SUSTAINABLE YIELD MANAGEMENT THROUGH FRUITFULNESS AND BUNCH ARCHITECTURE MANIPULATION

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Abstract:

Context and purpose of the study - Vineyards are highly variable and this variation is largely driven by environmental conditions and seasonal variation. For example, warm temperatures and sunny days during bud initiation generally result in high yields in the next season while cold periods during flowering and fruitset can reduce yield. As such, this variation in yield and potentially quality is difficult to predict and therefore manage. Early and more accurate assessments of fruitfulness and bunch architecture may improve these predictions. Vineyard management can be used to manage this variation and limit negative impacts on production. This study summarises research that; (1) investigated different methods for the assessment of bud fertility and bunch architecture and (2) assessed the impact of different management techniques on fruitfulness, bunch architecture and resultant yield.

Material and methods – Vineyard management trials were carried out in South-eastern Australia during the last 4 years and were performed on Syrah, Cabernet Sauvignon, Semillon, Riesling, Grenache, Tempranillo, Merlot and Sauvignon Blanc. Management strategies investigated include; winter pruning, shoot thinning, shoot leaf removal, and bunch thinning. Bud dissection and image analysis was used to assess bud fertility and the size of inflorescence primordia. Image analysis during the growing season and at harvest was used to assess bunch architecture and bunch volume. Bunch weight and yield were determined at harvest to assess yield performance and validate early predictions.

Results – Bud dissection using image analysis was an effective method for early prediction of fruitfulness and bunch weight (R^2=0.79). Similarly, assessing bunch volume at veraison correlated with bunch weight at harvest (R^2=0.78). Assessment methods used in these studies have the potential to be used commercially for yield prediction and management. Management strategies applied in different experimental trials varied in their impact on both bud fertility and bunch architecture (in the current and future seasons). Not surprisingly, timing, extent of application as well as variety had an impact on the final outcome. Understanding how different vineyard management approaches can manipulate components of yield can help producers to manage their vineyards to desired yield and quality outcomes.

Keywords: bunch architecture, canopy management, bud fertility, fruitset, yield management

1. Introduction

Reproductive development in grapevines occurs over two seasons with inflorescence primordia developing in grapevine buds in the season before a crop is produced (May, 2004). As such conditions during the growing season and especially the flowering period are important for both the current and following season's reproductive performance. To optimise vine productivity producers have adopted canopy management practices to alter the distribution and amount of leaves, shoots and bunches to improve yield and fruit composition (Smart, 1985). The effects of canopy management practices on yield components has been studied previously with mixed results. Examples of these practices and studies include lighter pruning (Smart et al., 1982; Bindon et al., 2008), shoot thinning (Naor et al., 2002; Reynolds et al., 2005; Sun et al., 2012; Jogaiah et al., 2013), bunch removal (Santesteban et al. 2011; Sun et al., 2012), leaf removal (Vasconcelos and Castagnoli, 2000; Lohitnavy et al., 2010; Intrigliolo et al., 2014; Frioni et al., 2017), rootstocks (Cox et al., 2012; Kidman et al., 2014), plant growth regulators (Collins and Dry, 2009) and irrigation (Kidman et al., 2014). By altering the source-sink ratio as well as canopy microclimate these practices change vine vigour and influence vine physiology (Smart, 1985) and hence the reproductive performance. Canopy management therefore needs to be applied with thorough consideration to reach targeted yield and/or quality while minimizing cost (Hunter, 2000).
If we accept the climate change projections of a hotter and water-constrained environment in many wine growing regions around the world, such as Australia, it is important to understand how different grapevine cultivars will adapt to these challenges so that we can sustainable manage yield in the future. This aim of this study was to; (1) investigate different strategies for bud fertility and bunch architecture assessment and (2) assess the impact of different management techniques on fruitfulness, bunch architecture and resultant yield.

2. Material and methods

Plant material and experimental design - Experiments presented were conducted at the Waite Research Institute, University of Adelaide (Lat 34°58'3.0"S, Lon 138°38'0.6"E) from 2015 until 2018. The cultivars Syrah, Cabernet Sauvignon, Semillon, Riesling, Grenache, Tempranillo, Merlot and Sauvignon Blanc were used for investigations. Vines were trained to a vertically shoot positioned cordon, spur pruned and drip irrigated (0.5ML/ha/yr). Canopy management practices shoot thinning (50% removal at E-L stage 15-17 (Coombe, 1995)), bunch removal (50% removal at veraison), light pruning (double the number of nodes per vine left at pruning), leaf removal (50% removal at veraison) were applied to Semillon in 2017 and 2018 to assess the impact on reproductive performance.
Bud fertility measures - Bud dissections were performed in autumn after harvest, but before winter pruning (EL stage 43-47). Between 30-60 canes (minimum of 120 compound buds dissected) were collected per variety and treatment replicate for assessment. Canes were dissected at room temperature but were stored for no longer than three weeks in sealed plastic bags with a moistened paper towel and refrigerated at 4°C. As all vines in these studies were spur pruned only the first 1-4 node positions were dissected with the aim to provide more accurate information for yield estimation. Compound buds were dissected and image analysis used to determine the cross sectional area of IP for primary and secondary buds. Area assessments were determined using 'ImageJ' software (NIH, USA).
Bunch measures - Bunch weight, bunch length and bunch width were measured for all bunch samples.The morphological volume of each bunch was estimated as the volume of a cone or cylinder depending on bunch morphology of the cultivar (Shavrukov et al., 2004). Using the average IP area and bunch volume calculations an estimate of bunch weight was determined and compared to actual bunch weight at harvest.
Statistical analysis - Pearson correlation was used to assess the relationship between IP area and bunch weight and bunch volume and bunch weight. A one-way analysis of variance (ANOVA) was used to assess whether there were significant differences between treatments for reproductive parameters. Least significant difference (LSD) was applied at the 5% level ($p < 0.05$) for post hoc tests to assess differences between treatments. All statistical analyses were performed using XLSTAT Version 2015.4.01.20116 (Addinsoft SARL, Paris, France).

3. Results and discussion

3.1. *Inflorescence primordia cross-sectional area and bunch volume at veraison correlate to bunch weight*

As shown in Figure 1 the average cross-sectional area of inflorescence primordia correlate with average bunch weight. A similar relationship was observed between bunch volume assessed at veraison and bunch weight at harvest (Figure 2). A study by Tello et al. (2015) found that the two key parameters that influence bunch architecture are total berry number and length of the first ramification of the rachis and that these parameters can vary between cultivars. Our findings support this research as both the IP area and bunch volume measures are related to these parameters. Previously research has shown that the number and size of IP are positively related to light exposure during bud initiation and differentiation which can change between growing seasons and be influenced by cultivar and management (Buttrose, 1969; Dry, 2000; Sánchez and Dokoozlian, 2005).

3.2. *Canopy management practices can be used to manipulate reproductive performance*

Canopy management practices were effective at manipulating reproductive performance of Semillon (Figure 3). However, when shoot thinning and to a lesser extent bunch thinning were applied, the expected yield difference was either not present or minimal, which suggests that the vine compensates with heavier bunches due to a larger berry weight (Figure 3). The opposite was observed with lighter pruning where bunches were lighter and berry weight lower. Canopy management techniques such as early shading and leaf removal have been used to manipulate bunch architecture (Lohitnavy et al. 2010, Intrigliolo et al. 2014, Basile et al. 2015).Lighter pruning was found to decrease berry size (Bindon et al. 2008) but generally increased yield (Smart et al. 1982). Shoot thinning reduced yield by a decrease in bunch number but did increase bunch weight, berry weight and berry number (Sun et al. 2012, Jogaiah et al. 2013). Conversely, Reynolds et al. (2005) observed that shoot thinning had relatively minor impacts on yield components and Naor et al. (2002) reported that the number of shoots per vine did not influence berry weight. As observed in our research bunch removal did lower yield, but increased bunch weight and berry number (Sun et al. 2012). Leaf removal led to smaller, less compact bunches with fewer berries when applied early in the season (Lohitnavy et al. 2010, Intrigliolo et al. 2014). But had no influence on yield components when applied four weeks after flowering or at veraison (Vasconcelos and Castagnoli 2000, Frioni et al. 2017).

4. Conclusions

The assessment of IP area using bud dissection and image analysis has potential to be a useful tool for early yield prediction. Combining this assessment with a bunch volume later in the season, close to veraison may improve yield estimations and aid in harvest planning and winery logistics. To manage vineyards to meet desired yield and quality outcomes it is important to understand how different vineyard management approaches can manipulate components of yield.

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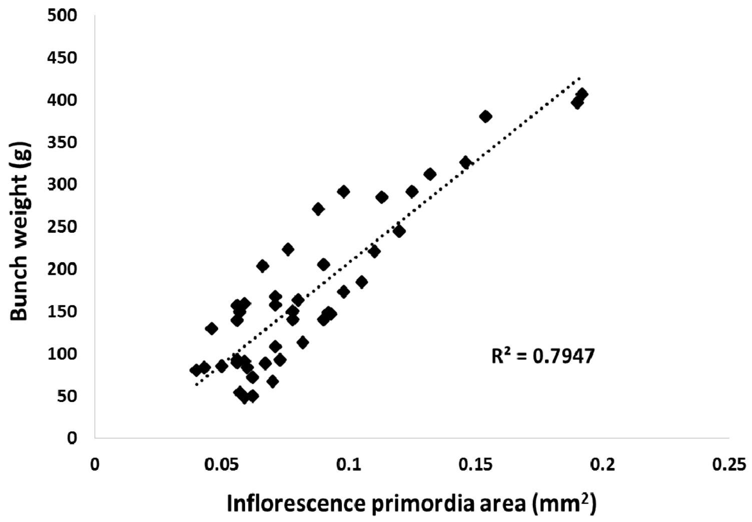

Figure 1: Correlation of average inflorescence primordia cross-sectional area with average bunch weight for Syrah, Cabernet Sauvignon, Semillon, Riesling, Grenache, Tempranillo, Merlot and Sauvignon Blanc vineyards from 2015-2018 growing seasons. Correlation is significant at $p \leq 0.05$.

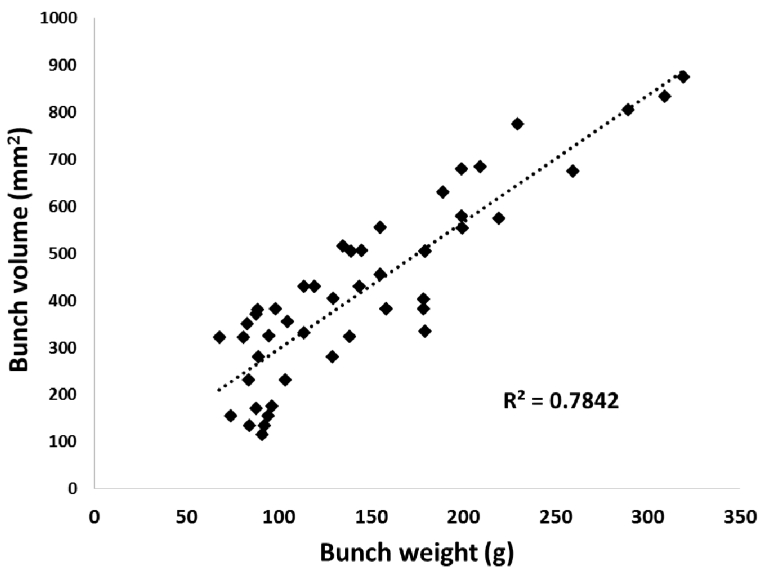

Figure 2: Correlation of average bunch volume with average bunch weight for Syrah, Cabernet Sauvignon, Semillon, Riesling, Grenache, Tempranillo, Merlot and Sauvignon Blanc vineyards from 2015-2018 growing seasons. Correlation is significant at $p \leq 0.05$.

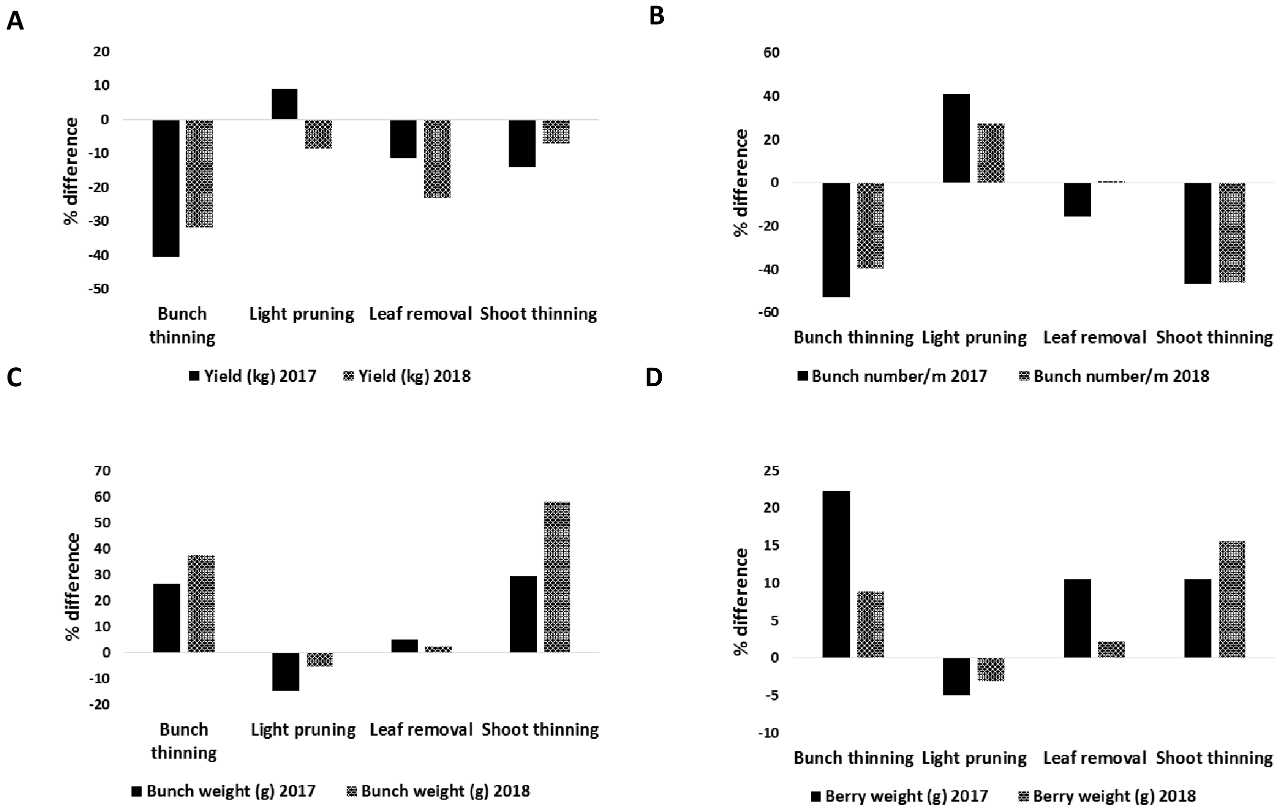

Figure 3: Percentage difference between control treatments and bunch thinning, light pruning, leaf removal and shoot thinning treatments for (A) yield, (B) bunch number, (C) bunch weight and (D) berry weight in the 2017 and 2018 growing season at the Waite Research Institute, Australia