DEVELOPING A LOW-INPUT UNDER-VINE MANAGEMENT SYSTEM TO IMPROVE PROFITABILITY WITHOUT COMPROMISING YIELD OR QUALITY

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Abstract

The under-vine region of the vineyard floor contains the greatest concentration of vine roots, so management of this zone directly impacts vine yield, quality and profitability. The removal of weeds involves regular use of herbicides or cultivation, neither of which is recognized as best practice soil management. Resultant herbicide resistant weeds, poor soil quality and restricted access to soil moisture may adversely affect vine growth. Under-vine cover crops are being compared with herbicide and straw mulch controls for their impact on yield, fruit, wine and soil quality, suppression of weeds and economic response at five sites in South Australia. The cover crop species consist of annual and perennial native or exotic grasses and legumes.

Despite under-vine cover crop biomass of up to 8 t/ha following a very dry spring, at some sites treatments showed improved grape yields in 2016 compared with the herbicide and straw mulch controls. Different cover crop species had distinctive effects on grapevine root colonisation by beneficial arbuscular mycorrhizal fungi (AMF). Next Generation Sequencing of the vineyard soil showed that some cover crops were more strongly associated with Glomeromycota, the fungal division containing the AMF. Fruit quality was not compromised by the cover crops, and in a sensory analysis of Shiraz wine from the Barossa site, the herbicide control was rated lowest of seven treatments. Perennial cover crops which remained active over summer helped to suppress summer weeds but also reduced yields at most sites. In this paper we report on results from one selected site.

Keywords: cover crops, weeds, herbicides, soil quality, wine quality.

Introduction

The under-vine strip of about 1 metre width represents approximately 30% of the vineyard floor area, but receives a much greater proportion of management inputs, mostly as herbicide applications or cultivation. This is a costly use of resources with potentially deleterious environmental impacts, especially to the zone of soil in which the greatest concentration of vine roots are found. Management of this zone is therefore likely to impact vine yield, fruit quality and vineyard profitability. Cover cropping is now common practice in the vineyard mid-rows with its recognised benefits to the soil, plants and general ecosystem (Pardini et al, 2002, Ingels et al. (1998). By growing desirable plant species in the under-vine zone, it is intended to enhance those ecological benefits without reducing vine yield or fruit quality.

The vineyard conundrum is that the zone of soil with the greatest level of root activity and potential influence on quality is not being treated in line with best soil management practice because undesirable plants (weeds) are growing in that space and need to be removed. There are several alternatives to herbicides available to grape-growers, such as mulching, mowing, cultivation and sheep grazing, but all have their limitations. A proposed option is to instead grow desirable plant species in the under-vine zone, which provide benefit to the vine while suppressing the growth of weed species. Ideally the desirable species will be self-regenerating annuals or summer dormant perennials which grow in autumn to smother weeds, provide root matter to improve soil structure, then die or go dormant either before extracting valuable moisture or later where excess vigour is an issue.

Soil organic matter (SOM) is the key to improving soil health, which can either be imported as compost or mulch, or grown in-situ. Other researchers have investigated using cover crops to improve the mid-row soil health. Sanderson (1998) noted a 75% increase in SOM over 4 years when vigorous medics were allowed to complete their life cycle. Fourie (2007), found that medic cover crops grown over a ten year period, increased SOM by over 20% compared with the herbicide control, and at greater than 1.5% SOM meant nitrogen additions were unnecessary in South African conditions.

Bell and Henschke (2005) discuss the implications of providing adequate nitrogen to ensure there is sufficient canopy for fruit ripening and yeast available nitrogen (YAN) levels to support a complete fermentation. In the proposed study, legumes are potentially important components of the ground cover, which could in reasonable rainfall environments provide most of the N required by the vine.

In this paper we report the impact of sown cover crops grown under-vine on numerous important parameters for determining their fit within a sustainable viticultural system.

Materials and Methods

The trial was established in a block of 13 year old own-rooted shiraz in 2014 at the South Australian Research and Development Institute's Nuriootpa Research Centre in the Barossa Valley ($34^{0}28^{'}24$” S; $139^{0}00^{0}24^{'}$E). The duplex soil consists of an A horizon of sandy loam over a B horizon of sodic medium textured clay with high soil strength and the potential for inhibiting vine root growth. Ten treatments (Table 1) were replicated 4 times in a randomised complete block design, with each plot consisting of three panels, each with three vines. The vine spacing was 2.25 metres, giving a plot length of 20.25 metres. Row spacing was 3.5 metres. Following leaf fall in 2014, herbicide (glyphosate 540 g.a.i./l @ 2.0 l/ha and oxyfluorfen, 240 g.a.i./l @ 75 mls/ha) was applied to provide weed control. Plots were sown using a Taege® vineyard disc seeder, with a single row sown each side of the vines at a depth of 10 mm within 20 cms of the vine trunk, and chains behind the disc to cover the seed. No fertiliser was applied, but the legumes were inoculated with the appropriate rhizobium strain. Redlegged earth mite, lucerne flea and sitona weevil were controlled with chlorpyrifos @ 350 mls/ha. The herbicide controls were maintained as bare earth with herbicide applications as required and straw mulch (triticale) was applied at 55 t/ha to the one metre wide under-vine zone. All plant species were allowed to fully express their phenology with no intervention used to manage or terminate growth. Seasonal conditions restricted cover crop growth and seed set in the first year, requiring some treatments to be re-sown in the second year. Cover crop productivity was high in both the second and third years.

Cover crop composition and dry weight was estimated 4 times per year using the Botanal (Tothill, et al. 1978) methodology. Vine vegetative production was determined from pruning weights, while vine canopy balance was estimated using the leaf area index generated by the VitiCanopy phone App (De Bei et al 2015). Petioles were sampled at 80% flowering for tissue analysis and vines were mechanically harvested and weights determined from load cells on a trailer which followed the harvester. Hand harvested fruit was used for winemaking, which followed the red winemaking protocols established by the Australian Wine Research Institute, using 10 L demijohns for the secondary fermentation. Wine sensory evaluation was conducted by a 26 member panel of Barossa Valley winemakers, using a 20 point scoring system.

Results and Discussion

Rainfall over the three growing seasons differed considerably (Figure 1). The rainfall in the 2014/15 and 2015/16 spring/summer periods were both below average and in 2016, with warmer soil temperatures, led to an early harvest. The 2016/17 spring/summer was comparatively wet, providing very contrasting seasons to test the impact of cover cropping on vine yield and fruit quality.

The establishment, performance and dry matter production of the cover crops varied considerably between species and over the two years post-establishment (data not shown). Although Kasbah cocksfoot was planted as a summer dormant species, the dry spring of 2015 necessitated early initiation of vineyard irrigation, which maintained its active growth and prevented it from entering true dormancy. Wallaby grass also remained green, though with much lower biomass produced. Strawberry clover remained green under the drippers and was the dominant species in 2015/16 while the fescue became more prevalent in 2016/17. The medics, annual clovers, *Vulpia* spp. and annual ryegrass set seed then senesced, leaving a dry mulch on the soil surface over the summer periods.

Petiole analysis from samples taken in December, 2016 showed higher nitrogen levels in the herbicide control and straw mulch treatments. By harvest, a trend to higher YAN's in the must from legume treatments was apparent. From a winemaking perspective, adequate nitrogen availability in the must is preferred to additions in the winery, though excess nitrogen may lead to undesirable consequences such as rapid ferments and protein haze (Bell and Henschke, 2005). It is expected however that legume biomass production could potentially be manipulated to meet the winery requirements for YAN in fruit by mowing or grazing the forage.

While the cane number was lower on the straw mulch and strawberry clover treatments in 2016, there were no differences in cane weights, suggesting compensatory growth from those treatments.

Effective leaf area index (ELAI) and canopy porosity were used to determine canopy vigour prior to harvest. In the dry spring and summer of 2015/16, canopy vigour was greater with straw mulch and the herbicide control. The much wetter spring and summer of 2016/17 provided very different results, with the annual treatments (medic, medic and ryegrass, annual fescue) having the higher ELAI and lower crown porosity. As shown in table 2, there were yield benefits compared to the herbicide control from some cover crop treatments in both years. In the dry 2015/16 season, the mulch treatment, driven by higher bunch numbers, was the highest yielding, and the annual medic and grasses were similar to the herbicide control. Perennial species of grass and legumes provided excess competition, compromising yields considerably. The wetter 2017 season showed the medic treatments to perform as well as the mulch treatment, while the perennials had similar yields to the herbicide control. In two years with very different amounts of rainfall the medic and ryegrass treatments performed equal to or better than the herbicide control. Soil carbon (0-10 cm) was also highest on the medic/ryegrass and perennial fescue/clover treatments. With only 3 years of data it is only possible to speculate that yield improvements occurred because the medics and ryegrass were feeding the soil microbial biomass, which in turn improved soil structure and root access to soil moisture. This hypothesis is however supported by gypsum block soil moisture tension data (not shown) which displayed less soil moisture at 100 cm in the medic/ryegrass treatment than the control over the spring period, but more at harvest, despite the high yield. The use of ryegrass to improve soil aggregate stability, reduce bulk density and improve available water is advocated by Tisdall and Oades (1979), who found ryegrass was more effective than white clover in stabilizing soil because it supported a larger population of Arbuscular Mycorrhizal Fungi (AMF) hyphae. Cockroft (2012) recognized soil coalescence and the resultant impediment to root growth as a major limitation to productivity in irrigated horticulture, and used dense plantings of ryegrass to improve soil structure.

Also of interest are two poor performing treatments, the annual *Vulpia* (2017) and the Mintaro sub-clover / Prima gland clover blend (2016), which is possibly a result of allelopathic interactions from the respective cover crops. Weckert (pers. com) found the Zorro fescue reduced young vine growth (and AMF colonisation) which may also translate to mature vines. Wang (et al, 2005) found coumarins on the leaf surface and in the leaf of *Trifolium glanduliferum* (cv. Prima) were the primary deterrent mechanism for red-legged earth mite which are a significant pest of pastures. Alexiava et al (1995) noted the plant growth regulating effect of coumarins on stem and root growth of wheat and cucumber while Razavi (2011) also recognized their fungitoxic nature, which may also impact on AMF populations. It is therefore possible this species of clover, which was expected to be desirable as a vineyard cover crop, has reduced grape yields through an allelopathic interaction with the vine.

Wine made from fruit harvested in 2016 was presented to a tasting panel nine months later. Their assessment showed a preference for wine made from the Kasbah cocksfoot treatment while the herbicide treatment was the least preferred. Belda et al. (2017) reviewed the current literature concerning the influence of the soil and its associated microbiota on wine characteristics and terroir. They noted how Next Generation Sequencing technology has enabled researchers to ascertain links between soil and root microbiomes and those in the grapes, and ultimately in the fermentation tanks. Potentially the cheapest and easiest way to alter the soil microbiology and influence wine flavour is by changing management practices of the under-vine zone, including the use of a range of cover crops. Further research will aim to determine the influence of cover crops on wine quality, and whether the association is via the soil microbiome or due to other edaphic factors such as changes to the soil's structure and impact on soil water relations.

A gross margins analysis compared the herbicide and straw mulch controls with the ryegrass/medic and cocksfoot treatments (Nordblom et al 2017). Not taking wine quality differences into account, the latter treatment had significantly lower gross margins due to the lower fruit yields, but there was no difference between the other treatments. Due to the limited yield and wine quality data set, this analysis has not attempted to determine impacts of potential improvements in soil or wine quality on financial returns. As more data is attained over coming years a broader focus will be possible in determining the real benefits (or costs) of under-vine cover cropping.

Conclusion

The continued removal of vegetation from the zone of greatest root activity in a vineyard will have negative impacts on soil quality. Growing under-vine cover crops using desired plant species which have low management demands but beneficial impacts on soil quality has the potential to also improve wine quality through edaphic or microbial means, which should lead to improved vineyard ecological and financial sustainability. It is expected the continuation of this research will provide a greater understanding of the changes in soil and wine characteristics resulting from implementing under-vine cover cropping systems.

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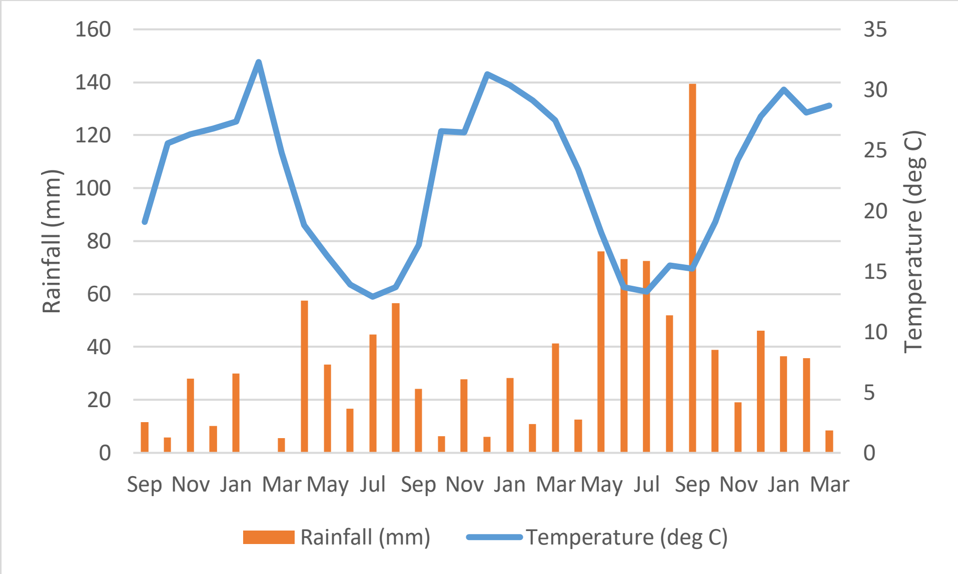

Figure 1: Monthly rainfall and average monthly maximum temperature over three growing seasons from September 2014 until March 2017, Nuriootpa, South Australia.

Table 1: List of treatments, plant species and under-vine sowing rates, Nuriootpa, South Australia 2014.

Common name (cultivar)	**Scientific name**	**Seeding Rate (kg/ha)**	**Plant type**
Cocksfoot (cv. Kasbah)	*Dactylis glomerata*	8	Summer dormant perennial grass
Rats tail fescue (cv. Zorro)	*Vulpia myuros*	10	Annual self-regenerating grass
Wallaby grass	*Rytidosperma geniculata*	10	Native perennial grass
Strand medic (cv. Angel); Barrel medic (cv. Sultan)	*Medicago littoralis* *Medicago truncatula*	20 20	Annual self-regenerating legumes
Spineless burr medic (cv. Scimitar); Annual ryegrass (cv. Safeguard)	*Medicago polymorpha* *Lolium rigidum*	20 30	Annual self-regenerating pasture legume and grass
Strawberry clover Sheep fescue	*Trifolium fragiferum* *Festuca ovina*	20 3	Perennial legume and grass
Gland clover (cv. Prima) Sub clover (cv. Mintaro)	*Trifolium glanduliferum* *Trifolium subterraneum ssp. brachycalycinum*	7 20	Annual self-regenerating pasture legumes
Regenerated weeds	*Medicago spp., Lolium rigidum, Trifolium spp.*		
Straw mulch (Triticale)	× *Triticosecale*		
Herbicide control			

Table 2: Treatments and selected measurement parameters, Nuriootpa, 2016-17

Treatment	Canes 2016 (#/m)	Canes 2016 (kg/m)	ELAI 2017	Crown Porosity 2017	Yield 2016 (kg/m)	Yield 2017 (kg/m)	Petiole N 2017 (%)	YAN	Soil Total C (%)
Triticale mulch	17.4	0.68	1.85	0.249	3.41	4.09	0.87	207	1.00
Kasbah cocksfoot	24.02	0.63	1.68	0.254	2.72	3.33	0.80	186	1.01
Wallaby grass	21.64	0.71	2.09	0.219	2.52	3.33	0.82	232	1.09
Zorro fescue	19.25	0.69	2.47	0.178	3.01	2.94	0.78	211	1.06
Regenerated weeds	19.92	0.82	2.32	0.193	3.04	3.28	0.83	218	1.14
Angel/Sultan medic	19.72	0.60	2.76	0.151	3.06	4.12	0.78	246	1.03
Safeguard RG/Scimitar medic	21.4	0.63	2.34	0.186	3.19	3.93	0.83	225	1.19
Sheep fescue/Strawberry clover	17.32	0.54	2.45	0.173	2.74	3.68	0.81	233	1.23
Mintaro sub-clover/Prima gland	18.41	0.59	1.89	0.24	2.46	3.47	0.84	213	1.10
Control (herbicide)	19.74	0.73	2.08	0.218	3.09	3.06	0.92	219	1.00
F pr.	0.03	0.40	0.004	0.01	0.04	0.05	0.02	0.29	0.02
Average LSD (P = 0.05)	3.8	NS	0.49	0.06	0.58	0.78	0.07	NS	0.14