SUBSURFACE IRRIGATION: A MEANS TO REDUCE CHEMICAL AND WATER INPUTS IN VINEYARDS

Authors: Mark KRASNOW[1*], Danielle MCMILLAN[1], Allison HAYWOOD[1]

[1]*Thoughtful Viticulture Ltd., Blenheim, New Zealand*

*Corresponding author: *thoughtfulviticulture@gmail.com*

Abstract:

Context and purpose of the study – Grape growers around the world are seeking to reduce their reliance on herbicides. However, traditional alternatives to chemical weed control do not always integrate seamlessly into established vineyard operations. Employing nonchemical weed management often requires trellis alterations, purchasing or hiring new equipment, and depending on region, may significantly increase tractor passes required to reach desired level of weed control. Critical thinking and thoughtful strategies are necessary to minimize expenditures and maintain quality during the transition away from herbicides. In this trial, irrigation was installed underground in an effort to minimize water loss due to evaporation, better direct the water to the vines, and reduce weed growth in the difficult to control undervine area.

Material and methods - Split-plot trials were established, with sections of the vineyard having dripline installed 30 cm below the surface and 30 cm off the vine row, rather than the standard above ground in-row configuration. Trials were carried out in Syrah vineyards in Hawke's Bay and Sauvignon blanc vineyards in Marlborough, both in New Zealand. Vines received the same irrigation amounts and timing, canopy management, and spray regime as the control, the only difference being the location of the dripline. Five two vine replicates were set up in each treatment for measurements of vine performance, fruit development, juice composition, and productivity. Undervine weed growth was assessed visually as well as by measuring fresh biomass within a 625 cm^2 quadrat in the vine row at budburst, flowering, veraison, and harvest.

Results - There were no consistent significant differences in canopy development, midday stem water potential, berry growth, juice chemistry, and productivity between vines receiving their water from below ground rather than above. The major consistent difference between treatments was in the amount of weed growth in the challenging undervine area. Once regular irrigation was established in the blocks, there were significant differences in the undervine weed growth between treatments. Irrigation fed weeds in the subsurface treatment grew in the alleyway, where they could be controlled with a normal mowing pass, rather than specialized under vine equipment. Having some blocks with subsurface lines allows growers to irrigate the subsurface blocks during the day and above ground blocks at night, reducing evaporative losses. Industry trials with subsurface irrigation showed that water use could be reduced by 30% with no loss in yield or quality compared with aboveground irrigation. Subsurface irrigation offers a viable way to reduce the need for herbicide sprays, and offers the potential to more efficiently irrigate, thereby reducing both the water and chemical footprints of vineyards.

Keywords: Irrigation, Subsurface Irrigation, Herbicide reduction, Climate Change, Sustainability.

1. Introduction

Negative effects of herbicides on microbial populations have been shown in many studies (Araujo et al., 2003; Mekwatanakarn and Sivasithamparam, 1987; Gorlach-Lira et al, 1997). Herbicides have also been shown to affect nutrient cycling in soils (Sannino and Gianfreda, 2001) and to induce resistance in weed species (reviewed by Warwick, 1991). In addition to these, there is growing consumer demand for herbicide-free products. It is therefore necessary that the wine industry develop ways to farm that reduce, or ideally eliminate, the need for herbicides.

An impediment to growers moving away from herbicides is the increased cost and slow groundspeed of nonchemical weeding equipment. To economically farm without herbicides, undervine weeding passes need to be minimised. Weeds directly in line with the vine trunks require articulating machinery, rather than stationary machinery like a rollhacke or mower. This type of machinery generally requires slow tractor speed (2-4 km/h), compared with herbicide spraying, mowing, or a rollhacke (7-8 km/h).

Irrigated vineyards throughout New Zealand utilise drip irrigation to water the vines, with the dripline suspended on the trellis in the vine row. Drip irrigation has the potential to use water resources efficiently, especially compared with sprinkler or furrow irrigation (Locascio, 2005). Compared with other forms of irrigation, drip irrigation reduces evaporative losses, and improves irrigation uniformity (Schwankl et al., 1996). However, applied irrigation water and fertigation from aboveground in the vine row feeds any undervine weeds first, and the vines only receive what they do not take up. Installing the dripline underground has the potential to further increase water efficiency by preventing evaporation from the surface, reducing soil erosion or irrigation runoff on slopes, and decreasing humidity and disease pressure in the vineyard. Previous work in grapes has shown no negative effect on growth or productivity of grapevines from subsurface irrigation (Pisciotta et al., 2018; Ma et al., 2020). A side benefit to subsurface drip irrigation, which heretofore has not been investigated, is the potential reduction in weed growth under the vines. Since water is applied beneath the surface and off the vine row, it is less available to the weed seed bank under the vines, and thus the germination and growth of undervine weeds is entirely reliant on rainfall. This would greatly reduce the amount and speed of weed growth in the challenging undervine area, and thus the time and expense of dealing with them for the vineyard manager.

While subsurface irrigation has been primarily marketed and studied in terms of the water savings it offers to growers, another potential benefit of its use in vineyards could be reduced need for herbicides. Considering the potential benefits of subsurface irrigation, this trial assessed the effects of relocating the dripline underground and off the vine row on the vines' growth and productivity, berry growth, fruit quality and health, and the weed growth with various undervine weed control methods (herbicide, cultivation, or mowing).

2. Material and methods

Trial design - The trial was a split plot with above ground drip irrigation (the industry standard) and subsurface dripline (Netafim Uniram AS, installed 30 cm below the surface and 30 cm off the vine row) as the two treatments. There were five sampling replicates per treatment. The subsurface lines were installed using a modified mole plow. All control plots were root pruned with the same plow used to install the lines, so that any damage done to the root systems during installation was equal for both treatments. Both treatments received the same irrigation, the only change being the location of the lines. Trials were conducted in three Syrah and two Sauvignon blanc vineyards in 2019-20 and three vineyards of each variety in 2020-21. The number and type of undervine weed control passes (herbicide, cultivation, or mowing) was at the discretion of the manager, but was done identically across both treatments so direct comparisons could be made. All other vineyard operations (i.e. spraying, leaf plucking, etc.) were done the same in both treatments.

Vine and weed assessments – Vines were measured for canopy development by image analysis (using a method similar to Diago et al., 2019), and for midday stem water potential using a Scholander pressure chamber. 100 berry samples were assessed for berry weight and juice chemistry (using FOSS winescan). Yield per vine and bunch number were determined at harvest. *Botrytis cinerea* infection at harvest was assessed visually on 60 bunches per treatment using the method of Hill et al. (2010). Undervine weed growth was assessed by measuring the biomass of all plant material growing in a 625 cm^2 quadrat placed in the vine row at two

locations per replicate at budburst, flowering, veraison, and harvest.

3. Results and discussion

Undervine weeds need to be controlled in vineyards because they can compete with grapes for water and nutrients, and because they can grow into the canopy, where they can compromise harvestability and/or health of the fruit. Most vineyards currently use herbicide sprays to manage the undervine area. Organic growers, and those that would prefer not to use herbicides for weed control, rely on mechanical means like undervine cultivation, scarification, or mowing. Most of these weeding implements articulate into the vine row between trunks and posts, and retract when a sensor arm or the implement itself hits a trunk or post. Since the blades or mowing heads articulate into the row, they can damage irrigation infrastructure if it is not protected. Another benefit of subsurface irrigation is that all the infrastructure is underground, and so less susceptible to mechanical damage from weeding equipment or grazing animals.

It was thought that moving the lines underground would result in the subsurface irrigated vines having higher water status due to less weed competition and evaporation. The midday SWP data did not back this up, as more often than not there were no differences in midday stem water potential (SWP), and when differences were found, the subsurface did not always have higher water status (data not shown). Midday SWP ranging from -0.3 MPa all the way down to -1.3 MPa were measured during the study, so even when the vines were quite dry, there was no indication that subsurface irrigation was more efficient at keeping SWP less negative than aboveground irrigation, despite reduced evaporation from the soil surface. There was no consistent significant effect on canopy growth, berry weight, fruit chemistry, yield, bunch number, or *Botrytis* incidence (data not shown), indicating that moving irrigation lines underground does not affect vine performance, productivity, or fruit quality.

Early in the season, before regular irrigation began, undervine weed growth was similar between treatments (Table 1). However, from veraison onward, once all vineyards were receiving irrigation, there were generally significantly less weeds in the undervine area of the subsurface irrigation treatment (Table 1, Figure 1). There were still weeds growing above the lines, presumably accessing the water that moved up through the soil via capillary action (Figure 1). The location of weeds that grew was the major difference between treatments. It may seem trivial to have weeds relocated by 30 cm, but this slight change in location of the weeds makes a huge difference in terms of vineyard management. Utilising subsurface irrigation, weeds grow outside the vine row, where they are much easier to deal with mechanically in a cost and time efficient manner. Weeds growing off the vine row can be controlled with a rollhacke, disc, or midrow mower (8 km/h groundspeed) as opposed to the 2-4 km/h groundspeed required by articulating equipment needed for weeding in the vine row. Subsurface irrigation allows a way to manage vineyards necessitating less chemical weed control, since the weeds grow in an area where they are easier to control by other means. As the New Zealand wine industry moves towards less reliance on herbicides, subsurface irrigation offers the possibility of fewer, faster, and cheaper weeding passes. It is possible that burying the lines deeper would prevent weeds from accessing applied irrigation at all, and lead to higher water status in the subsurface vines, however the experimental design used in this study did not allow for this question to be answered.

While not assessed in this study, subsurface irrigation also offers the potential to reduce water use in vineyards. A Marlborough wine company found that blocks irrigated using subsurface lines were able to produce similar yields to those with above ground in-line drip irrigation, but using 30% less water. Burying the irrigation line also offered this company the logistical ability to water subsurface blocks during the day, so that aboveground irrigated blocks could be watered only at night, reducing evaporative losses (New Zealand Winegrowers Grape Days, 2021).

Costs of the subsurface lines are slightly more than traditional drip irrigation line, but installing the lines underground means no need for an irrigation wire and for labour and clips to secure the line to the wire, so the cost of materials and installation is actually similar. Obviously, repairs are more costly with subsurface irrigation lines, but reports from managers are that repairs are much less frequently needed with subsurface lines since the infrastructure cannot be damaged by stock or machinery (Author's personal communication). With the

growing demand for subsurface irrigation in New Zealand, irrigation supply companies are building installation plows for use by clients. Considering the benefits of subsurface irrigation, the cost parity with aboveground dripline, and the growing capacity to easily and quickly install lines, it is anticipated more and more vineyards in New Zealand will either develop new vineyards with subsurface lines, or install subsurface lines when their current dripline reaches the end of its useful lifespan.

4. Conclusions

As our industry moves toward chemical reduction, any technique that allows for fewer weed sprays is a benefit. Because the location of the buried line determines where the weeds grow, moving it outside the vine row moves the weeds from an area that requires slow machinery than can damage vines, such as undervine mowing heads and blades, to an area where much faster and less damaging machinery can be used, such as a rollhacke, disc, or a mower. Subsurface irrigation, therefore, has the potential to reduce the chemical footprint of winegrape growing in New Zealand.

It is anticipated that subsurface irrigation will become more popular in vineyards in New Zealand, especially in vineyards looking to reduce or eliminate herbicide use. The findings from this trial that subsurface irrigation (at 30cm off the row and 30cm down) does not substantially affect vine growth, yield, or fruit composition should embolden growers to move the lines underground. A major impediment to growers moving to organic management is dealing with undervine weed growth, which is expensive and labour intensive to deal with without herbicides. Subsurface irrigation can make this transition easier by moving the weeds from a difficult to control area to a more manageable area and reducing the need for undervine weed control.

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Table 1: Undervine weed biomass (g) from a 625 cm2 quadrat in the vine row. Data are averages of ten measurements. Values from the same vineyard, season, and sampling time in bold with different lower case letters denote significant differences using the Student's t-test at the t=0.05 level. ND indicates the data was not determined.

Variety	Season	Weed control method	Treatment	Budburst	Flowering	Veraison	Harvest
Sauvignon blanc	2019-20	Mowing	Control	51.1	37.7	**68.6 a**	**55.2 a**
			Subsurface	55.3	28.2	**43.3 b**	**29.8 b**
Sauvignon blanc	2019-20	Cultivation	Control	1.8	0.3	**2.5 a**	**37.46 a**
			Subsurface	6.7	0.3	**0.3 b**	**3.1 b**
Syrah	2019-20	Cultivation	Control	15.9	**18.7 a**	**21.3 a**	**13.6 a**
			Subsurface	18.9	**10.3 b**	**10.2 b**	**5.6 b**
Syrah	2019-20	Herbicide	Control	1.1	1.6	**4.0 a**	18.6
			Subsurface	1.3	2	**1.1 b**	17.4
Syrah	2019-20	Herbicide	Control	16.5	13.7	**30.0 a**	**17.9 a**
			Subsurface	14.6	13.5	**18.9 b**	**7.5 b**
Sauvignon blanc	2020-21	Mowing	Control	39.6	40	**72.9 a**	**73.9 a**
			Subsurface	40.5	42.7	**47.3 b**	**25.1 b**
Sauvignon blanc	2020-21	Cultivation	Control	35.4	26	**9.1 a**	**41.9 a**
			Subsurface	40.1	13.1	**1.9 b**	**3.4 b**
Sauvignon blanc	2020-21	Herbicide	Control	0	4	**4.7 a**	**20.5 a**
			Subsurface	0	2.9	**0.3 b**	**0.9 b**
Syrah	2020-21	Cultivation	Control	4.7	10.7	6.2	21.2
			Subsurface	5.6	24.9	8.3	6.6
Syrah	2020-21	Herbicide	Control	7.5	3.1	**27.0 a**	36.8
			Subsurface	10.2	2.3	**8.4 b**	29.9
Syrah	2020-21	Herbicide	Control	16.5	13.7	**30.1 a**	ND
			Subsurface	14.6	13.5	**18.9 b**	ND

Figure 1: Photos of the undervine in a Syrah vineyard shortly before harvest, control on the left and subsurface on the right, illustrating the different location of weed growth.