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Under-trellis cover crop and deficit irrigation to regulate water availability and enhance Tannat wine sensory attributes in a humid climate

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ABSTRACT

The goal of our study was to improve Tannat grape and wine composition by achieving vine balance in high-capacity conditions. The current Uruguayan grape-growing paradigm accepts unpredictable periods of water deficit or excess in non-irrigated vineyards, only applying herbicides to eliminate weed competition (H). We used an under-trellis cover crop (UTCC) to limit vine water availability and to reduce vine growth rate and final canopy size. However, to avoid excessive vine water stress due to UTCC competition, irrigation was used as needed during water deficit periods. The experiment was conducted over three consecutive growing seasons from 2011 to 2013, in two experimental vineyards located in southern Uruguay (34° S 56° W). Treatments were: UTCC (full cover of the vineyard soil with tall fescue) versus conventional alleyway tall fescue with a 1.0 m-wide weed-free strip under the trellis. Deficit drip irrigation was provided at mid-day stem water potential (SWP) thresholds of −0.9 MPa early in the season and −1.1 MPa later. Shoot growth rate, SWP, berry size and berry composition (Brix, organic acids, total anthocyanins) were monitored over the season as well as final yield, cluster and pruning weights and wine sensory attributes. UTCC regulated vine vegetative growth and final canopy size and reduced bunch rot incidence as well as increasing fruit Brix and anthocyanin concentration in grapes and wines. Wines from UTCC treatments had an increased fruity aroma and overall aroma intensity levels and had distinctive sensory characteristics that exceeded those of H wines during overall palatability tests (liking tests).

1. Introduction

In areas such as Uruguay where the temperature, water availability and soil fertility induce high growth rates, it is common to observe dense and unbalanced canopies which provide an unfavorable microclimate for fruit maturation and disease management (Smart and Robinson, 1991). The need to maintain good vegetative development capable of maximizing vine capacity and yield potential, in a traditional non-irrigated vineyard, has led to the strategy commonly adopted by most Uruguayan growers of using medium- to high-vigor rootstocks combined with a 1.0 m-wide weed-free strip under the trellis.

Although the appropriate balance may vary with variety and desired yield or wine style, regulating vegetative growth is a key vineyard practice. Increasing growth tends to be easier to achieve, as adding adequate water, nutrients or soil amendments is practical. Reducing excessive growth, however, is often difficult, as removing or limiting resources is more difficult, especially in humid climates and deep fertile soils. The current local commercial production practices in the humid climate of Uruguay (1) accept unpredictable periods of water deficit or excess in non-irrigated vineyards, and (2) reduce competition from cover crops.

The use of under-trellis cover crops (UTCC) has been studied in cool humid climates that often experience abundant water availability and fertile soils. Apparently due to competition for soil moisture and mineral nutrients, UTCC has been reported to reduce vine growth (Tesic et al., 2007; Lopes et al., 2008; Giese et al., 2014, 2015; Hickey et al., 2016; Karl et al., 2016), improving exposure of fruit to sunlight (Hatch et al., 2011; Giese et al., 2014, 2015). Additionally, increases in total soluble solids and/or berry skin phenols and anthocyanins have been reported (Tesic et al., 2007; Hickey et al., 2016), though it is not clear if those are direct or indirect effects of the reduction in canopy density.

The goal of our study was to evaluate an integrated management strategy of cover cropping with supplemental irrigation to regulate canopy growth, in order to optimize vine balance and improve Tannat

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Table 1
Irrigation by treatment and site, and evapotranspiration, precipitation and growing degree-days (> 10 °C) from Las Brujas weather station located 400 m from the experimental sites.

	Phenological stage[a]	Degree-days (> 10 °C)	Eto Penman (mm)	Precipitation (mm)	Irrigation (mm) Site 1		Site 2	
					H	UTCC	H	UTCC
Historical	budbreak-bloom	338	208	227				
	bloom-veraison	718	359	291				
	veraison-harvest	664	257	266				
	post-harvest	421	136	252				
Season 2011/12	budbreak-bloom	328	224	132	0	0	0	0
	bloom-veraison	722	391	177	16.7	103.5	14.7	98.5
	veraison-harvest	665	271	212	23.7	70.7	20.3	76.8
	post-harvest	435	157	147	0	0	0	0
Season 2012/13	budbreak-bloom	403	211	359	0	42.2	0	0
	bloom-veraison	753	381	288	0	9.7	0	27.1
	veraison-harvest	641	291	199	0	0	0	8.2
	post-harvest	352	139	173	0	0	0	0
Season 2013/14	budbreak-bloom	332	214	204	0	51.2	0	20.1
	bloom-veraison	804	398	284	7.3	60.2	0	50.2
	veraison-harvest	692	228	641	0	0	0	0
	post-harvest	395	146	194	0	0	0	0

(a) data from Las Brujas weather station located at 400 m from experimental sites.

grape and wine composition and wine sensory characteristics. Tannat is noted as a very tannic and often harsh wine. Our approach was to use UTCC to limit vine water availability via competition, thus reducing vine growth rate and limiting final canopy size and density. To avoid excessive water stress due to cover crop competition during dry periods, supplemental irrigation was applied to regulate the stress and thus vine growth, function and fruit development. Wines were made to evaluate wine composition and characteristics.

2. Materials and methods

2.1. Experimental sites

The experiment was conducted over three consecutive growing seasons from 2011 to 2014 in two experimental vineyards located in southern Uruguay (34° 44′ S, 56° 13′ W). The Uruguayan climate can be classified as temperate–humid without a prolonged dry season, Cfa according to the Köppen-Geiger system (http://en.climate-data.org/location/3741/). Historical mean total annual rainfall in southern Uruguay (1972–2015) is 1100 mm/year, with 650 mm occurring during the growing season (Table 1). Further weather data details can be accessed at https://www.inia.org.uy/gras/agroclima/cara_agro/index.html. Both sites' soils were similar and characteristic for the region. Soils were classified as silty clay loam (Typic Argiudoll by the USDA soil classification system), with a variable depth of 0.90–1.1 m and 0.90–1.0 m for Sites 1 and 2, respectively. The total soil available water (field capacity–permanent wilting point) to 1.0 m depth was from 100 to 110 mm for both soils.

In both locations, Tannat grapevines, grafted on to SO_4 rootstock, were trained on vertical shoot-positioned training systems (VSP) in north–south-oriented rows (0.8 m × 2.8 m vine × row spacing at Site 1 and 1.0 m × 2.6 m vine × row spacing at Site 2). The Site 1 and 2 vineyards were 7 and 10 years old, respectively, when the cover crop was installed in March 2011 (seeding rate, 60 kg/ha of tall fescue, *Festuca arundinacea*).

2.2. General vine management

Cordon-trained vines were pruned to seven two-bud spurs per meter during dormancy. The height of the cordon was 1.0 m, and the top of the canopy was approximately 2.1 m above the ground. At approximately 30 cm shoot length, all shoots not located on spurs were removed. During the growing season, shoots were positioned by hand vertically above the spurs, and topped 30 cm above the top wire. Catch wires were used to keep shoots in position.

To avoid overcropping during ripening, the crop level was adjusted by cluster thinning in each experimental plot at veraison (stage 35 –Eichhorn and Lorenz, 1977). Based on prior research (Coniberti et al., 2011), optimal crop level was estimated to be about one cluster/shoot. With a full canopy, this provides a ratio of at least 1.8 m^2 leaf area/kg fruit weight which is needed to maximize sugar and anthocyanin accumulation. To estimate the potential yield for every plot, thinned clusters were counted and weighed. No significant differences were detected in berry weight from veraison to harvest, so similar behavior was assumed for the remaining clusters, and the assumed final weights were thus added to the harvested yield. The potential yield provides insight into the crop load during periods before thinning.

Standard disease-control fungicide programs were applied for downy mildew, powdery mildew and *Botrytis* bunch rot. Irrigation water was applied with drip emitters (4 L/min) located directly under the vines and distributed 0.3 m apart. The irrigation system was designed to allow independently irrigated single experimental plots.

2.3. Treatments

Two treatments (UTCC versus conventional floor management) were evaluated in a complete random block design with five and four replicates for Site 1 and Site 2, respectively.

At both experimental sites, replications comprised eight adjacent grapevines, the outer vines serving as guard vines. Buffer rows separated ground cover treatments. The UTCC treatment consisted of full cover of the vineyard soil with tall fescue (*F. arundinacea*). The UTCC treatment was compared with a conventional herbicide management scheme with the same inter-row groundcover but combined with a 1.0 m-wide weed-free strip under the trellis (H). The under-trellis weed-free strip was maintained with a combination of herbicides.

To avoid the effect of the treatment due to nitrogen (N) competition, in every UTCC plot, ammonium nitrate (NH_4NO_3) was applied twice at a rate of 20 kg N/ha when shoots reached approximately 30 cm and after fruit set (stage 29 –Eichhorn and Lorenz, 1977). No statistically significant differences among treatments were detected in leaf N%, P%, K%, Ca% and Mg% at bloom or veraison (data not shown). Average leaf N% content ranged from 2.1% to 2.5% at both sites. No visual nutrient deficiency symptoms were detected.

To monitor water stress in the treatments, mid-day stem water potential (Ψstem) was measured periodically (~bi-weekly) between 1400

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