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Rootstock and Training System Affect 'Sunbelt' Grape Productivity and Fruit Composition

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Abstract

'Sunbelt' is a 'Concord'-type juice grape (*Vitis labrusca* Bailey) suitable for warm climates. In early trials, the yield of 'Sunbelt' was too low for commercial juice grape production in Arkansas. An experiment was initiated in 1998 to determine if the observed limitations to yield were due to the root system. Treatments included nongrafted 'Sunbelt' and 'Sunbelt' grafted onto Couderc 3309, Extra, and 1103 Paulsen rootstocks. Data were collected for two years on vines trained to a bilateral cordon (BC) system. These vines had low yields (7.3-13.7 $t \cdot ha^{-1}$) and low Ravaz indices (1.8-3.3). The vines were converted to a Geneva Double Curtain (GDC) training system, and an additional two years of data were collected. After conversion to GDC, yields were 200-300% higher with improved Ravaz indices regardless of root system. The GDC training system gave yields of 26.8-41.9 $t \cdot ha^{-1}$ in the final year. On GDC, yields were 39% greater the second year on vines grafted to Couderc 3309 than own-rooted vines. However, low pruning weights raise questions of vine sustainability. The high yield suggests that Couderc 3309 could increase long-term yields with proper vine management and requires further study. Fruit composition was acceptable for juice production on all root systems. Yields of 27 and 30 $t \cdot ha^{-1}$ over two years for nongrafted vines on GDC with good fruit composition and dormant pruning weight indicate that the yield-limiting factors were above ground and not below. With GDC training, 'Sunbelt' produced commercially acceptable yield and fruit composition when grown on its own roots in Arkansas.

The Arkansas Agricultural Experiment Station released the juice grape cultivar 'Sunbelt' (*Vitis labrusca* Bailey) in 1993 (8). 'Sunbelt' fulfills the need for a *V. labrusca*-type processing grape that can be grown in warm climates where 'Concord' grapes display uneven fruit ripening (2). 'Sunbelt' is similar to 'Concord' in many plant and fruit characteristics, differing primarily in its ability to ripen evenly under warm growing conditions of the southern United States (U.S.). Clusters are small; berries are blue, large and seeded. Total soluble solids and harvest date correspond closely with those of 'Concord' grown under warm climatic conditions. However, color, acidity, and pH of 'Sunbelt' are superior to 'Concord' produced under these conditions. Yield of 'Sunbelt' grapes was low (5.9 to 10.9 $t \cdot ha^{-1}$) in initial testing (8). A break-even yield for 'Sunbelt' grape production in Arkansas has been projected at 15.3 $t \cdot ha^{-1}$ at a price of \$406 t^{-1} (12). Therefore, increased yields are necessary for commercial production.

The use of rootstocks is increasing in the Midwestern and Eastern U.S. viticultural districts. The primary use of rootstocks is for pest resistance. However, rootstocks also influence vegetative growth, yield, and fruit composition (4,6,7).

The hypothesis tested was that observed limitations to yield were due to root system problems. Nongrafted 'Sunbelt' was compared to 'Sunbelt' grafted to rootstocks representative of native Midwestern and Eastern U.S. grape species. The objective was to increase vine size and yield without negatively affecting vine nutrition or fruit composition. Three rootstocks plus nongrafted vines were used in this study: Extra [*V. lincecumii* Buckley X (*V. labrusca* L. X *V. vinifera* L.)], Paulsen 1103 (1103P) [*V. berlandier* Planch.

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X *V. rupestris* Scheele.], Couderc 3309 (3309C) [*V. riparia* Michx. X *V. rupestris* Scheele.] and nongrafted 'Sunbelt'. Extra is a vigorous T.V. Munson hybrid that grows well in south Texas (11). The rootstocks 3309C and 1103P are phylloxera tolerant (4,7).

Materials and Methods

'Sunbelt' scion wood was grafted in the spring of 1997 onto Extra, 1103P, and 3309C by Sunridge® Nurseries Inc., Bakersfield, CA. Grafted and nongrafted vines were planted at the Arkansas Agricultural Research and Extension Center, Fayetteville, AR, as one-year-old dormant vines in April 1998. Soil was a Captina silt loam (fine-silty, mixed, mesic Typic Fragiudults) with pH 6.9. The site had previously been a self-rooted 'Concord' grape vineyard. The 'Concord' grapes had been removed, and agricultural lime and poultry litter had been applied. A cover crop of rye was grown for two years before grapes were replanted. The vineyard soil was high in K, P, and Ca (950, 1125, and 5487 $kg{\cdot}ha^{-1}$, respectively) when the study was initiated. Soil K was 180 to 239% higher than the 280 to 335 $kg{\cdot}ha^{-1}$ recommended for grapes (3) and P and Ca were similarly abundant. Nitrogen, applied through drip irrigation, and foliar magnesium were applied equally to all vines and were the only fertilizers applied during the experiment. Application of nitrogen and magnesium was variable between years and was based on tissue analysis and observation of leaf color.

Vines were planted in a completely randomized block design with three replications of 4-vine plots. A high wire, bilateral cordon (BC) training system was used. The cordon height was 1.8 m and vine spacing was 1.8 m x 2.7 m with north-south row orientation. The BC vines were balanced pruned to a 20 + 10 system (20 buds retained for the first 454 g of dormant prunings and an additional 10 buds left for each addition 454 g of dormant prunings removed) on five-node spurs with a maximum of 50 buds retained. The BC training system was converted to a Geneva Double Curtain (GDC) system in 2002 due to low fruit yield and excessive vine growth. The GDC system had a four-foot separation between canopies. Vines were balance pruned to a 50 + 10 level on five-node spurs with an 80-bud maximum. Both training systems were shoot positioned in a downward direction two times per year and drip irrigated. Studies at the University of Arkansas showed that 'Concord' produced high yields when vines were trained to GDC, balanced pruned and irrigated (9,14). Data were collected on the BC system during 2000 and 2001 seasons and on the GDC system during the 2004 and 2005 seasons. Yield and fruit composition data were also collected during 1999 and during the year after conversion to GDC in 2003. However, these data were not reported due to the immaturity of vine cordons and variability in cropping.

The 'Concord' grape juice industry normally uses 15% total soluble solids (TSS) as the lower level of acceptable quality and pays a premium for each increase in TSS up to 18% (10). In 'Concord', grape flavor and acidity generally decrease above 18% TSS, reducing quality. 'Sunbelt' grapes taste best at 16% TSS or higher and 'Concord'-like flavor begins to deteriorate at TSS levels over 19% (personal observations). Therefore, in this study grapes were harvested between 16 and 19% TSS.

Cluster weight and yield were determined by counting clusters and harvesting individual vines within the 4-vine plots. Yield ($t{\cdot}ha^{-1}$) was extrapolated from fruit weight × the number of vines ha^{-1}. Dormant pruning weights were obtained, and the Ravaz index (kg fruit/kg dormant cane prunings) was calculated (1). Fruit composition (TSS, pH, titratable acidity, and berry weight) was determined from four basal-cluster samples per plot in 2000 and 2001 and from 150-berry samples in 2004 and 2005. Berry samples were used in the later years to reduce any influence that cluster selection may have had on berry size. For berry size determination, frozen berries were removed from the rachis and weighed in 2000 and 2001. In 2004 and 2005, 150 berries were randomly collected from each four-vine plot and frozen for determination of fruit composition and berry weight. For composition analyses, berries were thawed overnight at 21°C. The grapes were pureed for 15 sec in a blender at the lowest speed. The puree was placed in a 250-mL beaker, covered with a watch glass, and heated in a water bath (85°C) until the sample temperature reached 71°C. Hot puree was squeezed through two layers of grade 60 cheesecloth. One hundred fifty mL of juice was collected to which 100 µL of Scottzyme Pec 5L (Scott Laboratories, Petaluma, CA), a pectolytic enzyme, was added. The hot-pressed juice was cooled to room temperature (21°C) prior to centrifugation for 10 min at 13,250 g-force. This hot-press method extracts more color, acids, and minerals from skins as contrasted with non-heated methods (16) and is similar to commercial juice extraction processes. Standard methods for juice analysis were then followed (5). TSS was measured using an AO ABBE Mark II refractometer (AO® Scientific Instruments, Keen, NH) in temperature-compensated mode. Total red pigment is a measure of red and potentially red pigments (5). For this test, absorbance of juice diluted with 1M HCl was measured at 520 nm using a Thermo Spectronic Helios Beta UV-VIS Spectrophotometer (Thermo Spectronic, Cambridge, Great Britain) and values obtained were standardized to a 10-mm cell path length. Petioles were collected at veraison in 2004 and 2005 to determine nitrogen and mineral composition. Plant tissue was digested in concentrated nitric acid and hydrogen peroxide on a heating block. Juice and petiole minerals were measured using method EPA 200.7 (17) with a Spectro Cirros Inductively Coupled Plasma Emission Spectrometer (Spectro Analytical Instruments, Fitchburg, MA). Total nitrogen was determined by combustion on a LECO FP428 nitrogen analyzer (LECO Corp., St Joseph, MI).

Data were analyzed using analysis of variance with JMP statistical software (version 6.0.2; SAS Institute, Cary, N.C.). Yield data for individual vines were averaged for each plot before statistical analysis. Separation of the mean values was determined using standard least squares to fit the model with "lsmeans" separation using Student's t-tests at $p \leq 0.05$.

Results and Discussion

Fruit harvest dates were Aug. 23, 2000, Aug. 28, 2001, Aug. 19, 2004, and Sept. 6, 2005. Vines in all treatments were picked the same day. In 2000 veraison was unusually warm, with 12 days of 36°C or higher prior to harvest, followed by 12 days of 36°C or higher including 9 days above 38°C. This was followed by a killing frost that occurred one month earlier than normal.

Yield and vegetative growth

Bilateral Cordon. Yield was similar among treatments in 2000. In 2001, fruit yield from vines grafted on Extra and 1103P rootstocks were lower than those on 3309C (Table 1). Extrapolated yields ranged from 7.2 to 10.7 $t \cdot ha^{-1}$ in 2000 and 7.3 to 13.7 $t \cdot ha^{-1}$ in 2001. This is similar to the 5.9 to 10.9 $t \cdot ha^{-1}$ reported by Moore et al. (8) for own rooted 'Sunbelt'. However, this yield is much lower than the 15.4 $t \cdot ha^{-1}$ calculated by Noguera et al. (12) to "break even" (net return on operations equal zero) for 'Sunbelt' grown in Arkansas and sold for \$406 t^{-1}. In 2001, yields were highest on nongrafted (12.4 $t \cdot ha^{-1}$) and vines grafted to 3309C (13.7 $t \cdot ha^{-1}$). 'Sunbelt' on 3309C had more clusters/vine than when grafted to 1103P in both years. Cluster weights, berries/cluster, and berry weight did not differ among treatments in either year.

Due to unripened periderm from the early freeze of 2000, pruning weights were abnormally low and did not reflect observed vine growth. Therefore, pruning weight and Ravaz index (ratio of yield to pruning weight) data are only shown for 2001. There were no differences in pruning weights or Ravaz indices among rootstocks in 2001. Shoot growth on

Table 1. Effect of year and rootstock on yield parameters of'Sunbelt' grapes grown on a bilateral cordon and Geneva Double Curtain training systems.

Year and rootstock	Clusters/ vine	Cluster weight (g)	Berries/ cluster	Berry weight (g)	Yield (kg•vine^{-1})	Extrapolated Yield (t•ha^{-1})	Pruning weight yield	Ravaz index
	Bilateral Cordon							
2000								
Nongrafted	44 c[z]	105 a	27 a	3.8 a	4.6 a	8.2 a	-[y]	-[y]
Extra	62 ab	81 a	22 a	3.7 a	4.0 a	7.2 a	-	-
1103P	50 bc	92 a	25 a	3.6 a	5.6 a	10.1 a	-	-
3309C	71 a	85 a	22 a	3.8 a	6.0 a	10.7 a	-	-
2001								
Nongrafted	63 ab	114 a	23 a	4.9 a	6.9 ab	12.4 a	2.10 a	3.3 a
Extra	51 b	93 a	19 a	5.0 a	4.1 b	7.3 b	2.31 a	1.8 a
1103P	51 b	96 a	21 a	4.6 a	4.2 b	7.6 b	2.28 a	1.8 a
3309C	74 a	106 a	24 a	4.5 a	7.6 a	13.7 a	2.42 a	3.3 a
	Geneva Double Curtain							
2004								
Nongrafted	104 a	144 a	34 a	4.3 a	15.2 a	27.2 a	1.14 a	13.5 a
Extra	94 a	133 a	28 a	4.6 a	12.5 a	22.5 a	1.51 a	9.0 b
1103P	112 a	131 a	31 a	4.2 a	14.7 a	26.4 a	1.75 a	9.2 b
3309C	111 a	146 a	31 a	4.8 a	16.2 a	28.9 a	1.25 a	13.1 a
2005								
Nongrafted	145 a	119 ab	27 a	4.4 a	16.8 b	30.1 b	1.58 b	10.7 b
Extra	132 a	113 b	24 a	4.7 a	14.9 b	26.8 b	1.58 b	9.7 b
1103P	161 a	115 b	24 a	4.9 a	18.6 ab	33.3 ab	2.18 a	9.1 b
3309C	163 a	144 a	28 a	5.2 a	23.4 a	41.9 a	1.28 b	17.6 a

[z] Means within column, training system and year with the same letter(s) are not significantly different according to Student's t-tests, $p \leq 0.05$.

[y] Data not shown for 2000 due to an early freeze that prevented normal periderm ripening and produced pruning weights that did not match observed growth.

the BC system was excessive with shoots extending into row middles. The vines did not have balanced fruit-to-vegetative growth on the BC system as indicated by Ravaz index. The Ravaz Index is an indication of vine balance; a value of 5 to10 for *V. vinifera* cultivars indicates the vine is balanced, a value greater than 12 indicates over cropping, while a value less than 3 indicates excessive vine size (13). The BC system, with a Ravaz index ranging from 1.8-3.3, was not appropriate at this site and with this vine spacing and pruning severity.

Geneva Double Curtain. There were no differences in clusters/vine, berries/cluster, or berry weight among nongrafted vines and rootstocks in either year. Cluster weight was higher for 'Sunbelt' on 3309C than on Extra or on 1103P in 2005. Yield did not differ among vines in 2004. In 2005, yield for 'Sunbelt' on 3309C was higher than 'Sunbelt' on Extra or nongrafted vines. Yields were numerically lowest on both training systems and in all years when Extra was used as the rootstock. Pruning weight did not differ among treatments in 2004. In 2005, pruning weights were higher for 'Sunbelt' on 1103P than other rootstocks. The Ravaz index was lower for 'Sunbelt' on Extra and 1103P than on 3309C or nongrafted vines in 2004. In

2005, 3309C-grafted vines produced high yield (41.9 t·ha^{-1}) with a high Ravaz index of 17.6, while other rootstocks had more acceptable Ravaz indices. The high yield on 3309C-grafted vines may not be sustainable. The Ravaz index indicated the fruit load was too great for vine size. This issue could be addressed by fruit thinning or changing the fruit pruning formulation. Yield increased on the remaining treatments in 2005 while retaining similar Ravaz indices as 2004. This indicates a balanced increase in vine size with age. 'Sunbelt' grown on GDC produced commercially acceptable yields of 27.2 and 30.1 t·ha^{-1} over two years when grown on its own roots. In a California study of 'Sunbelt' grafted on 'Chenin blanc' and trained to a GDC training system with similar pruning severity, yields were 23.2 and 21.6 t·ha^{-1} over two years (15). Thus, most of the yield-limiting factors for 'Sunbelt' are above ground and not below. Therefore, unless there are mitigating factors, such as soil pests, or soil type, the use of rootstocks does not appear necessary for 'Sunbelt' grapes under Arkansas conditions.

Upon termination of the experiment, vines were pulled and the root systems were examined for insects. There was no observed damage due to grape root borer (*Vitacea polistiformis* Harris) on the roots of any vine. Phylloxera (*Phylloxera daktulosphaira vitifoliae* Fitch) nodosities were present on the fine roots of all nongrafted and grafted vines (D.T. Johnson, personal communication, 2006).

Petioles were collected at veraison to access vine nutrition on the GDC trained vines. The nutritional components N, P, K, Ca, Mg, B, Fe, and Zn were measured. All values fell within normal ranges (3) regardless of root system and differed little between root systems. The only exception was boron; it was lower in nongrafted vines (26.2 mg·kg^{-1}) than in grafted vines (32.4 mg·kg^{-1}). However, these values are still within the normal range for boron.

Juice Composition

Data are available for comparison from own rooted 'Concord' grown at our location on GDC, with the same vine spacing, pruning severity, and juice analysis method for 2004 and 2005. 'Concord' grapes had 18.3% TSS, 3.62 pH, 7.6 g/L titratable acidity, and 28-32 a.u. total red pigment in 2004 and 17.7% TSS, 3.65 pH, 6.4 g/L titratable acidity, and 15-18 a.u. total red pigment in 2005. 'Sunbelt' juice composition parameters were better than 'Concord' with lower pH, higher acidity, and 2 to 3 times higher color values (Table 2). Rootstock did not seem to affect juice composition. Differences within a year are usually attributable to yield or fruit maturity. If the treatments were picked at the same TSS rather than calendar date, the differences in juice composition would probably have been minimal. This has been observed in a mechanization study on 'Sunbelt' grapes with differing fruit loads that were picked at the same TSS (Justin Morris, unpublished data).

Bilateral Cordon. Even with excessive maximum temperatures in 2000, 'Sunbelt' had excellent values for TSS, pH, titratable acidity, and color (Table 2). There were few differences among juices from nongrafted and grafted vines in either year. Differences that did exist may have been due to the high vine vigor and low fruit yields and not directly due to vine root system.

Geneva Double Curtain. In 2004, there were no differences in TSS, pH, or total red pigment between treatments. Titratable acidity was lower in juice from vines grafted to 3309C than the other treatments. Juice potassium values were higher in nongrafted vines in 2004 but did not differ in 2005. Juice potassium decreased over the course of the experiment as the grapes removed potassium from the soil. In 2005, juice from 'Sunbelt' on Extra and 3309C had similar soluble solids, pH, titratable acidity, and total red pigment values. However, 'Sunbelt' on Extra did not advance fruit maturity considering its

Table 2. Effect of year and rootstock on juice composition and color of 'Sunbelt' grapes grown on bilateral cordon and Geneva Double Curtain training systems.

Year and rootstock	Total soluble solids (%)	pH	Titratable acidity (g/L)	Total red pigment (a.u.)	Potassium (mg/L)
	Bilateral Cordon				
2000					
Nongrafted	18.4 ab[z]	3.51 a	11.3 a	68 b	2434 a
Extra	18.1 b	3.42 b	10.7 ab	67 b	2518 a
1103P	19.1 a	3.44 b	10.6 ab	72 ab	2913 a
3309C	18.6 ab	3.46 b	9.8 b	80 a	2650 a
2001					
Nongrafted	16.3 b	3.61 a	8.4 b	44 a	2542 a
Extra	17.0 ab	3.48 b	8.4 b	47 a	2416 a
1103P	16.3 b	3.49 b	9.4 a	45 a	2563 a
3309C	17.5 a	3.53 ab	8.2 b	53 a	2405 a
	Geneva Double Curtain				
2004					
Nongrafted	16.4 a	3.39 a	11.2 a	71 a	2332 a
Extra	15.9 a	3.36 a	11.0 a	58 a	2161 c
1103P	16.8 a	3.37 a	10.9 a	77 a	2250 b
3309C	15.8 a	3.39 a	10.0 b	60 a	2095 c
2005					
Nongrafted	18.0 ab	3.50 a	8.1 a	76 a	1877 a
Extra	17.3 b	3.49 a	8.0 a	58 b	1881 a
1103P	19.0 a	3.51 a	8.0 a	75 a	1937 a
3309C	17.7 b	3.49 a	7.8 a	59 b	1850 a

[z]Means within column, training system and year with the same letter(s) are not significantly different according to Student's t-tests, $p \leq 0.05$

lower yield of 14.9 kg·vine^{-1} vs. 23.4 kg·vine^{-1} for 'Sunbelt' on 3309C. It was noted in most years that vines with Extra and 3309C rootstocks had some green fruit on the vines at harvest. This may explain why total red pigment was higher for nongrafted and vines grafted to 1103P than for vines grafted to 3309C and Extra in 2005. Additional ripening time before harvest might have improved red color and soluble solids for vines grafted to Extra and 3309C.

Conclusion

Excessive dormant cane prunings and low yield in the 2000 and 2001 seasons indicated that the vines were not in balance on the BC training system. Doubling the canopy area by converting to GDC increased yield 200 to 300% while still producing adequate pruning weights and good fruit composition. All root systems used produced vines with adequate mineral nutrition and fruit with acceptable composition. The high yields and good fruit composition obtained from nongrafted vines on the GDC system indicate that the limitation to yield observed in the original description for this cultivar did not originate in the root system. On GDC, 'Sunbelt' can produce commercially acceptable yield (27 to 30 t·ha^{-1}) and fruit composition when grown on its own roots. In the final year of the study, 'Sunbelt' grafted to 3309C had 39% greater yield than own rooted 'Sunbelt' with comparable fruit composition. However, low pruning weights raise questions of vine sustainability. The results for 'Sunbelt' on 3309C suggest that this rootstock may increase long-term yield over own-rooted 'Sunbelt'. 'Sunbelt' on 3309C and possibly other vigorous rootstocks should be further investigated with differing pruning formulations and soil conditions to maximize yield.

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