Pruned vine biomass exclusion in a clay loam vineyard soil – Examining the impact on soil chemical properties

B. Pike[1], R. Muhlack[1,2], T. Cavagnaro[1] and C. Collins[1,2]

[1] School of Agriculture, Food and Wine, Waite Research Institute, University of Adelaide, Adelaide, Australia
[2]ARC Industrial Transformation Training Centre for Innovative Wine Production, Waite Research Institute, Adelaide, Australia

*** Corresponding author: benjamin.pike@adelaide.edu.au**

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Abstract

This project seeks to establish the feasibility of harvesting winter pruned vineyard biomass (PVB) for potential use in carbon footprint reduction, through its use as a renewable biofuel for energy production. The contribution that PVB makes to the soil carbon budget is under reported and its effect is not clearly identified. To progress this further, a preliminary project was established in the University of Adelaide's Waite Campus vineyard (South Australia) to test for any differences in C sequestration under two management strategies. Planted in a Red Dermosol clay loam soil with well managed midrow swards, two 0.25 ha blocks (Shiraz and Semillon) were utilised. Soil management (13 years) for both included seed bed preparation, introduced swards, the exclusion of PVB in every third row and the incorporation of the remainder in every other two rows at an average of 3.4 and 5.5 t ha^{-1} for respective cultivars. At 30cm depth, soil carbon %, cation exchange, nitrogen and phosphorous measures were not significantly different between treatments and yielded an estimated 42 t ha^{-1} of sequestered soil carbon in both blocks. Preliminary results suggest that in this vineyard, there is no long term negative impact on soil carbon sequestration through harvesting PVB.

Introduction

Although agricultural enterprises contribute approximately 21% (including viticulture) of greenhouse gasses (GHG) to the atmosphere, through the use of fertilisers, fossil fuels, livestock and soil cultivation (Carlyle *et al.*, 2010; Longbottom, 2014), the agriculture sector identifies reducing its carbon footprint as important to mitigating climate change. Plant waste biomass streams from agriculture have been identified as a potentially important feedstock for bio energy and continues to be developed in many countries (Dale *et al.*, 2011; Johnson *et al.*, 2006). Pruned Vineyard Biomass (PVB) PVB can be considered a renewable source for bioenergy as it can offer appropriate thermal/chemical properties required for successful combustion for gasification or pyrolysis (Stucley *et al.*, 2008). Importantly, PVB satisfies a key sustainability parameter; that being a by-product of a high quality crop, which does not require the dedication of extra land for production (Spinelli *et al.*, 2010).

Preliminary research consistently demonstrates that PVB has a Higher Heating Value of between 13.08 and 22 MJ kg^{-1} (Di Blasi *et al.*, 1997; Manzone *et al.*, 2016; Tenu *et al.*, 2019). These values are comparable to those of forestry hardwood trees species, but lower than those of soft wood tree species, traditionally used for combustion (Manzone *et al.*, 2016). Based on these observations, PVB seems a suitable fuel for bioenergy. However, if removed from the vineyard, a valuable source of soil carbon maybe compromised.

In some vineyards, PVB removal is performed routinely. The end fates of PVB vary from controlled open air burning, composting, pyrolysis for bio char production and various forms of bio energy. In other vineyards PVB, it is left in situ and either incorporated in to the soil through cultivation or remains on the soil surface. What is not clear in the literature is the impact removal of PVB might have on the soil carbon budget. To establish the role PVB actually plays in the dynamics of soil carbon in viticultural soils requires experimental trials over a number of years, if not decades (Garcia *et al.*, 2018). In a rare 28 year trial in a calcareous sandy soil in the Loire Valley (France), differences in sequestered soil C with and without PVB were reported. Dried

PVB was incorporated at 2 t ha^{-1} compared with a control of no PVB. No mid row crops were included. At the conclusion of the trial in 2008, sequestered carbon in the treatment had declined by 7%, yet at 7.9 t ha^{-1} was significantly higher than the control (6.3 t ha^{-1}); a 19% decline (Morlat and Chaussod 2008). This finding suggested that PVB can be an important source of sequestered C if incorporated into the vineyard soil.

In terms of carbon sequestration, the complex cyclical interactions between soil type and climate, and cover crops are widely reported (Tezza *et al*., 2019; Vendrame *et al*., 2019; White, 2015). Cover crops in particular could play a more important role in carbon sequestration than the addition of PVB, which were not inlcuded in the Morlat and Chassoud (2008) trial. It is possible that in vineyards with a well managed permanent sward PVBs importance to the C cycle may be insignificant and therefore could be removed for further processing with little or no impact on sequestered C.

To test the hypothesis that PVB may not be an important contributor of C to vineyard soils, soil and biomass sampling was conducted at a vineyard site where, for 13 years, PVB has been deliberately excluded from every third row while in every other two rows, within the same vineyard, all PVB had been incorporated into the soil by cultivation.

Materials and methods

The Coombe vineyard (2.75 ha), Waite Campus of the University of Adelaide, in South Australia (34°58'02S; 138°38'58E; elevation 119m) was used for this project. Dominated by hot dry summers (Mean January temperature 23.4°C) and mild wet winters (Mean June temperature 12.1°C). Winter dominant average annual rainfall, is 547.1mm (BOM, 2021). The soil type is described as Eutrophic, Red Dermosol; thick, non-gravelly, clay loam which possess a high water holding and strong cation exchange capacity (Hall, 2016).

Two 0.25 ha blocks planted in 1992 to Shiraz (clone BVRC12) and Semillon (clone SA32) on own roots were identified for use. North-south rows are 85m long spaced at 3m and vine spacing for Shiraz is 2.7m (1234 vines ha) and for Semillon 1.8m; (1852 vines ha). Vines were trained to a single bi lateral permanent cordon at a height of 0.75m and are hand pruned to two node spurs. Irrigation is typically applied at the equivalent of 1-1.2 ML ha^{-1} for Shiraz and 1.5–2 ML ha^{-1} for Semillon, season dependant.

From 2008 to 2018 annual rotation of mid row crops consisted of rotated plantings of cereals and legumes. Seed beds were prepared in autumn with one cultivation followed by one herbicide pass. PVB was deliberately excluded from every third row to protect bird nets from damage by canes. Consequently, all PVB was randomly distributed in the remaining two rows.

In 2019 permanent swards were introduced. In the autumn of 2019 and 2020, mid rows were cultivated once with no herbicide for seed bed preparation. Species included, annual rye grass (*Lolium perenne*), Convoy Continental cocksfoot (*Dactylis glomerata*), summer active tall fescue (*Festuca arundinacea*), SARDI Rose Clover (*Trifolium hirtum*) and Silver Snail Medic (*Medicago scutellata*). Crops were allowed to set seed, slashed in early summer and left in situ.

Being unable to randomly distribute treatments, a strip plot design was used to allocate sample sites. Each cultivar block was divided into three sub-blocks (replicates) of three mid-rows each and divided in to North and South zones. To eliminate border effects, a 5.4 m no sample zone at each end of every mid-row was established. North and South were separated by a 10.8 m zone in the middle of each row (Figure 2).

- Treatment 1: Without PVB - PVB is deliberately excluded from every third row.

- Treatment 2: With PVB - PVB was randomly distributed and incorporated into the soil during cultivation. PVB weights for each block over three seasons ranged between 92.48 kg per mid row to 184.96 kg per mid row for Shiraz and 142.08 kg per mid row to 284.16 kg per mid row for Semillon. Air dried PVB was incorporated into the top 30cm of soil by a rotary hoe used for cultivation the following season.

Representative vines were pruned during dormancy to two node spurs and their collective weight recorded for each cultivar. Average pruning weights for Shiraz and Semillon were calculated; 2.71 kg per vine and 2.96 kg per vine respectively. Samples of cane fragments between 5cm to 7cm long from 100 canes per cultivar, were also collected and homogenised. Sub samples were sent for analysis to Australian Precision Ag Laboratories, Hindmarsh, South Australia to determine nutrient status, including carbon concentration.

In each mid row, twelve evenly distributed sample sites in the centre of each row were identified and aligned with the middle of each corresponding panel. Soil samples were collected in August of 2021 when the soil was at field capacity after winter rains. For each sample site, two separate topsoil sample fractions, 0-10 cm and 10-30 cm, were collected by hand auger, head diameter 10 mm. A homogenous composite sample of each replicate at each depth fraction in the North and South zones was obtained, resulting in a total of 6 samples from the 'with biomass' treatment and 12 'without biomass' in each of the cultivar blocks. Samples were processed by Australian Precision Ag Laboratories to determine soil chemistry measures.

Results from soil and plant tissue analysis, were subjected to a paired T-Test assuming equal variance. Significant differences level ($p<0.05$) (Microsoft Excel Data Analysis 2016; Version 16.0.5266.1000).

Results and discussion

Based on average pruning weight values and nutrient concentration levels in dried PVB from the Coombe vineyard, Shiraz and Semillon contribute the equivalent of 3.35 t and 5.48 t of biomass ha^{-1} per year, respectively. Consistent with the findings of (Cavalaglio & Cotana, 2007; Mendívil *et al.*, 2013), data from chemical analysis of the PVB shows that the carbon concentration in Shiraz is 50.13 % and that Semillon is 49.98%. And that chemical concentration of other key elements are likewise consistent. These results support the previous findings that the chemical properties of PVB make it a suitable feedstock for bioenergy.

With the exception of measures for salinity in both depth fractions (which are all well below toxicity thresholds), and pH for the 10-30 cm depth fraction, no significant differences were found between treatments in any key soil characteristics at either depth fraction. Concentrations of most key characteristics (Cation Exchange Capacity, ammonium and phosphorous) were generally within or close to the desired range (Table 1). The pH values indicate slightly acidic conditions, but are well within the range acceptable for nutrient accessibility by the vines.

The measures of soil Nitrate indicate a concentration below the desired level in soil (Table 1). Additionally annual petiole samples taken in the Shiraz and Semillon blocks at flowering (E-L 23), indicate that nitrate concentration (34mg kg^{-1} and <30mg kg^{-1} respectively) found in plant tissue analysis is consistent with sub-optimal levels (500 -1200 mg kg^{-1}) (McCarthy *et al.*, 1992). However evidence of nitrogen deficiencies do not manifest themselves in the vines or in fruit production, vigour is consistently high and canopies are moderately dense. All other key nutrient concentrations satisfy optimal target levels. For each individual depth fraction of soil, carbon concentration was lower than the desired level.

The results in Tables 1 and 2 suggest that after 13 years of mid row management where PVB has been deliberately excluded there is no difference in OC concentration in the top 30cm of soil (2.38%), when compared with the PVB incorporated treatment (2.40%). And that for each individual depth fraction of soil, carbon concentration was lower than the desired level. Factors used to convert soil carbon % to total sequestered carbon are provided in Table 2. It is not unexpected therefore, that given no significant differences in soil carbon concentration (Table 1) that total Sequestered Carbon at 42 t ha^{-1} is equal in both treatments, regardless of cultivar (Table 2). A direct time comparison is not possible with Morlat and Chaussod (2008), but in the early 1990's they reported that, while not significant, a separation of carbon sequestration rates was occurring between the treatment and control. Culminating in the results at trials end. Of particular interest to this current project is the differences in soils between the two projects and at the Waite site the incorporation of mid row crops, which may play a more important role in carbon sequestration than PVB (Vendrame *et al.*, 2019).

Conclusion

The physio/chemical characteristics of PVB in this project are consistent with those reported from Europe. The preliminary findings indicate that the contribution PVB to in C sequestration is negligible at this site. It is more likely that a combination of soil type and the use of cover crops fulfil this role more effectively. We do not know the starting concentration of soil C and are not able to comment on how rapidly, or not, changes to carbon cycling and sequestration have occurred. Or indeed how this change may have been affected by the changes to soil and cover crop management over time. It is clear though given the same level of C sequestration in both treatments that the harvest of PVB in this situation could occur. Further investigation where PVB is removed from vineyards in varying climatic regions, other soil types and appropriately designed experiments may provide additional insight.

Table 1. Mean characteristics of initial soil samples from long term treatments (2007-2021) of vine pruned biomass exclusion [a], in selected rows. Coombe Vineyard, Waite Campus, South Australia

Key Characteristic	Unit	Biomass Treatment[a]	Depth 0_10 (cm)[b]	Depth 10_30 (cm)[b]	Significance Level P-Value [c]	Optimal Level [d]
Organic Carbon	%	N	1.55 ± 0.04	0.83 ± 0.03	ns	1.80-3.50
		Y	1.58 ± 0.03	0.82 ± 0.03	ns	
Cation Exchange Capacity	cmol kg^{-1}	N	7.64 ± 0.25	6.48 ± 0.32	ns	5.00-25.0
		Y	8.12 ± 0.23	6.50 ± 0.34	ns	
pH 1:5 water	pH	N	6.19 ± 0.06	6.02 ± 0.05	ns	6.50-7.50
		Y	6.31 ± 0.03	6.13 ± 0.04	0.04	
Nitrate - NO_3^-	mg kg^{-1}	N	6.71 ± 0.57	1.55 ± 0.91	ns	20-50
		Y	7.69 ± 0.47	1.58 ± 0.61	ns	
Ammonium - NH_4^+	mg kg^{-1}	N	1.43 ± 0.10	1.93 ± 0.25	ns	1.0-10
		Y	1.48 ± 0.26	2.27 ± 0.21	ns	
Colwell Phosphorus	mg kg^{-1}	N	49.50 ± 3.30	49.50 ± 1.89	ns	40-60
		Y	45.38 ± 1.95	45.38 ± 2.29	ns	
Salinity EC 1:5	dS m^{-1}	N	0.045 ± 0.001	0.045 ± 0.002	0.03	0.04-0.25
		Y	0.048 ± 0.001	0.048 ± 0.001	0.03	

[a] Biomass from two cultivars Shiraz (BVRC12) and Semillon (SA32) incorporated into soil; N = No biomass, Y = With biomass

[b] Data are combined means from 6, 0-10cm samples and 12, 10-30cm samples for each cultivar ± the standard error

[c] T-test assuming equal variance. Significant differences level ($p<0.05$)

[d] Sample analysis and optimal levels provided by Australian Precision Agriculture Laboratories Pty Ltd, 2021

Table 2. Estimated sequestered carbon by treatment in the top 30cm of soil. Coombe Vineyard Waite Campus 2021

Treatment	Depth (cm)	Soil Carbon (%)	Bulk Density (g cm^{-3})[a]	Volume of Soil (m^3 ha^{-1})	Sequestered Carbon (t ha^{-1})	Total Sequestered Carbon (t ha^{-1})[b]
Without Biomass	0 -10	1.55	1.3	1000	20	42
	10 - 30	0.83		2000	22	
With Biomass	0 - 10	1.58	1.3	1000	21	42
	10 - 30	0.82		2000	21	

[a] Bulk density measures based on historic data for Urrbrae Red Brown Earths: ρ_{soil} (Greacen, 1981)

[b] Calculation for sequestered carbon: $\Sigma = (\rho_{soil}*V)*SC\%$. Where: $\rho_{soil} = 1.3$ g cm^{-3}: bulk density of Urrbrae Red Brown Earths; V = Volume of soil: m ha^{-3}, 1000 m ha^{-3} at 0 -10cm; 2000 m ha^{-3} at 10 – 30cm; SC% = Soil carbon concentration/100

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