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Yield responses in Flame seedless, Thompson seedless and Red Globe table grape cultivars are differentially modified by rootstocks under semi arid conditions

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ABSTRACT

A field study was conducted during six seasons (2004–2009) to assess rootstocks effects over yield in three table grape cultivars (Thompson seedless, Flame seedless and Red Globe). Nine commercially available rootstocks (Couderc 1613, Freedom, Harmony, Paulsen 1103, Richter 99, Richter 110, Ruggeri 140, Saint George and Salt Creek) plus a control treatment (own-rooted vines) were evaluated under semiarid conditions of northern Chile. A multivariate analysis approach consisting of principal components analysis and cluster analysis was used to segregate those rootstocks with similar influence within each cultivar scion. Three significant clusters were found in Flame seedless and Thompson seedless, while Red Globe showed four significant clusters. Analysis of variance were conducted to evaluate differences in fruit yield, pruning weight, budburst, fruit set, bunch weight, berry weight, berry diameter and rachis weight between rootstock clusters. All rootstocks but Saint George increased yield in Flame seedless, while Salt Creek was the only rootstock with positive effects in Thompson seedless. The use of either Couderc 1613, Freedom, Harmony, Paulsen 1103 or Salt Creek was recommended in Red Globe. This is the first mid-term study with a multivariate analysis of yield components in three table grape cultivars evaluating nine rootstocks in semiarid conditions.

1. Introduction

The use of rootstocks in table grape cultivation has become a common practice among viticulturists worldwide, mainly because rootstocks provide means for cultivation under unfavourable soil conditions, including the presence of nematodes and pests, high salinity or active lime, among others (Dry, 2007; Meggio et al., 2014; Walker et al., 2014). Most of the vineyards over the world are grafted on commercial rootstocks, which are hybrids of three species: *Vitis berlandieri*, *V. riparia*, or *V. rupestris* that were developed before 1930 from American *Vitis* species in an effort to control phylloxera damage (Serra et al., 2013; Berdeja et al., 2015), which devastated the European vineyards in the last half of the 19th century (Whiting, 2012).

Nowadays, a large rootstock selection is commercially available, which allows growers to choose those more adequate for their site conditions with the purpose of obtaining good yield and quality products (Dry, 2007). However, rootstock evaluations are commonly conducted using one single cultivar as the scion, assessing physiological parameters such as photosynthesis, stomatal conductance or transpiration (During, 1994; Soar et al., 2008; Koundouras et al., 2008); plant nutritional aspects (Williams and Smith, 1991; Garcia et al., 2001; Ibacache and Sierra, 2009); or plant biomass production, measured as growth rate (Jones et al., 2009; Tandonnet et al., 2010). The limitation for rootstock recommendations based on these studies is that significant interactions exist between different scion-rootstock genotype combinations, therefore results from single variety studies cannot be generalized to all cases (Serra et al., 2013; Vršič et al., 2015).

Long-term information on rootstock effects over yield and yield components is scarce and the response is primarily associated with the level of vigour conferred to the scion by the rootstock (Dry and Loveys, 1998), which in turns affect bud fruitfulness and vine productivity (Satisha et al., 2010). It is necessary to consider that these effects are highly responsive to the level of soil fertility, which

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Table 1
Description of the rootstocks studied in the mid-term field study.

Rootstock	Pedigree	Origin
Couderc 1613	(*V. solonis* × *V. vinifera*) × (*V. labrusca* × *V. riparia*)	France
Freedom	Couderc 1613 × *V. champinii*	USA
Harmony	Couderc 1613 × *V. champinii*	USA
Paulsen 1103	*V. berlandieri* × *V. rupestris*	Italy
Richter 110	*V. berlandieri* × *V. rupestris*	France
Richter 99	*V. berlandieri* × *V. rupestris*	France
Ruggeri 140	*V. berlandieri* × *V. rupestris*	Italy
Saint George	*V. rupestris*	USA
Salt Creek	*V. champinii*	USA

makes difficult to project the results to conditions other than those in the specific study (Lambert et al., 2008).

Table grapes are cultivated in northern Chile under semiarid conditions, where a severe reduction in irrigation water availability accompanied by temperature increases has been registered in the last decade, a trend that is expected to continue in the following years (Cline, 2007; Fiebig-Wittmaack et al., 2012; Núñez et al., 2014). The diversity of commercial rootstocks adapted for these conditions is scarce, but significant scion-rootstock interactions in water use efficiency and drought tolerance have been reported (Serra et al., 2013; Tomás et al., 2014), therefore, a broader study is required to achieve useful scientific data to be used in rootstock recommendations for table grape varieties used in this particular region.

The aims of this study were to (1) group rootstocks with similar performance in terms of yield when used in three table grape cultivars (Thompson seedless, Flame seedless and Red Globe) under semiarid conditions and (2) identify differences in yield components affected by rootstocks in the three cultivars.

2. Materials and methods

The study was conducted throughout six growing seasons, from 2003–2004 to 2008–2009, in an experimental station located at Vicuña (30°02′ S; 70°44′ W), Coquimbo Region, Chile. The soil is a loamy alluvial Entisol, with flat topography (<1%), moderate depth (>50 cm), pH value of 7.9, 2.4% organic matter and 1.0 dS m^{-1} electrical conductivity in saturated paste. The analysis for nematodes showed the presence of *Meloidogyne* sp., *Criconemoides* sp., *Pratylenchus* sp. and *Tylenchulus semipenetrans*. In all cases, the populations were less than 18 individuals per 250 g of soil. The region has a semi-arid climate with a mean annual rainfall of 84.4 mm during the years of the experiment. The mean annual temperature was 15.5 °C, minimum average of 4.8 °C and maximum average of 30.0 °C.

Three table grape (*Vitis vinifera*) cultivars, named Flame seedless, Thompson seedless and Red Globe, were evaluated using nine different rootstocks plus a control (own-rooted vines) treatment (Table 1). The experiment was established in the winter of 2001. Plants were grafted using a grafting machine (model Omega-Uno; H.L. Wahler, Germany), and then planted in the field using an overhead trellis system at a distance of 3 × 3 m. The vines were cane pruned leaving 4 to five nodes in Flame seedless and Red Globe cultivars and six to eight nodes in Thompson seedless, depending on cane thickness. Standard growth regulators were employed to improve bunch quality. Plants were drip irrigated and fertilized with N, P and K at an annual rate of 90, 50 and 60 kg ha^{-1}, respectively. Irrigation was scheduled accordingly with crop evapotranspirative demands, using the reference evapotranspiration information collected with a meteorological station.

In the field, plants were segregated by scion variety. Within each variety, rootstock treatments were assigned in a completely randomised block design with four replicates. The experimental unit consisted of three plants, with a total of 12 plants per treatment per variety.

2.1. Measurements

Plants were pruned in winter (May–June) and the pruning weight was recorded for each plant. Later in the season, budburst percentage (number of buds that burst/total number of buds left at pruning) and fruitfulness percentage (number of bunches/total number of buds left at pruning) were measured on each plant.

Flame seedless and Red Globe plants were harvested once berries reached full color, while Thompson seedless was harvested when the soluble solids:acidity ratio was equal to 20. All treatments were harvested simultaneously as soon as the control treatment within each cultivar reached the above mentioned characteristics. At harvest, total yield and the number of bunches per vine in each treatment were recorded. This data was used to determine average bunch weight. Fresh samples of bunches were also collected at this stage and yield components, i.e. berry number, berry diameter, berry weight and rachis weight, were measured. All measurements were repeated each year during six consecutive seasons.

2.2. Statistical analysis

Data across all seasons was averaged and a principal component analysis (PCA) ('prcomp' library on 'R') was used to segregate the effects of rootstocks and scion varieties on yield and its components. Additionally, a cluster analysis was performed on each cultivar to differentiate rootstocks groups. Clusters were built using the average linkage method where the distance between clusters was calculated based on the Euclidean distance ('cluster' library on 'R'). The number of clusters within each cultivar was determined by an ANOVA on the yield data, choosing the minimum number of clusters resulting in significant differences ($p < 0.05$). ANOVA's were performed on the clusters for each variable using a General Linear Model (GLM) approach and mean separation was carried out using the least significant difference (LSD) test ('nlme' library on 'R').

To determine the contribution of each component to the variance of yield, a multiple linear regression was conducted on the data set organized by variety, cluster and season. On this model, an ANOVA with type I sum of squares was performed and the contribution of each component to the variance of yield was calculated as the ratio of the sum of squares due to this component to the total sum of squares of the model.

All the analyses were conducted using the 'R' statistics software (R Development Core Team, 2008) through the InfoStat console (Di Rienzo et al., 2014).

3. Results

The effects of nine different rootstocks and own-rooted vines (control) on yield and bunch traits were analysed in three cultivars over six growing seasons at field trails. Data from each cultivar was assigned to different areas in the PCA plot (Fig. 1), indicating greater variability among cultivars than within them. Two principal components (PC) explained 76.8% of the variability in the combined data, showing that plant yield has a positive and significant correlation with bunch weight ($r = 0.89$, $p < 0.0001$), pruning weight ($r = 0.59$, $p < 0.0007$), budburst ($r = 0.49$, $p < 0.0062$), fruitfulness ($r = 0.45$, $p < 0.0117$), berry weight ($r = 0.48$, $p < 0.0074$), berry diameter ($r = 0.54$, $p < 0.0020$), and the number of bunches per plant ($r = 0.74$, $p < 0.0001$). The number of berries per bunch showed a negative correlation with plant yield ($r = -0.38$, $p < 0.0398$).

When the analysis was conducted individually for each variety (graphs not shown), the weight of the PC was similar to that of the