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Espaldero DOV – A New Training System Design for Mechanical Raisin Harvest

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ABSTRACT

Farmers around the word are increasingly interested in the adoption of mechanization methods, especially in dry-on-vine raisin production. The lack of profitability in the raisin industry is a problem that demands the development of new technologies that allow mechanical raisin harvesting, leading to reduced investment. The aims of this research were to assess the performance of two designs of *Espaldero* DOV on raisin production and to measure the vegetative and productive features of Fiesta grapevines in San Juan, Argentina. The double and the simple *Espaldero* DOV were designed based on three trellis systems: Scott Henry, T-trellis and single-wire trellis. A completely randomised design with three replicates was performed. In the growing season, the number of shoots and clusters per meter, shoot length, leaf area, raisin yield (kg/m) and manual and mechanical harvest losses were determined. Descriptive statistics and ANOVA were performed. There were no significant differences in the number of shoots, shoot length, and leaf area between Simple *Espaldero* DOV and double *Espaldero* DOV. Among them, double *Espaldero* DOV almost duplicated simple *Espaldero* DOV production (7.8 t/ha vs. 4.1 t/ha respectively). However, according to the literature, both technologies reduced the yield per hectare compared to other DOV trellis systems or *Parrales*. Both growing systems allowed a mechanical harvesting with 98% efficiency, making this the main advantage of this technology due to the markedly lower harvesting costs.

Keywords: number of shoots, shoot length, dry on vine.

RESUMEN

En el sector productivo y a nivel mundial, crece el interés en adoptar métodos de mecanización, especialmente en la producción de pasas en sistemas DOV. La baja rentabilidad en la industria de la pasa es un problema que demanda nuevas tecnologías que permitan la mecanización de la cosecha de pasas con sistemas de menor inversión. Los objetivos de esta investigación fueron evaluar el desempeño de dos diseños de Espaldero DOV para producción de pasas de uva y medir las características vegetativas y productivas en vides de la variedad Fiesta en San Juan, Argentina. Los Espalderos DOV doble y simple se diseñaron con base en tres sistemas de conducción: Scott Henry modificado, T Californiano y Cordón Bilateral. Se realizó un diseño completamente aleatorizado con tres repeticiones. En la temporada de crecimiento, se determinó el número de brotes y racimos por metro de cordón, el largo de brotes, área foliar, rendimiento de pasas (kg/m) y pérdidas por cosecha manual y mecánica. Se realizaron estadísticas descriptivas y ANOVA. No hubo diferencias significativas en el número de brotes, largo de brotes y área foliar entre Espaldero DOV simple y doble. El Espaldero DOV doble casi duplicó la producción del Espaldero DOV simple (7,8 t/ha vs. 4,1 t/ha respectiva-

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mente). Sin embargo, ambas tecnologías se asocian a un menor rendimiento en pasas por hectárea en comparación con otros sistemas DOV o Parral, según la literatura. Ambos sistemas de cultivo permitieron una cosecha mecanizada con una eficiencia del 98%, lo que representa la principal ventaja de esta tecnología con menor costos de cosecha.

Palabras clave: *número de brotes, longitud de brotes, secado en la vid.*

INTRODUCTION

Argentina is the eighth world raisin producer, with the province of San Juan producing over 40000 tons of raisins per year (USDA, 2021). This province exports 95% of the Argentine raisin production (INV, 2022). Hand harvesting technology is used for raisin production in San Juan. Raisin grapes are traditionally dried in yards and the drying process is carried on in plastic nets placed on the ground. This drying method is laborious and costly, and it uses up to 100 wages per hectare in hand harvesting, including placing the grape on the floor, turning it over and picking the raisin up (Espindola, 2022). The drying process usually takes place from late January to April. The maximum temperature during the drying season is up to 45 °C. At the beginning, the drying process takes from 10 to 15 days; afterwards, it increases up to 25 days due to the decreasing temperature (Gutierrez *et al.*, 2019). Dry-on-vine method (DOV) was introduced in 2010 in San Juan (Espindola *et al*., 2014) due to the lack of labour crews and their high cost. DOV increases the profitability of raisin production (Gutierrez *et al*., 2019); however, it is difficult to train people for cane-cutting once grapes have ripened and the drying process in the vine begins (Fidelibus, 2018).

DOV was created in Australia in 1958 (May and Kerridge, 1967) and it is currently very well known in California (Fidelibus, 2022; California Raisin Industry, 2024). In this method, the grapes are left on the trellises to dry after the canes are pruned; consequently, grapes begin to lose water. The drying process can last between 24 and 53 days, depending on the variety (Espindola *et al*., 2014; Espindola, 2018) and the month of the summer season (Fidelibus, 2021).

Considering the province of San Juan, if we compare the wages spent during the drying process using DOV and those spent using a traditional system, the relationship is 1:10. Therefore, DOV has higher profit than the traditional drying method due to its lower production costs (Christensen, 2000; Espindola, 2022).

On the other hand, as an example of new raisin production technologies, Sunpreme is a new variety trained to single-wire trellis and T-trellis systems (Fidelibus *et al*., 2018). It does not need DOV since it dries naturally, which reduces investment and allows raisin harvest mechanization, avoiding the cane-cutting in the summer season (Fidelibus *et al*., 2022). It is not possible to train other DOV varieties to single wire or T-trellis systems (Espíndola, 2014). It is only possible with Sunpreme because of its spontaneous drying process of the berries, which avoids the cutting of canes (Fidelibus, 2021).

In Argentina, the most important varieties for raisin production are Flame Seedless and Fiesta (INV, 2018). The *Parral* is the most common training system and it is more expensive than any other vertical trellis system. *Parral* is alike the Overhead Arbor trellis system (Fidelibus, 2018); therefore, vertical harvest machines cannot be used to pick up the raisins (Battistella, 2017). The *Parral* raisin production goes from 2 to 5 kg/plant (In Fiesta variety) or from 6 to 8 t/ha (In Flame Seedless variety) (Gutierrez *et al*., 2019).

Regarding DOV In San Juan, when grapes have over 20°Brix soluble solid content, at the end of January, the cutting of canes is performed (Gutierrez *et al*., 2019; Espindola, 2022). In general, the temperatures during the DOV drying process are around 38°C (Pugliese and Espíndola, 2011). The aims of this study were to measure the agronomic variables in the Fiesta variety trained to the *Espaldero* DOV *system*, to record the raisin yield and to evaluate the losses in raisin production due to mechanical harvesting, thus proving that the Espaldero DOV reduces the costs of production. For these reasons, in this study, a new trellis system has been designed in Argentina for DOV raisin production which combines modified T-trellis, single wire, and Scott Henry trellis systems[1] (figure 1). It is called *Espaldero* DOV (figure 2 and 3) and it allows the mechanical harvesting of raisins.

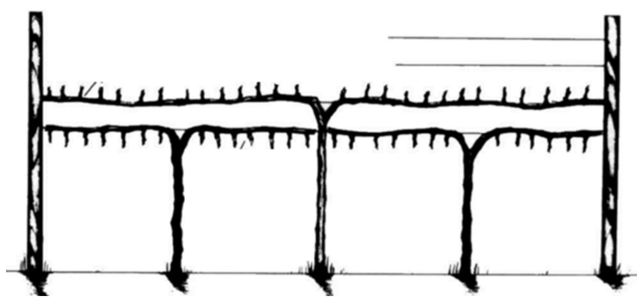

Figure 1. Scott Henry modified. In *Espaldero* DOV all the shoots go upward, and the upper and lower cordon belong to different plants. Source: Viticulture Course – Agriculture Science School – National Cuyo University.

MATERIAL AND METHODS

The experiment was conducted in a vineyard in 25 de Mayo, province of San Juan, located 40 km from downtown (-31.707123, -68.340941). The vineyard was established in the winter of 2018 on a deep sandy loam soil. Cuttings of own-rooted *Vitis vinifera cv. Fiesta* grapevines were planted in a north-south direction with 2.5 m row spacing and 1.1 m plant spacing at Cassab Ahun Company. The irrigation plan was based both on the potential reference evapotranspiration (ET0) provided by a nearby meteo-

[1] Scott Henry trellis system divides the canopy and the shoots are trained up and downward; the difference in *Espaldero* DOV is that all the shoots go upward, and the upper and lower cordon does not belong to the same plant.

rological station and on the crop coefficient (Kc), with Kc values taken from literature (Liotta and Sarasua, 2013). The fertilisation plan was calculated based on the nitrogen that had been removed from the vineyard (20 nitrogen units per hectare).

Two *Espalderos* DOV were established: simple and double *Espaldero*. The first one (figure 2) had only a single upper cordon wire, while the second one (figure 3)had two cordon wires (upper and lower) at 0.8 m from the ground; the upper wire was placed 1. 4 m above the ground and spaced 0.6 m from each other; the total width was 0.4 m, with a total height of both systems of 1.8 m. In both simple and double *Espaldero* DOV, each cordon wire had two parallel wires mounted on crossarms attached to steel stakes. The cordon in the main wire supported renewal spurs and fruit canes. The parallel wire helped to support the canes and their cuttings. Renewal spurs and canes originated from the cordon placed in the main wire (figure 4). The pruning method left enough space for 2-3 canes per metre in the cordon and up to 4 spurs in the same cordon. This means there were between 20 to 25 buds per plant.

A completely randomised design was performed with two treatments: 1) simple *Espaldero* DOV and 2) double *Espaldero* DOV (hereafter referred to as ES and ED), with three replicates of 100 m each one and six plots in total. Two experimental groups conformed by four vines were selected from each replicate. The average of each replicate was calculated for all the variables. The canes were cut at the end of January, when the grapes reached 21°Brix content.

Figure 2. Simple *Espaldero* DOV with only one upper cordon. The middle wire holds the cordon with long canes which are tied to the lateral wires at both sides of the middle one.

Figure 3. Double *Espaldero* DOV with two cordons (upper and lower).

Figure 4. Double *Espaldero* DOV. Canes and spurs come from the central cordon in the main wire. Canes are placed in lateral wires for better cutting performance. Renewal spurs are placed on the main cordon.

The following variables were recorded after three growing seasons in 2022: total number of shoots, number of shoots per metre, number of clusters, shoot length (m), leaf area (LA) (cm^2), yield per plant and per hectare (kg/m - t/ha), and drops in production (%) due to manual and machine harvest. All these measurements were taken from each experimental unit (four plants and 5 m cordon long). Leaf area calibration was determined using the method proposed by Vila (2010), while 30 shoots were taken and measured by a CI-203 AI laser. Leaf area measurements—which were also taken using Vila's method (2010)—were made during veraison. The total number of shoots were recorded per plot, while the average shoot length (30 shoots per experimental unit) was calculated per plant.

The cutting of canes—initiating the drying process—began when the mean experimental units got 21° Brix. The drying process took 30 days. The yield per plant was measured with a Digital Weighing Scale 30 kg – CAS. During the summer season, from veraison to preharvest, 100 berries per sample were collected weekly from each experimental unit to determine soluble solids (°Brix). Plastic nets were placed under each experimental unit to collect any raisin that might have fallen to the ground during manual and machine harvesting. For machine harvesting, a New Holland 9090 dual olive-vid model was used. For each harvesting method, descriptive statistics were performed and the differences among treatments in all the variables were evaluated using one-way ANOVA and a LSD comparation test. The InfoStat program (2016 version, Universidad Nacional de Córdoba, Argentina) was used for all statistical analyses and differences were considered statistically significant at the 0.05 probability level.

RESULTS

There were no significant differences in the number of shoots, shoot length, and leaf area (table 1) between the DOV systems. The average number of shoots per metre was 18.93% higher in ED (table 1). The leaf area equation calculated was LA (cm^2) = -69.32 + 23.6 x shoot length (cm). Regarding plant performance, the number of clusters and the yield (kg/m – t/ha) significantly increased in ED: both variables were 47% higher than in ES. Consequently, the average raisin production was 7.8 t/ha in ED and 4 t/ha in ES (table 1).

DISCUSSION

Zhuang and Fidelibus (2018) showed that 12-20 nodes per cane and a 2 m cane length are needed for a right performance and canopy vigour in DOV. Nevertheless, in this study, the shoot length is half of that obtained with a regular DOV vine. This could be due to the condition of the soil or another external factor that negatively affected the ES and ED vigour. Furthermore, Fidelibus *et al*. (2018) calculated 89-101 fruit clusters per vine or 35-40 fruit cluster per meter in DOV. In this study, ES and ED had 67% less clusters per metre and, therefore, less production. Likewise, Parpinello *et al*. (2012) and Fidelibus (2021) indicated in their studies a regular raisin production, ranging from 7 up to 11 t/ha. In this research, the production was lower in ES (36% less) but similar in ED compared to other DOV systems. That means ED could be used in mechanical harvesting without any yield loss.

Smart; Kliewer and Weaver (1972; 2001) indicated that a leaf area of 10 cm^2/g is associated with an appropriate plant balance. Moreover, Christensen (2000) said that if water is not limiting the leaf area of a Thompson seedless grapevine can measure from 10 to 15 m^2 per vine at bloom and 20 to 25 m^2 at harvest. In this study, ES and ED presented similar leaf areas in comparison to the values presented by other authors (Smart, 2001; Christensen, 2000), which is a positive aspect for an adequate DOV performance. The raisin yields (kg/m - t/ha), number of shoots and number of clusters showed lower values in ES than in ED, as expected.

CONCLUSION

The shoot length and number of shoots were more similar in ES than in ED. The presence of a single cordon (the upper one) or a double one does not mean more or less vegetative competition regarding the performance of the vegetative variables. The leaf area was similar both in ED and ES, with a higher production in ED because of the presence of two cordons and more buds, but with a similar number of shoots per metre (the upper one and the lower one). Vines have a natural compensation mechanism, so ES and ED performed similarly in terms of vegetable variables after all. The main difference is the number of clusters per metre. Two cordons were associated with almost a doubled number of clusters per metre. For this reason, the yield (t/ha) was higher in ED than in ES and, under this condition, the benefit was also bigger. ES and ED presented a lower performance regarding raisin production compared to regular DOV systems in Argentina. Moreover, ES and ED allowed mechanical harvesting, which reduces labour costs.

Treatment	Yield loss manual harvest (%)	Yield loss, machine harvest (%)	Shoots per m	Shoot length (m)	Clusters per m	Leaf area (m^2/m)	Yield (kg/ha)	Raisin (kg/m)
ES	0.10 ± 0.04	0.07 ± 0.03	15.67 ± 5.75	1.07 ± 0.64	**6.96a ± .031**	24.5 ± 15.1	**4082a ± 101**	**1.00a ± 0.51**
ED	0.07 ± 0.03	0.03 ± 0.02	19.33 ± 3.18	1.03 ± 0.4	**13.29b ± 4.8**	26.291 ± 7.9	**7886b ± 312**	**1.92b ± 0.3**
p-value	0.3574	0.0699	0.3885	0.943	**0.0478**	0.8722	**0.0127**	**0.0117**

Each value is the mean of 12 measurements ± standard deviation. Different letters within the same column indicate statistical difference at p≤0.05 significance level.

Table 1. Yield components, vegetative growth of Fiesta plants trained in two different training systems for raising production in DOV system: *Espaldero* DOV (ES) and Double *Espaldero* DOV (ED). 25 de Mayo, San Juan.

DATA AVAILABILITY STATEMENT

Authors are encouraged to make available any data and materials supporting the results or analyses presented in this paper.

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COMPETING INTERESTS

The authors have no relevant financial or non-financial interests to disclose.

DECLARATIONS

Ethics approval: This study has been approved by a research ethics committee of the National Institute of Agricultural Technology of Argentina (Regional Centre Salta—Jujuy). Acta N.° 14/20 of 18th August 2020.

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