effectively reduced. The danger of the virus being spread from infected vines to adjacent healthy vines by inter alia mealy bug, necessitates fast and effective removal of these vines as a source of contamination. Re-establishing new vines on soil that was previously occupied by infected vines poses a risk as well, as mealy bug carrying the virus may survive on live remnants of the vines previously established on the soil and in doing so infect the newly planted vines

when feeding on them. At present no herbicide is registered for the control of grapevines in existing vineyards or on soils to be re-planted with young vines. The aim of the project is to identify a herbicide(s) that will kill the whole root system of infected grapevines, without damaging the environment, in order to prevent the mealy bug from using it as a food source during winter or after the above-ground parts of the vines have been removed. Data from this project will supply the wine grape industry with guidelines for the safe application of these herbicides and supply data for the registration of these herbicides to this specific purpose. In doing so, the further spread of leaf-roll virus and the accompanying financial losses may be curbed.

The trial was executed in two phases. The aim of the first phase was to identify a herbicide (s) that will kill the whole root system of full bearing grapevines that have been infected with the leaf-roll virus for four years or more. The aim of the second phase of the project was to identify a herbicide/application method combination that will kill the whole root system of recently infected (two seasons or less) full-bearing grapevines.

3. Workplan (materials & methods)

3.1 Phase 1

This phase of the study was executed in a 14 year old leaf-roll infected Chardonnay/99 Richter vineyard established on a medium textured soil at Nietvoorbij Experiment farm in Stellenbosch. The leaf-roll virus and mealy bug status of the grapevines were determined visually before the treatments were applied. The different treatments were applied as described in Table 1. Fourteen treatments were applied post-harvest and fourteen treatments were applied during grapevine berry set to give a total of 28 treatments. The treatments were replicated three times in a randomised block design. Each plot (replication) consisted of 6 vines and the two adjacent working rows. A vine row functioned as a buffer zone between treatments situated in different working rows and two vines were left between treatment plots situated in the same vine row. The trial was repeated to determine whether a difference in the seasonal climatic conditions had an effect on the efficacy of the herbicides.

3.2 Phase 2

This phase of the study was executed in a six year old full bearing Chardonnay/Ramsey vineyard established on a medium textured soil at Nietvoorbij Experiment farm in Stellenbosch. The leaf-roll virus and mealy bug status of the grapevines were determined visually before the treatments were applied. According to the farm manager, affected vines were identified at the earliest during the 2004/05 and 2005/06 seasons (two seasons or less). The different treatments applied during the 2009/10 season and 2010/11 season is described in Tables 2 & 3, respectively.

The grapevines showing no above-ground re-growth were removed from the four most successful treatments during early June 2010 and early July 2011 and replaced by Cabernet/Richter 99 vines planted on 3 August 2010 and 30 August 2011, respectively.

Measurements

Efficacy of herbicides

To determine the grapevine control efficacy of the selected herbicides, the vines were monitored visually for regrowth. The roots of one grapevine per treatment plot (replication) in which no regrowth occurred were inspected visually to determine if they are dead or alive. This was done by digging a profile pit 1.5 m long x1.5 m wide x 1 m deep parallel to the vine row and by inspecting the four profile walls visually for any live roots. The depth at which live roots occurred was recorded. These measurement were done mid-October and mid- March, the two periods during which grapevine root growth is most active.

Occurrence of mealy bug

The effect of the different treatments on the occurrence of mealy bug on the grapevines, as well as the surrounding weeds and cover crops, was monitored visually once a month from August to May.

Occurrence of leaf- roll virus

The leaf-roll virus status of each treatment plot (replication) was determined visually before the treatments were applied. During the second phase of the trial, the occurrence of leaf-roll virus symptoms in the new vines replacing the old ones was monitored visually for one growing season (planted 30 August 2011) and two growing seasons (planted 3 August 2010), respectively. Leaves were sampled during early April 2012 from the Cabernet/Richter 99 vines planted during 2010 and 2011 that showed no visual leaf-roll symptoms. Indirect ELISA for specific or simultaneous detection of GLRaV-1, GLRaV-2 and GLRaV-3 in grapevines as developed by Dr. Goszczynski was done on these vines to verify that they were not contaminated with leaf-roll viruses.

Herbicide phytotoxicity

During the second phase of the trial, the newly planted vines were monitored visually for the first two seasons after planting for any symptoms that may indicate herbicide phytotoxicity. Soil samples were taken from the 0-300 mm soil layer near the trunk of the vines planted end of August 2011. These samples were taken from the all the replications of a treatment. The soil (approximately 500 g air dried soil) was put into a plastic pot with holes in the bottom covered with two layers of paper towel. Three tomato seedlings were planted per pot. Each

pot received 0.1 g of Chemicult dissolved in 50 ml of water directly after planting. The pots were watered by sub-irrigation to keep the soil at field water capacity. The plants were allowed to grow for three weeks and monitored for the development of symptoms that would illustrate herbicide phytotoxicity, such as chlorosis, stunted growth, malformed leaves and irregular leaf blades compared to that of the control treatment.

4. Results and discussion

Phase 1

Milestone (Phase 1)	Achievement (Phase 1)
Determine the grapevine control efficacy of selected herbicides, applied according to different application techniques.	Objective achieved end of March 2009.
Determine the effect of the treatments on the occurrence of mealy bug.	Objective achieved end of March 2009.
Determine the effect of the treatments on the occurrence of leaf-roll virus in grapevines established on the same soil.	Objective irrelevant. None of the treatments controlled the infected grapevines 100%.
Supply wine grape industry with information that may lead to the registration of an herbicide(s) and application method for the total control of leaf-roll infected grapevines.	Objective irrelevant. None of the treatments controlled the infected grapevines 100%.

Efficacy of herbicides applied March 2007

The herbicides were applied as described in Table 4. In contrast to the results of the 2006/07 season, three of the post-harvest treatments showed no above-ground re-growth up to one year after application (March 2008), namely the foliar application (FA) of Brush Off (same as 2006/07 season), as well as the FA treatments of Confront and Plenum (Table 4). The basal stem (BS) treatment of Garlon 480 EC gave promising results with only 6% of the grapevines showing above-ground re-growth. The efficacy of these treatments improved when applied directly after harvest, with the exception of Brush Off that did not seem to be affected by the time of application in the post-harvest period. This indicates the importance of applying these herbicides before grapevine growth declines too severely in the post-harvest period. Visual evaluation of the roots in the March 2007 application sites of the above-mentioned treatments showed that dieback of roots occurred down to a depth of 100 mm by the end of March 2008, one year later (data not shown). It is a concern that the live roots in the deeper soil layers may cause re-growth to occur over the long-term.

Efficacy of herbicides applied early December 2007

The berry set applications applied during 2007 resulted in the grapevines in the CS and the BS treatments showing no re-growth above ground after a period of approximately four months (Table 5). In the case of Garlon 480 EC the results of the current season was contradictory to that of the previous season. The reason for this is not clear.

Efficacy of herbicides applied April 2006 and early December 2006

The grapevines in the treatment in which Brush off (FA) was administered post-harvest during 2006 died back totally above-ground and showed no re-growth up to 18 months after application (Table 3). Seventy two percent of the grapevines, however, showed re-growth 24 months after application (March 2008). The re-growth occurred despite the fact that the roots had died back to a depth of between 350 mm and 500 mm as determined visually in profile pits during October 2007 and March 2008.

Garlon 480 EC (FA) and Confront (FA) administered during berry set 2006 caused the grapevines to die back totally and prevented re-growth up to 12 months after application (October 2007). In the case of Garlon 480 EC (FA) the roots died back to a depth of 300 mm, whereas poor root growth and damaged roots were observed to a depth of 900 mm in the Confront (FA) treatment. As far as the above-ground growth is concerned, similar results were achieved with the CS treatments of Timbrel 360 SL, Brush Off and Confront. Eighteen months (March 2008) after application, however, re-growth occurred on all treatments to a greater or lesser extent. At this stage, Roundup (FA) and Plenum (CS) gave the best margin of control.

Occurrence of mealy bug

The first evaluation was done during May 2006, during which it was found that 70% of the grapevines were infested with mealy bug. The above-ground level of infestation for the period October 2006 to March 2008 dropped to approximately 1%, while no mealy bug was found in the soil, although the grapevine roots were still alive.

Conclusions

None of the treatments gave total control of both the scion and rootstock of the leaf-roll infested grapevines. The 14 year old Chardonnay/Richter 99 vines were heavily infected with the leaf-roll virus at the beginning of the trial for a period of at least four years. The resulting poor vegetative growth might have caused poor translocation of the herbicides to the target areas in the roots. Grapevines that are heavily infected or have been infected with

the leaf-roll virus for a few seasons can, therefore, not be controlled 100% by the herbicides tested in the trial.

The foliar applied herbicides that gave the best margin of control are Brush Off, Garlon 480 EC and Plenum and Confront. The cut stump treatments executed during berry set, in which Brush Off, Timbrel 360 SL, Plenum and Confront were applied, gave promising results as well. The basal stem treatment of Garlon 480 EC also showed promise. These treatments were, therefore, included in phase two of the study (Table 2).

Phase 2

Milestone (Phase 2)	Achievement (Phase 2)
Determine the grapevine control efficacy of selected herbicides, applied according to different application techniques to both non-bearing grapevines, as well as recently infected full-bearing grapevines.	Objective achieved end of March 2012 for recently infected full bearing grapevines. Producers were not willing to allow tests to be done on non-bearing grapevines
Determine the effect of the treatments on the occurrence of mealy bug.	Objective achieved end of March 2012.
Determine the effect of the treatments on the occurrence of leaf-roll virus in grapevines established on the same soil.	Objective achieved March 2012.
Supply the wine grape industry with information that may lead to the registration of an herbicide(s) and application method for the control of leaf-roll infected non-bearing grapevines and full-bearing grapevines recently infected with the leaf-roll virus, which may help to prevent the transfer of the virus to young grapevines established on the same soil.	Objective achieved end of March 2012 for recently infected full bearing grapevines. Producers were not willing to allow tests to be done on non-bearing grapevines.

<u>Efficacy of herbicides applied March 2009 (post-harvest)</u>

All the post-harvest applications gave 100% control of the above-ground growth of the recently infected six year old Chardonnay/Ramsey grapevines during October 2009 (Table 7). However, only the roots of the foliar application of the 0.75% solutions of Garlon 480 EC and Plenum caused the grapevine roots to disintegrate to a depth of100 mm during October 2009. The foliar application of the 0.75% solutions of Garlon 480 EC and Plenum, as well as

the basal stem treatment with a 2% solution of Garlon 480 EC were the only treatments in which no above-ground growth occurred during February 2010 and in which dead roots occurred to a depth of 450 mm, 200 mm and 200 mm, respectively. These three treatments were, therefore, applied to previously untreated and recently infected seven year old Chardonnay/Ramsey grapevines on 25 March 2010 in order to determine the seasonal influence on grapevine control efficacy (Table 3).

Efficacy of herbicides applied December 2009 (berry set)

With the exception of the foliar application of a 0.5% solution of Garlon 480 EC and the 3% solution of Confront applied to the cut stump, all the treatments controlled the above-ground growth of the grapevines (Table 8). However, only the basal stem treatment with a 2% solution of Garlon 480 EC killed the grapevine roots in the 0-200 mm soil layer. This treatment was, therefore, the only berry set treatment that was repeated during the 2010/11 season to determine the seasonal influence on grapevine control efficacy (Table 3).

Efficacy of herbicides applied March 2010 (post-harvest)

All the post-harvest applications gave 100% control of the above-ground growth of the recently infected seven year old Chardonnay/Ramsey grapevines during November 2010 (Table 9). The foliar application of the 0.75% solution of Garlon 480 EC caused the grapevine roots to disintegrate to a depth of between 50-200 mm by November 2010. In the case of the foliar applied Plenum (0.75% solution) dead roots were detected to a depth of 400 mm. However, some of the roots were still alive in this soil layer. The roots in the basal stem treatment with a 2% solution of Garlon 480 EC were alive throughout the profile. This supports the data of the previous season. Similar to the 2009/10 season, no above-ground growth occurred during the post-harvest period (March 2011). During March 2011, 50% of the roots were dead to a depth of 400 mm in the treatment in which 0.75% of Garlon 480 EC was foliar applied post-harvest). This supports the data of the 2009/10 season. The foliar application of Plenum (0.75% solution) caused the roots to die back to a depth of between 200-500 mm, the treatment giving more effective control than that observed during the previous season. In the case of the 2% Garlon 480 EC basal stem treatment, all the roots died back to a depth of 300 mm with most of the roots dying back to a depth of 900 mm. The control achieved with this treatment during the 2010/11 season is much more effective than that achieved during the 2009/10 season. The above-mentioned results indicate a strong seasonal effect on the translocation and eventual grapevine control efficacy of Garlon 480 EC and Plenum.

Efficacy of herbicides applied December 2010 (berry set)

The basal stem treatment with Garlon 480 EC controlled the above-ground growth of the grapevines (Table 9). It also killed 50% of the grapevine roots in the 0-150 mm soil layer. This supports the results of the previous (2009/10) season.

Occurrence of leaf-roll virus and herbicide phytotoxicity symptoms in grapevines established on the same soil.

No visual symptoms indicating leaf-roll virus infection or herbicide phytotoxicity were detected on the grapevines planted 3 August 2010 and 30 August 2011. Indirect ELISA for specific or simultaneous detection of GLRaV-1, GLRaV-2 and GLRaV-3 was performed on leaf samples taken on 19 April 2012 from all the Cabernet/Richter 99 vines planted 3 August 2010 and 30 August 2011. Two years after these vines were established (vines planted 3 August 2010), one vine in the treatment where Garlon 480 EC was used as a foliar application post-harvest, as well as one vine where Garlon 480 EC was applied as a basal stem treatment at berry set, tested positive. One year after these vines were established (vines planted 30 August 2011), one vine in the treatment where Plenum was used as a foliar application post-harvest, tested positive. In all three cases, the Chardonnay/Ramsey grapevines adjacent to the affected Cabernet/Richter 99 vines did not show leaf-roll symptoms when the new vines where planted, but showed visual symptoms during the April 2012 visual evaluation. It is, therefore, possible that these infected full bearing Chardonnay/Ramsey vines could have facilitated the contamination of the newly planted grapevines.

Occurrence of mealy bug

The above-ground level of infestation never exceeded 1%, while no mealy bug was found in the soil, although some of the grapevine roots were still alive.

Conclusions

There are indications that climatic variation between seasons could have an influence on the ability of the herbicides to kill the roots of the grapevines in the deeper soil layers.

Full bearing grapevines recently (less than two years) infected with leaf-roll virus can be controlled chemically with Garlon 480 EC applied post-harvest as a basal stem treatment. The treatment takes a full season to kill all roots to a depth of 200 mm to 300 mm. Depending on grapevine root activity, most roots may be controlled in the 300-900 mm soil layer as well. A post-harvest foliar application of Plenum may also be considered as, within

the above-mentioned time frame, the roots of recently infected grapevines were controlled to a depth of 200 mm and depending on the season, as deep as 500 mm.

New grapevines planted after 18 months on the same sites where the infected grapevines were controlled chemically and removed after 14 months established successfully and showed no phytotoxic symptoms. However, 'normal' grapevines adjacent to the grapevines showing visual leaf-roll symptoms should be controlled as well, as the chances are that they are also infected with the leaf-roll virus. These grapevines may result in the newly planted vines becoming infected within a year or two.

5. Accumulated outputs

Technology development, products and patents

Full bearing grapevines recently (less than two years) infected with leaf-roll virus can be controlled chemically with Garlon 480 EC applied post-harvest as a basal stem treatment. The treatment takes a full season to kill all roots to a depth of 200 mm to 300 mm. Depending on grapevine root activity, most roots may be controlled in the 300-900 mm soil layer as well.

A post-harvest foliar application of Plenum may also be considered as, within the above-mentioned time frame, the roots of recently infected grapevines were controlled to repeatedly to a depth of 200 mm and depending on the season, as deep as 500 mm. This control measure should, however, only be applied in situations where a whole vineyard or big infected areas within a vineyard needs to be eradicated. The control of single vines within a vineyard will result in dieback of the adjacent vines, or at the least affect the vegetative growth of the nearest cordon arm of these vines negatively.

New grapevines planted after 18 months on the same sites where the infected grapevines were controlled chemically and removed after 14 months established successfully and showed no phytotoxic symptoms. However, 'normal' grapevines adjacent to the grapevines showing visual leaf-roll symptoms should be controlled as well, as the chances are that they are also infected with the leaf-roll virus. These grapevines may result in the newly planted vines becoming infected within a year or two.

These guidelines will be submitted to the agrochemical company that holds the patent to the above-mentioned herbicides to help facilitate registration of these chemicals for the control of leaf-roll infected grapevines.

Human resources development/training
None

Publications (popular, press releases, semi-scientific, scientific)
None

Presentations/papers delivered

FOURIE, J.C., 2006. The evaluation of different herbicides and herbicide application techniques for total chemical control of leaf-roll infected grapevines, as part of a strategy to prevent the transfer of the virus to newly planted grapevines. Grapevine Virus Workshop 6, 15 August, Stellenbosch.

FOURIE, J.C., 2007. Evaluation of herbicides and herbicide application techniques for total chemical control of leaf-roll infected grapevines. Grapevine Virus Workshop 7, 2 May, Stellenbosch.

FOURIE, J.C., 2008. Evaluation of herbicides and application techniques for total control of leaf-roll infected grapevines. Grapevine Virus Workshop 8, 19 August, Stellenbosch.

OCHSE, C.H., FOURIE, J.C. & FREITAG, K., 2009. Evaluation of herbicides and herbicide application techniques for chemical control of leaf-roll infected grapevines. Poster. Combined Congress, 21 January, Stellenbosch.

FOURIE, J.C., 2009. Chemical control of leaf-roll infected grapevines – part of a strategy to prevent transfer of virus to newly planted grapevines. *Talk.* Ninth Winetech Grapevine Virus Workshop, 15 September, Stellenbosch.

FOURIE, J.C., 2009. Chemical control of leaf-roll infected grapevines. *Talk.* ARC/Winetech project visit, 18 November, Stellenbosch.

FOURIE, J.C., 2009. Efficacy of post-harvest application of different herbicides for the control of leaf-roll infected grapevines. *Talk.* ARC/Winetech project visit, 18 November, Stellenbosch.

OCHSE, C.H., FOURIE, J.C. & FREITAG, K., 2010. Evaluation of herbicides and herbicide application techniques for chemical control of leaf-roll infected grapevines. Poster. 32nd Conference of the South African Society for Enology & Viticulture (SASEV) Congress, 18 & 19 November, Somerset West.

FOURIE, J.C., 2011. Evaluation of herbicides for the control of leaf-roll infected grapevines. *Talk.* Grapevine Virus Workshop no 9, 24 May, Stellenbosch.

4. Total cost summary of project

	Year	CFPA	Deciduous	DFTS	Winetech	THRIP	Other	TOTAL
Total cost in real terms for year 1	2007/08				134 847		209 151	**343 998**
Total cost in real terms for year 2	2008/09				174 875		182 013	**356 888**
Total cost in real terms for year 3	2009/10				124 961		130 061	**255 022**
Total cost in real terms for year 4	2010/11				196 423		204 440	**400 863**
Total cost in real terms for year 5	2011/12				196 423		204 440	**400 863**
TOTAL					**827 529**		**930 105**	**1 757 634**

Table 1. Treatments applied during phase 1.

Herbicide	Dosage	Application method
Roundup (360 g/L glyphosate)	5% solution	Foliar
MCPA 400 SL (400 g/L MCPA)	5 % solution plus 0.05 % Agral 90	Foliar
Brush Off (200 g/L metsulfuron methyl)	80 g/100 L water plus 0.05 % Agral 90	Foliar
Garlon 480 EC (480 g/L triclopyr)	0.5 % solution plus 0.05 % Actipron	Foliar
Confront (90 g/L triclopyr & 270 g/L clopyralid)	0.7 % solution plus 0.5 % Actipron	Foliar
Plenum (80 g/L picloram & 80 g/L fluroxypyr)	0.75 % solution plus 0.5 % Actipron	Foliar
Timbrel 360 SL (360 g/L triclopyr)	3 % solution plus 0.5 % Actipron	Cut stump
Confront	3 % solution plus 0.5 % Actipron	Cut stump
Plenum	1.5 % solution plus 0.5 % Actipron	Cut stump
Brush Off	180 g/100 L water plus 0.05 % Agral 90	Cut stump
Garlon 480 EC	2 % solution in diesel	Basal stem
Roundup	5 % solution	Fresh wounds
MCPA 400 S	5 % solution plus 0.05 % Agral 90	Fresh wounds
None (Control)	None (control)	None

Table 2. Treatments applied during phase 2, 2009/10 season.

Herbicide	Dosage	Application method	Time of application
Brush Off (200 g/L metsulfuron methyl)	80 g/100 L water plus 0.05 % Agral 90	Foliar	Post harvest
Brush Off	100 g/100 L water plus 0.05 % Agral 90	Foliar	Post harvest
Garlon 480 EC (480 g/L triclopyr)	0.5 % solution plus 0.5 % Actipron	Foliar	Post harvest
Garlon 480 EC	0.75 % solution plus 0.5 % Actipron	Foliar	Post harvest
Plenum (80 g/L picloram & 80 g/L fluroxypyr)	0.75 % solution plus 0.5 % Actipron	Foliar	Post harvest
Garlon 480 EC	2 % solution in diesel	Basal stem	Post harvest
None (Control)	None (control)	None	Post harvest
Garlon 480 EC	0.5 % solution plus 0.5 % Actipron	Foliar	Berry set
Garlon 480 EC	0.75 % solution plus 0.5 % Actipron	Foliar	Berry set
Garlon 480 EC	2 % solution in diesel	Basal stem	Berry set
Brush Off	180 g/100 L water plus 0.05 % Agral 90	Cut stump	Berry set
Brush Off	200 g/100 L water plus 0.05 % Agral 90	Cut stump	Berry set
Timbrel 360 SL (360 g/L triclopyr)	3 % solution plus 0.5 % Actipron	Cut stump	Berry set
Timbrel 360 SL	5 % solution plus 0.5 % Actipron	Cut stump	Berry set
Plenum	1.5 % solution plus 0.5 % Actipron	Cut stump	Berry set
Confront	3 % solution plus 0.5 % Actipron	Cut stump	Berry set
Confront	5 % solution plus 0.5 % Actipron	Cut stump	Berry set
None (Control)	None (control)	None	Berry set

Table 3. Treatments applied during phase 2, 2010/11 season.

Herbicide	Dosage	Application method	Time of application
Garlon 480 EC (480 g/L triclopyr)	0.75 % solution plus 0.5 % Actipron	Foliar	Post harvest
Plenum (80 g/L picloram & 80 g/L fluroxypyr)	0.75 % solution plus 0.5 % Actipron	Foliar	Post harvest
Garlon 480 EC	2 % solution in diesel	Basal stem	Post harvest
No herbicide	Control	None	Post harvest
Garlon 480 EC	2 % solution in diesel	Basal stem	Berry set
No herbicide	Control	None	Berry set

Table 4. The grapevine control efficacy of seven herbicides applied selectively by means of four application techniques after harvest on 26 April 2006 and 26 March 2007 in a Chardonnay/99 Richter vineyard as evaluated March 2007 and March 2008, respectively (approximately one year after application).

Application technique	Herbicide	Grapevines alive or showing re-growth (%)	
		Applied 26 April 2006	Applied 26 March 2007
Foliar	Roundup (360 g/L glyphosate)	6	28
	MCPA 400 SL (400 g/L MCPA)	100	100
	Brush Off (200 g/L metsulfuron methyl)	**0**	**0**
	Garlon 480 EC (480 g/L triclopyr)	100	44
	Confront (90 g/L triclopyr & 270 g/L clopyralid)	100	**0**
	Plenum (80 g/L picloram & 80 g/L fluroxypyr)	6	**0**
Cut stump	Timbrel 360 SL (360 g/L triclopyr)	100	67
	Confront	100	22
	Plenum	100	28
	Brush Off	28	56
Basal stem	Garlon 480 EC	33	6
Fresh wounds	Roundup	100	100
	MCPA 400 S	100	100
None	None (Control)	100	100

Table 5. The grapevine control efficacy of seven herbicides applied selectively by means of four application techniques during berry set on 6 December 2006 and 12 December 2007 in a Chardonnay/99 Richter vineyard as evaluated March 2007 and March 2008, respectively (approximately six months after application)

Application technique	Herbicide	Grapevines alive or showing re-growth (%)	
		Applied 6 December 2006	Applied 12 December 2007
Foliar	Roundup (360 g/L glyphosate)	11	44
	MCPA 400 SL (400 g/L MCPA)	100	100
	Brush Off (200 g/L metsulfuron methyl)	100	44
	Garlon 480 EC (480 g/L triclopyr)	**0**	**0**
	Confront (90 g/L triclopyr & 270 g/L clopyralid)	6	78
	Plenum (80 g/L picloram & 80 g/L fluroxypyr)	6	44
Cut stump	Timbrel 360 SL (360 g/L triclopyr)	**0**	**0**
	Confront	6	**0**
	Plenum	**0**	**0**
	Brush Off	**0**	**0**
Basal stem	Garlon 480 EC	22	**0**
Fresh wounds	Roundup	100	89
	MCPA 400 S	100	100
None	None (Control)	100	100

Table 6. The grapevine control efficacy of seven herbicides applied selectively by means of four application techniques during two growth phases of the Chardonnay/99 Richter vines in the 2006/07 season, as evaluated October 2007 and March 2008.

Application technique	Herbicide	Grapevines alive or showing re-growth (%)			
		Applied post-harvest 2006		Applied berry set 2006	
		October 2007	March 2008	October 2007	March 2008
Foliar	Roundup (360 g/L glyphosate)	33	22	6	6
	MCPA 400 SL (400 g/L MCPA)	100	100	100	100
	Brush Off (200 g/L metsulfuron methyl)	**0**	72	39	89
	Garlon 480 EC (480 g/L triclopyr)	39	28	**0**	28
	Confront (90 g/L triclopyr & 270 g/L clopyralid)	89	94	**0**	61
	Plenum (80 g/L picloram & 80 g/L fluroxypyr)	22	33	6	67
Cut stump	Timbrel 360 SL (360 g/L triclopyr)	28	44	**0**	39
	Confront	39	89	**0**	44
	Plenum	94	100	33	11
	Brush Off	28	67	**0**	39
Basal stem	Garlon 480 EC	17	28	22	22
Fresh wounds	Roundup	100	100	100	100
	MCPA 400 S	100	100	94	100
None	None (Control)	100	100	100	100

Table 7. The effect of the post-harvest treatments, applied 30 March 2009, on the above-ground growth and root growth of six year old Chardonnay/Ramsey grapevines as evaluated visually during October 2009 and February/March 2010.

Herbicide	Dosage	Application method	October 2009		February/March 2010.	
			Above-ground growth	Root growth	Above-ground growth	Root growth
Brush Off (200 g/L metsulfuron methyl)	80 g/100 L water plus 0.05 % Agral 90	Foliar	**Absent**	Alive throughout soil profile	Present	Alive throughout soil profile
Brush Off	100 g/100 L water plus 0.05% Agral 90	Foliar	**Absent**	Alive throughout soil profile	Present	Alive throughout soil profile
Garlon 480 EC (480 g/L triclopyr)	0.5 % solution plus 0.5 % Actipron	Foliar	**Absent**	Alive throughout soil profile	Present	Alive throughout soil profile
Garlon 480 EC	0.75 % solution plus 0.5 % Actipron	Foliar	**Absent**	**Roots dead 0-100 mm soil layer**	**Absent**	**Roots dead 0-450 mm soil layer**
Plenum (80 g/L picloram & 80 g/L fluroxypyr)	0.75 % solution plus 0.5 % Actipron	Foliar	**Absent**	**Roots dead 0-100 mm soil layer**	**Absent**	**Roots dead 0-200 mm soil layer**
Garlon 480 EC	2 % solution in diesel	Basal stem	**Absent**	Alive throughout soil profile	**Absent**	**Roots dead 0-200 mm soil layer**
None (Control)	None (control)	None	Present	Alive throughout soil profile	Present	Alive throughout soil profile

Table 8. The effect of the berry set treatments, applied 2 December 2009, on the above-ground growth and root growth of six year old Chardonnay/Ramsey grapevines as evaluated visually during February/March 2010.

Herbicide	Dosage	Application method	February/March 2010.	
			Above-ground growth	Root growth
Garlon 480 EC (480 g/L triclopyr)	0.5 % solution plus 0.5 % Actipron	Foliar	Present	Alive throughout soil profile
Garlon 480 EC	0.75 % solution plus 0.5 % Actipron	Foliar	**Absent**	Alive throughout soil profile
Garlon 480 EC	2 % solution in diesel	Basal stem	**Absent**	**Roots dead 0-200 mm soil layer**
Brush Off (200 g/L metsulfuron methyl)	180 g/100 L water plus 0.05 % Agral 90	Cut stump	**Absent**	Alive throughout soil profile
Brush Off	200 g/100 L water plus 0.05 % Agral 90	Cut stump	**Absent**	Alive throughout soil profile
Timbrel 360 SL (360 g/L triclopyr)	3 % solution plus 0.5 % Actipron	Cut stump	**Absent**	Alive throughout soil profile
Timbrel 360 SL	5 % solution plus 0.5 % Actipron	Cut stump	**Absent**	Alive throughout soil profile
Plenum (80 g/L picloram & 80 g/L fluroxypyr)	0.75 % solution plus 0.5 % Actipron	Cut stump	**Absent**	Alive throughout soil profile
Confront (90 g/L triclopyr & 270 g/L clopyralid)	3 % solution plus 0.5 % Actipron	Cut stump	Present	Alive throughout soil profile
Confront	5 % solution plus 0.5 % Actipron	Cut stump	**Absent**	Alive throughout soil profile
None (Control)	None (control)	None	Present	Alive throughout soil profile

Table 9. The effect of the post-harvest treatments (applied 25 March 2010) and the berry set treatments (applied 1 December 2010), on the above-ground growth and root growth of seven year old Chardonnay/Ramsey grapevines as evaluated visually during November 2010 and March 2011.

Herbicide	Dosage	Application method	November 2010		March 2011.	
			Above-ground growth	Root growth	Above-ground growth	Root growth
Post-harvest application						
Garlon 480 EC (480 g/L triclopyr)	0.75 % solution plus 0.5 % Actipron	Foliar	**Absent**	**Roots dead to a depth of 50 mm to 200 mm**	**Absent**	**50% of the roots dead to a depth of 400 mm**
Plenum (80 g/L picloram & 80 g/L fluroxypyr)	0.75 % solution plus 0.5 % Actipron	Foliar	**Absent**	**Some roots dead to a depth of 400 mm**	**Absent**	**Dead roots to a depth of 200 mm to 500 mm**
Garlon 480 EC	2 % solution in diesel	Basal stem	**Absent**	Alive throughout soil profile	**Absent**	**All roots dead to a depth of 300 mm, most roots dead to a depth of 900 mm**
None (Control)	None (control)	None	Present	Alive throughout soil profile	Present	Alive throughout soil profile
Berry set application						
Garlon 480 EC	2 % solution in diesel	Basal stem	NA[1]	NA	**Absent**	**50% of roots dead in 0-150 mm soil layer**
None (Control)	None (control)	None	NA	NA	Present	Alive throughout soil profile

[1]Not applicable

Table 10. The GLRaV-1, GLRaV-2 and GLRaV-3 status of the Cabernet/Richter 99 vines planted 3 August 2010 as determined 19 April 2012.

Herbicide	Dosage	Application method & time	Replication	Vine number	GLRaV-1, 2 & 3 ELISA
Garlon 480 EC (480 g/L triclopyr)	0.75 % solution plus 0.5 % Actipron	Foliar, Post-harvest	1	1	**Positive**
			1	2	Negative
			1	3	Negative
			2	1	Negative
			2	2	Negative
			2	3	Negative
			3	1	Negative
			3	2	Negative
			3	3	Negative
Plenum (80 g/L picloram & 80 g/L fluroxypyr)	0.75 % solution plus 0.5 % Actipron	Foliar, Post-harvest	1	1	Negative
			1	2	Negative
			1	3	Negative
			2	1	Negative
			2	2	Negative
			2	3	Negative
			3	1	Negative
			3	2	Negative
			3	3	Negative
Garlon 480 EC	2 % solution in diesel	Basal stem, Post-harvest	1	1	Negative
			1	2	Negative
			1	3	Negative
			2	1	Negative
			2	2	Negative
			2	3	Negative
			3	1	Negative
			3	2	Negative
			3	3	Negative
Garlon 480 EC	2 % solution in diesel	Basal stem, Berry set	1	1	Negative
			1	2	Negative
			1	3	Negative
			2	1	Negative
			2	2	Negative
			2	3	Negative
			3	1	Negative
			3	2	**Positive**
			3	3	Negative

Table 11. The GLRaV-1, GLRaV-2 and GLRaV-3 status of the Cabernet/Richter 99 vines planted 30 August 2011 as determined 19 April 2012.

Herbicide	Dosage	Application method & time	Replication	Vine number	GLRaV-1, 2 & 3 ELISA
Garlon 480 EC (480 g/L triclopyr)	0.75 % solution plus 0.5 % Actipron	Foliar, Post-harvest	1	1	Negative
			1	2	Negative
			1	3	Negative
			2	1	Negative
			2	2	Negative
			2	3	Negative
			3	1	Negative
			3	2	Negative
			3	3	Negative
Plenum (80 g/L picloram & 80 g/L fluroxypyr)	0.75 % solution plus 0.5 % Actipron	Foliar, Post-harvest	1	1	**Positive**
			1	2	Negative
			1	3	Negative
			2	1	Negative
			2	2	Negative
			2	3	Negative
			3	1	Negative
			3	2	Negative
			3	3	Negative
Garlon 480 EC	2 % solution in diesel	Basal stem, Post-harvest	1	1	Negative
			1	2	Negative
			1	3	Negative
			2	1	Negative
			2	2	Negative
			2	3	Negative
			3	1	Negative
			3	2	Negative
			3	3	Negative
Garlon 480 EC	2 % solution in diesel	Basal stem, Berry set	1	1	Negative
			1	2	Negative
			1	3	Negative
			2	1	Negative
			2	2	Negative
			2	3	Negative
			3	1	Negative
			3	2	Negative
			3	3	Negative