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Performance of Arkansas-grown 'Norton' Grapevines on Selected Rootstocks

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Abstract

'Norton'/'Cynthiana' grapevines (*Vitis aestivalis* Michx.) are a native U.S. species that grow well but can have low yield and produce fruit with high levels of pH, malic acid, and potassium. There has been limited research on the use of rootstocks for 'Norton' production that could overcome these challenging attributes. The impact of selected rootstocks on 'Norton' yield, fruit composition, and vegetative growth was evaluated at the University of Arkansas Division of Agriculture in Fayetteville, AR for three years. Rootstocks evaluated included 3309C (Couderc), 1103P (Paulsen), 44-53 (Malegue), 5C (Teleki), and 101-14 Mgt (Millardet et de Grasset) compared to own-rooted 'Norton'. Rootstock had limited effects on vegetative growth, fruit composition, and yield components during this study. Yield of 'Norton' grapevines and petiole nutrient content were influenced by rootstock. In particular, 3309C and 1103P rootstocks produced higher yields than 44-53 while the latter rootstock had the lowest Mg and highest K petiole nutrient content. Additionally, vines grafted to 44-53 exhibited some Mg deficiency symptoms in basal leaves. Rootstocks also impacted the titratable acidity and malic acid content of berries, with berries from vines grafted on 44-53 higher in titratable acidity and malic acid than own-rooted vines. More extensive research is needed to determine the long-term effect of rootstocks on 'Norton' grapevines.

Introduction

'Norton'/'Cynthiana' (*Vitis aestivalis* Michx.) is an important high quality wine grape cultivar for the Midwestern and Eastern grape industry. It is believed this cultivar was discovered as a seedling in the early 1800's by Dr. Daniel Norborne 'Norton' in his experimental vineyard located in Virginia that quickly established itself as a quality wine grape in the region (Ambers and Ambers 2004). In Missouri and Arkansas, 'Norton'/'Cynthiana' is the official state grape, and in Missouri, 'Norton' comprises the second greatest number of bearing acres encompassing 16.1% of the state's acreage in 2022 (USDA-NASS 2024). There is also significant acreage of the cultivar in Arkansas, Virginia, Illinois, Kansas, Oklahoma, Tennessee, and Georgia. 'Norton' is predominantly derived from native American species which imparts unique attributes that differ from European (*Vitis vinifera* L.) cultivars. Although the genetic background of 'Norton' is not completely known, it has been proposed as a hybrid cross between *V. aestivalis* (Michx.) and *V. vinifera* (L.) (Stover et al. 2009). More recently, Sparreo et al. (2025) have identified 'Norton's' parentage to be likely from three species, *V. aestivalis*, *V. vinifera*, and *V. labrusca*.

Positive attributes of 'Norton' include a high level of disease resistance, late budburst which aids in avoidance of spring frost, good cold hardiness, and potential for high-quality wine production (Hedrick 1908; Tarara and Hellman 1991). It is noted to have resistance to powdery mildew (*Erysiphe necator*), downy mildew (*Plasmopara viticolar*), and Botrytis bunch rot (*Botrytis cinerea*) making it an even more important cultivar for future genetic research and breeding of resistant cultivars (Sapko-

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ta et al. 2019). Challenges with this cultivar are low yield, excessive vine size, intolerance to poor soil drainage (Striegler et al. 1993) and high soil pH (Kering and Kaps 2011; Tarara and Hellman 1991), phytotoxicity due to use of sulfur and other pesticides (Long et al. 2025), and low propagation potential (Norton and Skirvin 2001). In addition, 'Norton' can produce fruit with high levels of titratable acidity, low tartaric/malic acid ratio, high pH, and variable quality and quantity of phenolic components (Main and Morris 2004). Cultural practices such as site selection, trellis system selection, pruning methods and canopy management are commonly used to improve the performance of 'Norton' (Main and Morris 2008; Morris and Main 2010). Canopy management, specifically increasing sun exposure in the fruiting zone, can improve fruit quality of 'Norton' (Jogaiah et al. 2012; Jogaiah et al. 2013; Patterson and Zoecklein 1990).

The main functions of the grapevine root system are to provide anchorage, water, nutrients, carbohydrate storage, and certain plant hormones (Richards 1983). Rootstock may have direct or indirect influence on the scion, the former of which are the root system functions noted above and the latter mediated through its influence on vine size and internal canopy shading (Striegler and Howell 1991). Rootstocks were originally selected for their tolerance or resistance to biotic and abiotic factors, but the alternative benefits of rootstocks are gaining greater interest. Grape phylloxera (*Daktulosphaira vitifoliae* Fitch) (Johnson et al. 2009) and nematode tolerance and resistance are the main functions of rootstocks followed by adaptability to tolerate high pH soils, saline soils, low pH soils, poorly drained soils, and drought conditions (Pongracz 1983). Further research has expanded the use of rootstocks to influence fruit composition (Chen et al. 2024b), yields (Jia et al. 2020), vine size, winter hardiness, nutrient uptake (Morel et al. 2024), and length of vegetative cycle (Chen et al. 2024a; Reynolds and Wardle 2001).

Of particular interest for 'Norton' is determination of the impact of rootstock selection on fruit composition by lowering fruit pH, malic acid, and potassium (K) levels. Rootstocks which impart high juice K can cause high pH (Xiao et al. 2020), while rootstocks that increase berry size can reduce the tartaric/malic acid ratio (Ruhl et al. 1988). Vegetative growth in terms of shoot growth can increase pH (Jackson 1986). Ruhl et al. (1988) found that the rootstock 101-14 can reduce pH, and K was closely related to malate, the ionized form of malic acid. Additionally, rootstock effect on pH depended on the genotype of the scion. On 'Cabernet Sauvignon', Xiao et al. (2020) found a general trend of lower juice K and lower pH when grafted. The lowest pH was observed for vines grafted on 110R.

While this study was implemented over 20 years ago, there is emerging interest in the use of species native to North America including 'Norton' in breeding programs (Negus et al. 2021). One such example is the breeding of a new white variety, 'Norton Blanc', derived from a cross between 'Norton' and 'Cabernet Sauvignon' which was developed at Missouri State University, Center for Grapevine Biotechnology by Wenping Qiu (Qiu 2025). This new variety is noted for its moderate resistance to downy mildew and bunch rots.

Rootstock selection is a potential avenue to mediate the challenging attributes of 'Norton' grapevines. More information on the impact of rootstock on yield, fruit composition, and vegetative growth of 'Norton' grapevines would be beneficial for growers in the region.

Materials and Methods

The research plot was planted in June 2001 at the University of Arkansas Division of Agriculture (UADA) Milo J. Schult Research and Extension Center in Fayetteville, AR. within USDA Hardiness Zone 6A. Soil type was a Captina Silt Loam (fine-silty, siliceous, active, mesic Typic Fragiudults) with starting pH 5.7-6.6 which was limed at a rate of 2.24 metric tons per hectare prior to planting. Vines used in the study were obtained from Sonoma Grapevines, Inc. (Santa Rosa, CA, USA). Vines were trained to a Geneva Double Curtain System with vineyard spacing of 2.4 m x 3.0 m (vine x row) and north to south row orientation. Irrigation was provided using a drip system. Vines were balance pruned using a 50+10 pruning severity formula with an upper node limit of 130. Downward shoot positioning was performed two to three times per season. Other canopy management practices such as shoot thinning and leaf removal were not performed as this was not commercial practice in the region. All other cultural practices were performed according to the Midwest Fruit Pest Management Guide (Long et al. 2025).

Experimental Design. The experimental design used was a randomized complete block with six blocks. Plots consisted of three vines. Rootstock treatments included in the study were 3309C (Couderc), 1103P (Paulsen), 44-53 (Malegue), 5C (Teleki), and 101-14 Mgt (Millardet et de Grasset) with an own-rooted control. These rootstocks have been in commercial use for many years and genetic origin is represented by several grape species. The rootstock 3309C and 101-14 are *V. riparia* x *V. rupestris* crosses, 5C is a *V. berlandieri* x *V. riparia* cross, 1103P is a *V. berlandieri* x *V. rupestris* cross, 44-53 is a *V. riparia* x (*V. cordifolia* x *V. rupestris*) cross and own-rooted 'Norton' vines are likely a *V. aestivalis* x (*V. labrusca* x *V. vinifera*) cross. Data were collected during the 2004-2006 season for petiole and soil nutrient content, yield, yield components, vegetative growth, and fruit composition.

Petiole and Nutrient Content. Petioles samples were collected when the fruit was at veraison by replication (100 petioles per treatment replication) and were analyzed for nitrogen (N), phosphorus (P), potassium (K), magnesium (Mg), zinc (Zn), boron (B), and iron (Fe) content. Petiole nutrient and juice mineral samples were analyzed utilizing methods described in Morris et al. (2007). Soil samples were collected in 2004 and 2005 at a depth of 20 cm approximately 0.6 m from the vines for each replicate. The soils were dried and then analyzed by the UADA, Agriculture Diagnostic Laboratory using Mehlich 3 (1:10) procedure (Baker et al. 2002).

Yield, Components of Yield, and Vegetative Growth. Fruit was sampled prior to harvest to determine harvest date, and once the harvest date was determined, all treatments were hand harvested on the same day. Yield data were collected on a per vine basis (kg/vine). Yield components included clusters per vine (number/vine), cluster weights (g) by calculation, berry weight (g) of 200 berry sample, and berries per cluster by calculation. Vegetative growth was measured as dormant pruning weights (kg/vine) collected from individual vines.

Fruit Composition. Two sets of berry samples were collected at harvest by treatment replicate. These consisted of a 200-berry sample for juice composition including soluble solids (%), titratable acidity (g/L), pH, organic acids (g/L), sugars (g/L) and mineral content. The other 200-berry sample was frozen at -29 °C for later analysis of color and total phenolics. The soluble solids, titratable acidity and pH were performed using methods described in Iland (1993). Juice samples were diluted to a 1:20 ratio of juice sample to 2.5% hydrochloric acid (HCl) w/v aqueous solution to measure mineral content using Inductively Coupled Plasma - Optical Emission Spectroscopy (ICP-OES) at the UADA Agriculture Plant Analysis Laboratory, Fayetteville, AR. Organic acids (tartaric and malic) and sugars (fructose and glucose) of the juice from berries were measured using the HPLC method described in Walker et al. (2003). Total phenolics and color of the juice from berries were measured spectrophotometrically using methods described by Iland et al. (2000) and Zoecklein et al. (1995) with total red pigments at 520 nm and 280 nm to measure total phenolics.

Statistical Analysis. Data were averaged for each component by year and subjected to analysis of variance, and means were separated with Tukey's Honestly Significant Difference (HSD) test using the SAS statistical software (SAS version 9.1.3; SAS Institute Inc., Cary, NC, USA). Data are presented as 2004-2006 mean to simplify interpretation since only a few attributes were impacted by year, mainly due to vine age.

Results and Discussion

Yield, Components of Yield, and Vegetative Growth. Choice of rootstock influenced productivity of 'Norton' grapevines grown in Arkansas. Cluster weight (82 g), berries/cluster (68), and pruning weight (0.81 kg/vine) were not impacted by rootstock treatment. Although pruning weights were not impacted, these values typically coincided with yields. Vines grafted onto 3309C (21.5 kg/vine) and 1103P (20.7 kg/vine) produced yields which were higher than the yield of vines grafted on 44-53 (14.7 kg/vine; Table 1). Own-rooted vines and vines grafted onto 101-14 and 5C had similar yields (18.9, 17.8, and 16.3 kg/vine respectively). Overall, yields were high for 'Norton' in this trial. The previous vineyard planted to 'Norton' on this site displayed an average yield of 11.7 kg/vine over a 6-year period (Morris and Main 2010). Similar to this trial, yield differences were observed among rootstocks grafted to 'Norton' in central Missouri, although differences varied by rootstocks and yields were lower, ranging from 12.0-15.0 kg/vine (Harris 2013). In the Missouri trial, own-rooted vines had the lowest yield, while 101-14 had one of the highest yields with 1103P and 3309C having intermediate yields. In both studies, 44-53 was among the lowest yielding rootstocks although in the Missouri trial it was slightly higher than own-rooted and comparable to 3309C and 1103P. Higher yields among rootstocks 3309C and 1103P have been shown in other studies with the cultivar 'Chambourcin' (*Vitis* hybrid) in Southwest Missouri (Bozzolo et al. 2023; Kaps 2017). Few differences were observed for yield components of 'Chambourcin' which aligns with this trial on 'Norton'.

In the current study, differences among rootstocks for 'Norton' were observed in clusters per vine and berry weight with vines grafted on 1103P (258 clusters/vine) and 3309C (257 clusters/vine) having more clusters than vines grafted onto 44-53 (190 clusters/vine; Table 1). Own-rooted vines and vines grafted onto 101-14 and 5C had similar clusters/vine (244, 216, and 198, respectively). Own-rooted vines had the lowest berry weight (1.1 g) when compared to vines grafted on rootstocks in this trial.

Rootstock selection had a minimal impact on vegetative growth as indicated by dormant pruning weight. Although there were limited differences among rootstocks for pruning weight, there were differences by year with a trend of increasing pruning weight over the three years of the study (data not shown). This was a young vineyard and as the vines matured, they increased in vine size. It is possible that the pruning severity used (50+10) was not as severe as needed for the young, developing 'Norton' vines in this study. In addition, shoot thinning of vines could have been beneficial and reduced the crop level. Other studies with 'Norton' have shown a positive impact from use of canopy management practices such as leaf removal (Main and Morris 2004), shoot thinning, and shoot positioning (Jogaiah et al. 2012; Jogaiah et al. 2013; Morris and Main 2010; Patterson and Zoecklein 1990).

Fruit composition. Similar to other studies, rootstock selection had a limited impact on fruit composition (Bozzolo et al. 2023; Harris 2013; Kaps 2017; Sabbatini and Howell 2013). In this study, soluble solids (21.4%), pH (3.8), potassium (2,187 mg/L), tartaric acid (4.1 g/L), total phenolics (31.8 au), and total red pigments (56.5 au) of the juice from berries were not impacted by rootstock treatment. Only titratable acidity and malic acid content displayed a response to rootstock treatment. Rootstock 44-53 had the highest levels of titratable acidity (7.6 g/L) and malic acid (3.9 g/L) while own-rooted vines had the lowest content of malic acid (3.3 g/L) and 1103P had the lowest titratable acidity (6.8 g/L; Table 2). In addition, own-rooted vines had a numerically lower juice pH (3.72) and juice K content (2044 mg/L) which coincided with lower K in the petioles (2.1%; Tables 2 and 3). Overall, higher levels of juice K were observed in this trial. In a previous study, high levels of juice K were correlated to high amounts of K in the soil across multiple cultivars including 'Norton' (Morris et al. 1987).

Petiole and Soil Nutrient Content. Rootstock treatment had an impact on petiole nutrient content. Specifically, rootstock treatment influenced N, P, Mg and Zn levels while K (2.1%), B (22 mg/L), and Fe (44 mg/L) levels did not display this effect. Own-rooted vines had the highest N (1.3%) and lowest P (0.18%) while 1103P had the highest P (0.25%) and lowest N (1.1%), however all root-

Table 1. Effect of rootstock on yield, yield components, and vegetative growth of 'Norton' grapevines (*Vitis aestivalis* Michx.) grown at the University of Arkansas Division of Agriculture, Fayetteville, AR (2004-2006).

Treatment	Yield (kg/vine)		Yield (MT/ha)		Clusters/ vine		Cluster weight (g)	Berry weight (g)		Berries/ cluster	Pruning weight (kg/vine)
Own	18.9	ab[z]	25.5	ab	244	abc	77.9	1.1	b	72	0.87
3309C	21.5	a	29.0	a	257	ab	85.5	1.3	a	67	0.88
101-14	17.8	ab	23.9	ab	216	abc	83.8	1.2	a	68	0.75
5C	16.3	ab	22.0	ab	198	bc	83.9	1.2	a	69	0.78
1103P	20.7	a	27.9	a	258	a	81.3	1.2	a	67	0.89
44-53	14.7	b	19.8	b	190	c	79.8	1.3	a	62	0.66
							n.s.[y]			n.s.	n.s.

[z]Means followed by the same letter within attribute do not differ significantly at $P \leq 0.05$. Mean separation by Tukey's Significantly Difference (HSD) Test.
[y]n.s. = not significant

Table 2. Effect of rootstock on fruit composition of fruit from 'Norton' grapevines (*Vitis aestivalis* Michx.) grown at the University of Arkansas Division of Agriculture, Fayetteville, AR (2004-2006).

Treatment	Soluble solids (%)	pH	Titratable acidity (g/L as tartaric)		Potassium (mg/L)	Tartaric acid (g/L)	Malic acid (g/L)		Total phenolics (au)	Total red pigment (au)
Own	21.4	3.72	7.5	ab[z]	2044	4.3	3.3	b	31.1	55.6
3309C	21.5	3.79	7.2	ab	2278	4.1	3.8	ab	32.2	56.4
101-14	21.4	3.81	6.9	ab	2237	4.1	3.8	ab	32.5	55.1
5C	21.4	3.80	6.9	ab	2213	4.1	3.6	ab	30.7	56.2
1103P	21.9	3.77	6.8	b	2138	4.1	3.6	ab	32.3	59.3
44-53	21.2	3.81	7.6	a	2214	4.0	3.9	a	32.0	56.3
	n.s.[y]	n.s.			n.s.	n.s.			n.s.	n.s.

[z]Means followed by the same letter within attribute do not differ significantly at $P \leq 0.05$. Mean separation by Tukey's Significantly Difference (HSD) Test.
[y]n.s. = not significant

Table 3. Effect of rootstock on petiole nutrient content of 'Norton' grapevines (*Vitis aestivalis* Michx.) and vineyard soil composition at the University of Arkansas Division of Agriculture, Fayetteville, AR (2004-2006).

	Petiole Analysis						
Treatment	**N (%)**	**P (%)**	**K (%)**	**Mg (%)**	**Zn (mg/L)**	**B (mg/L)**	**Fe (mg/L)**
Own	1.3 a[z]	0.18 b	2.1	0.30 ab	94 a	22	38
3309C	1.2 ab	0.23 ab	2.5	0.36 a	81 ab	21	57
101-14	1.1 bc	0.22 ab	2.6	0.34 a	93 a	21	37
5C	1.2 bc	0.22 ab	2.6	0.30 ab	83 ab	23	48
1103P	1.1 c	0.25 a	2.4	0.39 a	81 ab	21	34
44-53	1.2 abc	0.23 ab	2.7	0.22 b	72 b	24	47
			n.s.[y]			n.s.	n.s.
Desired range[x]	0.80-1.20	0.14-0.30	1.2-2.0	0.35-0.75	30-60	25-50	30-100
	Soil Analysis[w] (mg/kg)						
Measured		58	168	45	10	0.10	186
Desired range[x]		20-50	75-100	100-250	2	0.3-2.0	20

[z]Means followed by the same letter within attribute do not differ significantly at $P \leq 0.05$. Mean separation by Tukey's Significantly Difference (HSD) Test.
[y]n.s. = not significant
[x]Source: Bates and Wolf 2008.
[w]Average of soil samples taken at 20 cm depth in 2004 and 2005.

stocks within this study were in the desired range for both nutrients (Table 3). All treatments within the study were below the desired range for Mg except for 1103P which is likely due to the low Mg of the soil (45 mg/kg) where the desired range is 100-250 mg/kg. Vines grafted on 44-53 had the lowest Mg (0.22%) and displayed some deficiency symptoms although it did not differ from own-rooted vines and vines grafted on 5C (Table 3). Low levels of Mg were also seen when 44-53 was grafted on *V. vinifera* L. cultivars, Cabernet Sauvignon, Pinot Noir, Syrah, and Ugni Blanc (Morel et al. 2024). In addition, grafting to 44-53 increased K content (Galet 1998; Pongracz 1983). Similarly, in this study vines grafted on 44-53 had the highest amount of K (2.7%) in the petioles numerically. This in combination with the lowest Mg shows the expected response of this rootstock which displays preferential uptake of K over Mg. These results strongly support the selection of 44-53 for use on high Mg soils (Christensen 2003). However, on low Mg soils use of this rootstock may not be suitable. Zinc was the only micronutrient to display differences with own-rooted vines having the highest Zn (94 mg/L) and vines grafted on 44-53 having the lowest Zn (72 mg/L). All other rootstocks exhibited similar elevated levels of Zn which may have been due to the high Zn content of the soil (10 mg/kg; Table 3). Rootstock differences were minimal for N and differences for K, B, and Fe were not observed.

Conclusions

Rootstock selection impacted yield, clusters per vine, titratable acidity, and malic acid while grafting alone impacted berry weight. During this study, the impacts of rootstock selection on cluster weight, berries per cluster, berry weight, soluble solids, pH, juice K, tartaric acid, phenolic acids, red pigments, vegetative growth, and petiole nutrient content were limited, and the differences were often not of viticultural significance. This was a limited, preliminary study and further research is needed to determine long term rootstock effects on Norton grapevines. Based on the data collected in this study, grafting of Norton grapevines did not resolve many of the challenging attributes of this cultivar and cannot be recommended at this time. Although, in locations where high Mg soils are an issue, the use of 44-53 may be a potential option.

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