Yield, Quality, and Nutraceutical Potential of Selected Muscadine Cultivars Grown in Southwestern Arkansas

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SUMMARY. A muscadine grape (*Vitis rotundifolia*) planting was established in 1996 at the Southwest Research and Extension Center in Hope, Ark., to provide information on the performance of muscadine grape cultivars in a region where cold hardiness is not a major limitation. This research evaluated harvest parameters, fruit and juice quality, and nutraceutical potential of selected muscadine cultivars grown in southwestern Arkansas. The cultivars evaluated were 'Black Beauty', 'Carlos', 'Coward', 'Doreen', 'Early Fry', 'Fry', 'Granny Val', 'Ison', 'Jumbo', 'Late Fry', NC67A015-17, NC67A015-26, 'Nesbitt', 'Scarlett', 'Southern Home', 'Sterling', 'Sugargate', 'Summit', 'Supreme', and 'Tara'. Muscadine cultivars differed

in productivity and fruit quality. In 2002 and 2003, juice was produced from 'Carlos', 'Granny Val', 'Ison', 'Nesbitt', 'Southern Home', 'Summit', and 'Supreme' grapes. 'Black Beauty' was also produced into juice in 2003. In 2002, 'Nesbitt' grapes had the highest juice yield, 520 L·t⁻¹ (124.6 gal/ton). 'Ison' and 'Supreme' juice had the highest soluble solids level. In 2003, 'Granny Val' grapes had the highest juice yield, 551 L·t⁻¹ (132.0 gal/ton). 'Southern Home' juice had the highest soluble solids.

The press materials of muscadine grapes were a potential source of high levels of nutraceutical compounds. Dried seeds had the highest total phenolic and oxygen radical absorbance capacity (ORAC) levels followed by the dried skins, the grapes, and then the juice. The skins of the black cultivars had the highest total anthocyanins level. 'Supreme' seeds had the highest total phenolic and ORAC levels while 'Ison' skins had the highest total anthocyanin levels. Based on yield, harvest, and juice quality, cultivars recommended to growers in southwestern Arkansas and other areas with a similar climate include 'Black Beauty', 'Carlos', 'Fry', 'Granny Val', 'Nesbitt', 'Southern Home', 'Summit', and 'Supreme'.

Muscadine grapes are native to the southeastern United States and have been a significant component of the commercial grape industry in this region for almost 200 years (Olien, 2001). Within the southeastern United States, muscadines are generally grown where Pierce's disease (caused by *Xylella fastidiosa*) limits bunch grape production, while bunch grapes are grown where low winter temperatures do not allow muscadine production. Site, soil, and environmental requirements for muscadine production have recently been reviewed (Hegwood and Himelrick, 2001; Krewer et al., 1999; Olien, 1990, 2001; Poling et al., 2003).

Interest in production of muscadines has increased substantially in recent years. A major factor in this has been the recognition that muscadines are an important source of essential vitamins, minerals, fiber, antioxidants, and phenolic compounds (Ector, 2001; Ector et al., 1996; Lee and Talcott, 2004; Pastrana-Bonilla et al., 2003; Talcott and Lee, 2002; Yilmaz and Toledo, 2004). These compounds con-

tribute significantly to the sensory and nutritional properties of muscadines and processed muscadine products. Consumer interest in a healthier lifestyle has led to increased awareness of the importance of diet and nutrition. This increase provides an opportunity for the muscadine industry to capture a portion of the nutraceutical (food components that provide medical or health benefits) market that is projected to reach \$28 billion in the United States by 2006 (Green, 2003).

Muscadines have been produced commercially in Arkansas since 1972 (Lanier and Morris, 1979). Most muscadine cultivars currently available to growers in Arkansas were developed by the breeding programs at the University of Georgia, University of Florida, and North Carolina State University in cooperation with the U.S. Department of Agriculture, or Ison's Nursery of Brooks, Ga. Muscadine cultivars vary in winter hardiness, productivity, and fruit quality when grown at different locations (Mortensen, 2001; Olien, 1990). Cultivar evaluation studies were initiated in the 1960s at Clarksville, Hope, and Bald Knob, Ark., to determine adaptability and characteristics of cultivars under Arkansas conditions (Moore, 1972; Moore and Bowden, 1976). Black cultivars that exhibited superior performance were 'Albermarle', 'Creek', 'Duplin', 'Hunt', and 'James' while the best-performing bronze cultivars were 'Higgins', 'Magnolia', 'Roanoke', and 'Wallace'. Further research identified 'Noble' (black) and 'Carlos' (bronze) as muscadine cultivars with excellent performance for wine production (Striegler and Morris, 1984).

Since these evaluation studies were concluded, numerous new cultivars have been released by various breeding programs (Mortensen, 2001). Selected muscadine cultivars were evaluated at the University of Arkansas Fruit Substation, Clarksville (west-central Arkansas, hardiness zone 7a), from 1987–98 (Clark, 2001). Based on yield, berry size, and fruit quality data, as well as disease susceptibility and winter hardiness observations, the black cultivars Black Beauty, Cowart, Nesbitt, Jumbo, Southern Home, and Sugargate were recommended for consideration for planting. Bronze cultivars recommended were 'Carlos', 'Darlene', 'Doreen', 'Fry', 'Sterling', 'Summit', and 'Tara'. Since this location is near the north-

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ern limit of adaptation for muscadine grapes, low temperature exposure and subsequent winter injury were important factors in cultivar performance during this study (Clark, 2001). To corroborate and extend these results, a muscadine evaluation planting was established in 1996 at the University of Arkansas Southwest Research and Extension Center (SWREC) near Hope, Ark. The cultivars evaluated at the Clarksville location that showed the most potential (Clark, 2001), as well as some recently released cultivars and breeding lines, were included in the new planting at the Hope location. More information on the performance of muscadine cultivars, especially from a region of the state where cold hardiness is not a major limitation, would be beneficial for Arkansas growers. The objective of this experiment was to evaluate productivity, fruit and juice quality, and nutraceutical potential of selected muscadine cultivars grown in southwestern Arkansas.

Materials and methods

VINEYARD. The muscadine planting was established in 1996 at the SWREC (southwestern Arkansas, hardiness zone 7b) on a Bowie fine sandy loam soil (U.S. Department of Agriculture, 1979). The vines were spaced 6.1 m (20 ft) apart and rows were spaced 3.0 m (10 ft) apart. A single-wire trellis was used, and vines were trained to a bilateral cordon. Each spring, 0.23 kg (0.507 lb) of 13N-5.7P-10.8K fertilizer was surface applied prebloom to each vine, and vines were drip irrigated throughout the summer. Additional fertilizer applications were made in the 2001-03 seasons to improve vine canopy growth. This consisted of three additional fertilizer applications in 2001 (24 Aug., 4 Sept., and 14 Sept.) and 2002 (14 June, 8 Aug., and 13 Sept.) and one additional application in 2003 (25 July). Five fungicide sprays were applied annually in 2001, 2002, and 2003 to control macrophoma rot (caused by *Botryosphaeria dothidea*) and angular leaf spot (caused by *Mycosphaerella angulata*), which were the prevalent diseases observed in previous years (B.J. Smith, personal communication). All other cultural practices used followed University of Arkansas Cooperative Extension Service recommendations (Morris, 1971).

CULTIVARS. The cultivars included

in the experiment were 'Black Beauty' (Brooks and Olmo, 1991), 'Carlos' (Brooks and Olmo, 1970), 'Coward', 'Doreen' (Nesbitt et al., 1982a), 'Early Fry', 'Fry' (Lane, 1972), 'Granny Val', 'Ison' (Brooks and Olmo, 1991), 'Jumbo' (Lane, 1972), 'Late Fry', NC67A015-17, NC67A015-26, 'Nesbitt' (Goldy and Nesbitt, 1985), 'Scarlett' (Brooks and Olmo, 2000), 'Southern Home' (Mortensen et al., 1994), 'Sterling' (Nesbitt et al., 1982b), 'Sugargate' (Brooks and Olmo, 1982), 'Summit' (Lane, 1977), 'Supreme' (Brooks and Olmo, 1991), and 'Tara' (Lane, 1993) (Table 1).

HARVEST PARAMETERS. Prior to harvest, the percent soluble solids was measured weekly with a hand-held refractometer on randomly harvested berries from each plot. A given cultivar was hand-harvested when the average soluble solids were 16% or more for all replications. In 1999, vines were harvested once since this was the first year of production. In 2000-03, cultivars with potential for fresh market use were harvested twice during the season. Although 'Sugargate' is a fresh market grape, it was harvested only once because early ripening made it more susceptible to vertebrate feeding damage. During the first harvest, only the most mature berries (as determined

by color) were picked. The vines were completely stripped of fruit at the second harvest. In a commercial situation, the handpicked berries would be used for fresh market and the remainder would be harvested mechanically for processing. This harvest and marketing strategy is employed by commercial growers in Arkansas. For the cultivars used solely for processing, once-over harvest was employed.

PRODUCTIVITY AND FRUIT QUALITY. Yield per vine was recorded at harvest. A randomly selected 25-berry sample was collected to determine berry weight and percent soluble solids. A hand-held, temperature-compensated refractometer (model 51999; Atago, Tokyo) was used to determine soluble solids. A second 25-berry sample was collected and used for rating of fruit quality. Samples were rated subjectively each year for stem scar, flavor, and overall quality on a scale of 1 to 10 where 1 = very poor, 5 = average, 8 or above = very good to excellent. Berries were examined for stem scar (the point of attachment of the berry to the stem) wetness and rated highest if the cultivar had a high percentage of berries with small, dry scars. Flavor was rated on the basis of a combination of flavor components consisting of sweetness, true muscadine fruitiness, and the

Table 1. Fruit color, flower type, origin, and primary commercial use of selected muscadine grape cultivars under evaluation at the Southwest Research and Extension Center, Hope, Ark.

Cultivar	Fruit color	Flower type ^z	Origin ^y	Primary commercial use
Black Beauty	Black	P	Ison	Fresh or processing
Carlos	Bronze	SF	NCSU	Processing
Coward	Black	SF	UG	Fresh or processing
Doreen	Bronze	SF	NCSU	Processing
Early Fry	Bronze	P	Ison	Fresh
Fry	Bronze	P	UG	Fresh
Granny Val	Bronze	SF	Ison	Fresh or processing
Ison	Black	SF	Ison	Fresh or processing
Jumbo	Black	P	Ison	Fresh or processing
Late Fry	Bronze	SF	Ison	Fresh
NC67A015-17	Black	SF	NCSU	Processing
NC67A015-26	Black	SF	NCSU	Processing
Nesbitt	Black	SF	NCSU	Fresh or processing
Scarlett	Red	P	UG	Fresh or processing
Southern Home	Black	SF	UF	Processing
Sterling	Bronze	SF	NCSU	Processing
Sugargate	Black	P	Ison	Fresh
Summit	Bronze	P	UG	Fresh or processing
Supreme	Black	P	Ison	Fresh or processing
Tara	Bronze	SF	UG	Fresh or processing

^zSF = self-fruitful (perfect-flowered); P = pistillate (female-flowered). If pistillate cultivars are planted, one or more self-fruitful cultivars must also be planted to provide pollen.

^yIson = Ison's Nursery and Vineyard, Brooks, Ga.; NCSU = North Carolina State University, Raleigh; UG = University of Georgia, Griffin; UF = University of Florida, Leesburg.

absence of undesirable flavors. Overall quality was a rating assigned combining quality components of the fruit such as stem scar, evenness of ripening, flavor, berry size uniformity, and appearance along with absence of disease.

JUICE PRODUCTION. Grapes were harvested from the SWREC and delivered to the Department of Food Science experimental winery at ambient temperature, 26 °C (78.8 °F), for juice production in 2002 and 2003. The grapes used for juice production were obtained from the second harvest of the cultivar unless there was only one harvest. In 2002, the cultivars selected for juice production were 'Carlos', 'Granny Val', 'Ison', 'Nesbitt', 'Southern Home', 'Summit', and 'Supreme'. 'Black Beauty' was also produced into juice in 2003. In 2002, 64 kg (141.1 lb) of 'Carlos', 54 kg (119.0 lb) of 'Granny Val', 68 kg (149.9 lb) of 'Ison', 54 kg of 'Nesbitt', 55 kg (121.3 lb) of 'Southern Home', 57 kg (125.7 lb) of 'Summit', and 42 kg (92.6 lb) of 'Supreme' were processed into juice. In 2003, 36 kg (79.4 lb) of each grape cultivar were used for juice processing. The grapes were crushed twice and placed in a plastic container with a food-grade polyethylene liner. Pec5L enzyme (Scott Laboratories, Petaluma, Calif.) was added at a concentration of 16.5 mL·t⁻¹ (0.51 fl oz/ton), and the must was held for 4 h. The must was pressed in a 70-L (18.5 gal) Enrossi bladder press (Enoagricol Rossi, Calzolaro, Italy). Sulfur dioxide (SO₂) was added to the bronze cultivars at crush as potassium metabisulfite at a rate of 25 mg·L⁻¹ (ppm). The juice was placed in cold storage, 2 °C (35.6 °F), overnight, removed to room temperature [20 °C (68.0 °F)] and racked. The juice was cold stabilized for 2 weeks at 2 °C before being pasteurized, hot filled [85 °C (185.0 °F)] into 3.9-L (131.87 fl oz) and 375-mL (12.7 fl oz) glass bottles, sealed, and stored at 2 °C.

DEHYDRATION PROCESS. In 2003, 1 kg (2.2 lb) of press material (seeds and skins) was placed in a Harvest Saver dehydrator (Commercial Dehydrator Systems, Eugene, Ore.). After dehydration at 49 °C (120.2 °F) for 48 h, the seeds and skins were stored at -5 °C (23.0 °F). The samples were hand separated into seeds only and skins only, then ground to a powder with a Landers, Farey, and Clark grist mill (Richport, Conn.) for nutraceutical analysis.

pH, TITRATABLE ACIDITY, AND TOTAL SOLUBLE SOLIDS. Juice pH was measured with a Beckman model 250 pH meter (Beckman Coulter, Inc., Fullerton, Calif.). Titratable acidity (tartaric acid in grams per liter) was measured by placing 5 mL of juice sample into 125 mL of deionized water and titrating with 0.1 N sodium hydroxide to an endpoint of pH 8.2. Percent soluble solids were measured using a Bausch and Lomb Abbe Mark II refractometer (Scientific Instrument, Keene, N.H.).

COLOR ANALYSES. Color measurements of the juice were made using a Colorgard system/05 (BYK Gardner, Columbia, Md.) and a Unicam Helios Beta UV-VIS spectrophotometer (Unicam, Cambridge, U.K.). The Colorgard system was standardized with deionized water for Commission Internationale de l'Eclairage (CIE) Lab transmission values of 'L' = 100, 'a' = 0, and 'b' = 0. The CIE 'L' value indicated how light or dark the juice was with 0 being black (darkest) and 100 being white (lightest). Red color was determined spectrophotometrically by measuring absorbance at 520 nm (Ilund et al., 1993; Zoecklein et al., 1995).

HIGH-PERFORMANCE LIQUID CHROMATOGRAPHY (HPLC). Tartaric and malic acids and glucose and fructose levels were measured by HPLC (Walker et al. 2003).

NUTRACEUTICAL ANALYSES. Phenolics were extracted from whole grapes (including seeds), and dried seeds and skins by homogenizing samples (5 g) for 1 min in 20 mL of extraction solvent containing 60 methanol:37 water:3 formic acid (by volume). Homogenates were filtered through Miracloth (CalBiochem, La Jolla, Calif.), and filtrates were centrifuged for 5 min at 5000 *g*_n. The supernatants were diluted appropriately with deionized water and analyzed for total phenolics using the Folin-Ciocalteu assay described by Slinkard and Singleton (1977), with catechin as the standard. Results were expressed as milligrams of catechin equivalents per kilogram fresh weight (whole grapes), milligrams of catechin equivalents per kilogram dry weight (dried skins and seeds) and milligrams per liter fresh weight (juice). Total anthocyanin content of the phenolic extracts was determined by a pH differential method (Giusti and Wrolstad, 2001). Absorbance was measured in a

Hewlett Packard 8452A photodiode array spectrophotometer (Palo, Alto, Calif.) at 510 and 700 nm in buffers at pH 1.0 and 4.5, using

$$A = (A_{510} - A_{700})_{\text{pH } 1.0} - (A_{510} - A_{700})_{\text{pH } 4.5}$$

with a molar extinction coefficient of malvidin-3-glucoside (Mv) of 29,500 (Giusti and Wrolstad, 2001). Results were expressed as milligrams of Mv equivalents per kilogram fresh weight (whole grapes), milligrams of Mv equivalents per kilogram dry weight (dried skins and seeds) and milligrams of Mv equivalents per liter fresh weight (juice).

Oxygen radical absorbance capacity of extracts was measured using the method of Prior et al. (2003), modified for use with a FLUOstar Optima (BMG Labtechnologies, Durham, N.C.) microplate reader using fluorescein as fluorescent probe. Extracts were diluted appropriately with phosphate buffer (75 mM, pH 7) prior to ORAC analysis. The assay was carried out in clear 48-well Falcon plates. Each well had a final volume of 590 µL. Initially 40 µL of diluted sample, Trolox (TE) standards (6.25, 12.50, 25.00, and 50 µM), and blank solution (75 mM, pH 7 phosphate buffer) were added to each well using an automatic pipet. The FLUOstar Optima Instrument equipped with two automated injectors was then programmed to add 400 µL of fluorescein (0.11 µM), followed by 150 µL of 2,2'-Azobis (2-amidinopropane) dihydrochloride (AAPH) (31.6 mM) to each well. Fluorescence readings (excitation 485 nm, emission 520 nm) were recorded after the addition of fluorescein, after the addition of AAPH, and every 192 s thereafter for 90 min to reach a 95% loss of fluorescence. Final fluorescence measurements were expressed relative to the initial reading. Results were calculated based upon differences in areas under the fluorescein decay curve between the blank, samples, and standards. The standard curve was obtained by plotting the four concentrations of TE against the net area under the curve (AUC) of each standard. Final ORAC values were calculated using the regression equation between TE concentration and the AUC and were expressed as micromoles per gram fresh weight of TE equivalents (whole grapes), micromoles per gram dry weight of TE (dried skins and seeds), and micromoles per milliliter of TE

fresh weight (juice).

STATISTICAL ANALYSIS. The experimental design was a completely randomized design with three replications of each cultivar in the vineyard. Juice samples were analyzed in duplicate for each cultivar. Data were analyzed using SAS (SAS, 2001). Treatment means were separated at the 5% significance level using least significant difference tests.

Results and discussion

Viticulture performance of muscadine cultivars differed in this study (Table 2). Earliness of harvest, as identified by the average date of the first harvest, is an important factor in marketing muscadine fruit especially for fresh market sales. 'Sugargate' had the earliest average date of first harvest (21 Aug.), while 'Granny Val' and 'Southern Home' had the latest average date of first harvest (17 Sept.).

The highest yielding cultivar was 'Jumbo' [48 kg (105.8 lb) per vine], and the lowest yielding cultivar was 'Early Fry' [16 kg (35.3 lb) per vine]. 'Carlos', 'Fry', 'Granny Val', 'Ison', 'Southern Home', 'Summit', and 'Supreme' also produced high yields

[≥36 kg (79.4 lb) per vine] during the study. Moderate yield [≥25 and ≤35 kg (55.1 and 77.2 lb) per vine] was observed for 'Black Beauty', 'Cowart', 'Doreen', 'Late Fry', NC67A015-17, NC67A015-26, 'Nesbitt', 'Sterling', and 'Sugargate'. 'Ison', 'Jumbo', 'Nesbitt', 'Scarlett', 'Sterling', 'Summit', and 'Supreme' had 50% or more of their total yield from the second harvest. Yields obtained at the Hope, Ark., location were somewhat higher than those reported for comparable cultivars tested at the Clarksville, Ark., location (Clark, 2001). Yield loss and variability in yield were related to low temperature injury and recovery of vines from this problem at Clarksville. In general, the yield of cultivars was similar to that reported by Mortensen (2001). Berry weight was highest for 'Sugargate' and lowest for NC67A015-26. 'Black Beauty', 'Early Fry', 'Fry', 'Granny Val', 'Late Fry', 'Scarlett', and 'Sterling' also displayed large berry size. Percent soluble solids of berry samples was generally high for all cultivars during the course of the experiment. 'Sugargate' had the highest soluble solids (19.7%), while 'Doreen' had the lowest soluble solids (14.9%).

Cultivar performance can vary due to site, climate, etc. Several instances of this were noted in our study. 'Sterling' had higher berry weight and 'Doreen' had lower percent soluble solids than has been reported in other studies (Clark, 2001; Mortensen, 2001). This result may have occurred because 'Doreen' was picked early before reaching optimum maturity. Samples collected to determine harvest dates for this cultivar were apparently not accurate in all years. At the Clarksville location, this cultivar performed well with high soluble solids. Fruit from 'Doreen' matured late in the season compared with other cultivars in the study.

Differences between cultivars were noted when stem scar, flavor, and overall fruit quality ratings were recorded (Table 2). 'Black Beauty', 'Carlos', 'Granny Val', 'Late Fry', NC67A015-17, NC67A015-26, 'Nesbitt', 'Sugargate', 'Summit', 'Supreme', and 'Tara' were ranked fairly high (>6.5) for all fresh fruit rating parameters. 'Carlos', NC67A0115-17, and NC67A0115-26 had the highest stem scar rating while 'Cowart' had the lowest stem scar rating. 'Sugargate' had the highest flavor and overall

Table 2. Mean harvest date^a, yield, berry weight, soluble solids, and fresh fruit rating (stem scar, flavor, and overall quality) of muscadine grapes grown at the Southwest Research and Extension Center, Hope, Ark., in 1999–2003.

Cultivar	First harvest date	Second harvest date	Yield (kg/vine) ^y	First harvest yield (%)	Berry weight (g) ^x	Soluble solids (%) ^x	Stem scar ^w	Flavor ^w	Overall quality ^w
Black Beauty	11 Sept.	23 Sept.	33.4 a-c ^v	52	8.2 ab	17.8 a-c	6.9 a-c	8.1 ab	7.7 ab
Carlos	9 Sept.	---	36.2 a-c	100	3.7 fg	17.0 a-d	8.4 a	6.6 b-e	7.1 a-d
Cowart	30 Aug.	11 Sept.	27.4 b-d	63	4.9 c-g	19.3 ab	4.7 d	6.6 b-e	5.8 de
Doreen	13 Sept.	---	28.4 b-d	100	3.7 fg	14.9 d	6.0 cd	5.4 e	5.3 e
Early Fry	24 Aug.	18 Sept.	16.4 d	57	7.6 bc	18.6 a-c	6.1 cd	6.8 b-e	6.3 b-e
Fry	3 Sept.	27 Sept.	37.7 a-c	58	7.1 b-d	17.8 a-c	6.2 b-d	7.4 ab	7.1 a-d
Granny Val	17 Sept.	2 Oct.	39.3 a-c	74	7.3 bc	17.4 a-d	7.3 a-c	7.1 a-d	7.1 a-d
Ison	26 Aug.	11 Sept.	38.1 a-c	49	5.4 b-g	17.7 a-c	7.7 a-c	5.7 de	6.0 c-e
Jumbo	5 Sept.	25 Sept.	48.3 a	46	6.9 b-d	16.8 b-d	7.2 a-c	5.8 c-e	6.0 c-e
Late Fry	16 Sept.	1 Oct.	29.9 b-d	78	7.3 bc	17.4 a-d	7.6 a-c	7.0 b-d	6.9 a-d
NC67A015-17	2 Sept.	---	27.2 b-d	100	3.8 e-g	16.5 cd	8.1 a	7.7 ab	7.8 ab
NC67A015-26	29 Aug.	---	27.9 b-d	100	3.1 g	16.8 b-d	8.3 a	7.3 a-c	7.7 ab
Nesbitt	1 Sept.	16 Sept.	34.2 a-c	47	5.1 c-g	18.7 a-c	7.1 a-c	7.4 ab	7.1 a-cd
Scarlett	29 Aug.	6 Sept.	22.5 cd	37	7.1 b-d	19.3 ab	6.4 bc	7.0 b-d	6.8 a-d
Southern Home	17 Sept.	---	35.8 a-c	100	4.1 d-g	17.6 a-c	6.2 b-d	7.5 ab	7.1 a-d
Sterling	2 Sept.	13 Sept.	24.6 b-d	31	7.8 a-c	19.2 a-c	7.6 a-c	6.7 b-e	6.3 b-e
Sugargate	21 Aug.	---	25.9 b-d	100	10.5 a	19.7 a	6.8 a-c	8.7 a	8.0 a
Summit	3 Sept.	26 Sept.	41.7 ab	44	6.6 b-f	18.3 a-c	6.9 a-c	7.6 ab	7.2 a-d
Supreme	30 Aug.	18 Sept.	40.6 ab	35	6.4 b-f	17.6 a-c	7.3 a-c	7.7 ab	7.4 a-c
Tara	27 Aug.	16 Sept.	23.1 cd	65	6.8 b-e	19.2 a-c	7.9 ab	7.5 ab	7.5 a-c

^aIn 1999, vines were harvested once since this was the first year of production. In 2000–03, cultivars with potential for fresh market use were harvested twice during the season.

^y1 kg/vine = 2.20 lb/vine

^xBerry weight and soluble solids from the first harvest date.

^wRatings are based on a scale of 1–10, where 10 = excellent, 5 = average, and 1 = very poor.

^vWithin a column, numbers followed by the same letter are not significantly different by least significant difference test ($P \leq 0.05$).

Table 3. Juice yield and quality from muscadine grape cultivars grown at the Southwest Research and Extension Center, Hope, Ark., in 2002.

Cultivar	Juice yield (L·t ⁻¹) ^z	Soluble solids (%)	Glucose (g·L ⁻¹) ^z	Fructose (g·L ⁻¹) ^z	pH	Titrateable acidity (g·L ⁻¹) ^z	Tartaric acid (g·L ⁻¹) ^z	Malic acid (g·L ⁻¹) ^z	Red color (absorbance at 520 nm)	CIE 'L' value
Carlos	499	14.7 e ^y	62.7 ab	74.8 a	3.01 g	5.00 a	4.23 a	1.38 b	0.04 g	95.7 a
Granny Val	499	14.8 d	56.7 d	74.8 a	3.30 c	2.82 e	2.22 g	0.87 f	0.09 e	92.3 b
Ison	461	16.7 a	56.9 d	62.2 c	3.13 e	4.41 b	3.43 c	1.35 b	0.30 a	79.7 f
Nesbitt	520	14.5 f	56.9 d	49.4 d	3.12 f	4.98 a	3.68 b	1.47 a	0.23 b	80.6 e
Southern Home	419	16.4 b	63.9 a	68.6 b	3.33 b	3.67 c	3.14 d	1.23 d	0.18 c	82.8 d
Summit	443	15.8 c	61.5 bc	67.6 b	3.26 d	3.17 d	2.89 e	0.94 e	0.07 f	92.2 b
Supreme	447	16.7 a	60.1 c	63.2 c	3.36 a	3.22 d	2.44 f	1.29 c	0.10 d	91.1 c

^z1 L·t⁻¹ = 0.24 gal/ton; 1 g·L⁻¹ = 1000 ppm.^yWithin a column, numbers followed by the same letter(s) are not significantly different by least significant difference test ($P \leq 0.05$).

quality rating while 'Doreen' had the lowest. Again the difference between performance of 'Doreen' in this study and the study at the Clarksville location may have been related to early harvest before optimum fruit maturity was reached.

Observations made during the course of cultivar evaluation can often be valuable, especially those that are made following extreme events. Consequently, several observations are included in this report. During the 2000 season, angular leafspot and *Macrophoma* fruit rot were prevalent in the experimental planting (Cline, 2000; Kummuang et al., 1996). The presence of these diseases was confirmed when samples were sent to Dr. Barbara Smith, USDA-ARS, Poplarville, Miss. A minimal spray program was initiated in the 2001 season and repeated for the remainder of the study. No cultivar differences in susceptibility to these diseases were observed. In 2002, vine injury and mortality due to a late freeze, -10.0 °C (14 °F) on 6 Mar., were observed on a few vines of 'Summit', 'Supreme', and 'Black Beauty'. The affected vines were located in a low spot in the block that may have been cooler than the other areas of the block. The injured vines were not included in data collection. Cultivars were periodically rated for vigor. 'Black Beauty', 'Carlos', 'Cowart', 'Ison', 'Jumbo', NC67A015-17, 'Scarlett', 'Southern Home', 'Sugargate', 'Summit', and 'Supreme' were rated as having good vigor while 'Doreen' and 'Early Fry' were rated as having poor vigor.

Based on yield and fruit quality parameters, 'Black Beauty', 'Carlos', 'Fry', 'Granny Val', 'Nesbitt', 'Southern Home', 'Summit', and 'Supreme' are recommended to growers in southwestern Arkansas, and other areas of

similar climate. 'Carlos' and 'Southern Home' would be utilized for processing only, while 'Black Beauty', 'Fry', 'Granny Val', 'Nesbitt', 'Summit', and 'Supreme' could be used for the fresh-market processing strategy that is currently employed by some growers in Arkansas. Other potential cultivars include 'Sugargate' for fresh market and NC67A015-17 and NC67A015-26 for processing, but these cultivars should receive further testing. It is important to note that NC67A015-17 and NC67A015-26 have not been released and are unavailable for commercial plantings at this time.

After evaluation of the harvest quality in 2001, fruit from several promising cultivars were selected for juice production to further evaluate quality and provide a more complete profile of which cultivars are most suitable for this region. In 2002 and 2003, juice was produced from 'Carlos', 'Granny Val', 'Ison', 'Nesbitt', 'Southern Home', 'Summit', and 'Supreme'. 'Black Beauty' was also produced into juice in 2003. In 2002, 'Nesbitt' grapes had the highest juice yield, 520 L·t⁻¹, of the seven cultivars evaluated (Table

3). 'Ison' and 'Supreme' juice had the highest soluble solids level (16.7%). Fruit and juice percentage soluble solids differed somewhat in this study (Tables 2–4). Juice values were lower than those from fruit samples. This discrepancy is probably related to fruit sample collection. Berry samples often exceed must samples in percent soluble solids due to the tendency of personnel to sample the most mature fruit (Zoecklein et al., 1995). 'Nesbitt' and 'Carlos' juice had the highest titrateable acidity, tartaric and malic acid levels, and the lowest pH levels. 'Ison' juice had the highest red color and the lowest 'L' value (darkest juice). Nutraceutical analysis on the juice produced in 2002 showed that 'Nesbitt' juice had the lowest total phenolic level and one of the lowest ORAC values (Table 4). 'Ison' juice had the highest total anthocyanins level, followed by 'Southern Home' juice, then 'Nesbitt' juice. Although 'Supreme' is a black cultivar, the color of the juice was pale as indicated by the low red color (0.10 at 520 nm) value and lack of total anthocyanins. Color could be enhanced with the use of higher levels of enzymes or by heating

Table 4. Nutraceutical analysis of juice from muscadine grape cultivars grown at the Southwest Research and Extension Center, Hope, Ark., in 2002.

Cultivar	Total phenolics [mg·L ⁻¹ (ppm)]	Total anthocyanins [mg·L ⁻¹ (ppm)]	ORAC ^z (μmol·mL ⁻¹ TE)
Carlos	287 a ^y	0 d	3.05 ab
Granny Val	304 a	0 d	2.52 b
Ison	294 a	74.9 a	3.37 a
Nesbitt	224 b	53.9 c	2.55 b
Southern Home	331 a	56.8 b	2.95 ab
Summit	335 a	0 d	2.73 ab
Supreme	320 a	0 d	2.98 ab

^zORAC = oxygen radical absorbance capacity expressed as micromoles of Trolox equivalents (TE) per milliliter fresh weight.^yWithin a column, numbers followed by the same letter(s) are not significantly different by least significant difference test ($P \leq 0.05$).

Table 5. Juice yield and quality from muscadine grape cultivars grown at the Southwest Research and Extension Center, Hope, Ark., in 2003.

Cultivar	Juice yield (L·t ⁻¹) ^z	Soluble solids (%)	Glucose (g·L ⁻¹) ^z	Fructose (g·L ⁻¹) ^z	pH	Titrateable acidity (g·L ⁻¹) ^z	Tartaric acid (g·L ⁻¹) ^z	Malic acid (g·L ⁻¹) ^z	Red color (absorbance at 520 nm)	CIE 'L' value
Black Beauty	525	14.1 b ^y	59.6 bcd	62.1 c	3.42 a	3.35 g	3.73 e	0.88 e	0.13 e	89.5 b
Carlos	512	14.0 b	66.0 a	77.7 a	3.09 h	5.30 b	4.24 bc	1.43 c	0.02 f	96.6 a
Granny Val	551	13.1 c	54.1 e	59.9 c	3.31 d	4.29 e	3.41 f	1.50 bc	0.03 f	96.7 a
Ison	510	14.0 b	61.1 bc	65.4 b	3.11 g	6.00 a	5.05 a	1.43 c	0.63 a	68.6 f
Nesbitt	524	12.7 d	58.1 d	57.7 d	3.26 e	4.90 c	4.21 c	1.24 d	0.41 b	73.1 e
Southern Home	499	14.6 a	61.8 b	67.3 b	3.36 b	4.70 d	4.02 d	1.82 a	0.35 c	76.7 d
Summit	538	14.0 b	58.9 cd	65.4 b	3.32 c	3.86 f	3.23 g	1.31 d	0.02 f	97.0 a
Supreme	473	12.6 d	55.1 e	61.9 c	3.19 f	5.05 c	4.40 b	1.52 b	0.23 d	83.0 c

^z1 L·t⁻¹ = 0.24 gal/ton; 1 g·L⁻¹ = 1000 ppm.

^yWithin a column, numbers followed by the same letter(s) are not significantly different by least significant difference test ($P \leq 0.05$).

the must to extract higher levels of anthocyanins from the skins. The ORAC values, which ranged from 2.52 to 3.37 $\mu\text{mol}\cdot\text{mL}^{-1}$ TE, were generally lower than the values reported for two commercial white grape juices (3.4 and 12.4 $\mu\text{mol}\cdot\text{mL}^{-1}$ TE), and much lower than the values reported for commercial Concord grape (20.0 $\mu\text{mol}\cdot\text{mL}^{-1}$ TE) and red grape juices (19.1 $\mu\text{mol}\cdot\text{mL}^{-1}$ TE) (Prior et al., 2003). However, during processing of commercial red juice, the must is usually heated, which increases the extraction of compounds from the skins.

In 2003, 'Granny Val' grapes had the highest juice yield, 551 L·t⁻¹, of the eight cultivars evaluated (Table 5). All cultivars produced over 500 L·t⁻¹ (119.8 gal/ton), except 'Southern Home' and 'Supreme'. 'Southern Home' juice had the highest soluble solids and 'Carlos' juice had the highest glucose and fructose levels. 'Supreme' had the lowest soluble solids. 'Black Beauty' had the highest pH and the lowest titrateable acidity, while 'Ison' juice had the highest red color, titrateable acidity, tartaric acid level, and the darkest juice.

In 2003, the whole grapes, juice (Table 6) and dried press material (seeds and skins) (Table 7) were also evaluated for nutraceutical content. The juice had much lower levels of total phenolics, total anthocyanins, and ORAC than the whole grapes. The total phenolic content of the juices accounted for only 1.9% ('Carlos') to 9.9% ('Black Beauty') of the total phenolics present in the whole grape, total anthocyanin content of juices accounted for only 4.7% ('Supreme') to 27.8% ('Southern Home') of the total anthocyanins present in whole grapes; and the ORAC values of juices

Table 6. Nutraceutical analysis of juice and frozen, thawed whole grapes of muscadine grape cultivars grown at the Southwest Research and Extension Center, Hope, Ark., in 2003.

Cultivar	Total phenolics ^z [mg·kg or mg·L ⁻¹ (ppm)]	Total anthocyanins ^y [mg·kg or mg·L ⁻¹ (ppm)]	ORAC ^x ($\mu\text{mol}\cdot\text{g}^{-1}$ or $\mu\text{mol}\cdot\text{mL}^{-1}$ TE)
<i>Whole grapes</i>			
Black Beauty	3012 a ^w E ^y	303 a D	23 a C
Carlos	9498 a A	5 a E	66 a A
Granny Val	5740 a BCD	7 a E	43 a B
Ison	4560 a CDE	612 a B	53 a AB
Nesbitt	5099 a BCD	422 a C	51 a AB
Southern Home	4417 a ED	298 a D	42 a B
Summit	6586 a B	5 a E	50 a AB
Supreme	6072 a BC	737 a A	45 a AB
<i>Juice</i>			
Black Beauty	297 b ABD	35 b C	2.9 b BC
Carlos	179 b D	2 a D	3.9 b A
Granny Val	356 b A	3 a D	2.6 b BC
Ison	251 b BCD	104 b A	2.5 b BC
Nesbitt	206 b CD	97 b A	2.1 b C
Southern Home	251 b BCD	83 b B	4.1 b A
Summit	373 b A	4 a D	2.6 b BC
Supreme	339 b AB	35 b C	3.4 b AB

^zTotal phenolics expressed as milligrams per kilogram fresh weight (whole grapes) and milligrams per liter fresh weight (juice).

^yTotal anthocyanins expressed as milligrams per kilogram fresh weight (whole grapes) and milligrams per liter fresh weight (juice).

^xORAC = oxygen radical absorbance capacity expressed as micromoles per gram of Trolox equivalents (TE) fresh weight (whole grapes) and micromoles per milliliter of TE fresh weight (juice).

^wWithin a column and type, numbers followed by the same uppercase letter(s) are not significantly different by least significant difference test ($P \leq 0.05$).

^yWithin a column, numbers followed by the lower case same letter(s) are not significantly different by least significant difference test ($P \leq 0.05$).

accounted for only 4.1% ('Nesbitt') to 12.6% ('Black Beauty') of the ORAC values obtained for whole grapes. The results clearly show that low levels of phenolics are extracted from the fruit during juice processing, with the majority of phenolics presumably being retained in the press material. Our results are consistent with previous studies that reported low recoveries of anthocyanins (12% to 23%) and polyphenolics (36% to 39%) in pasteurized

blueberry juice (Lee et al., 2002; Rossi et al., 2003).

In comparing cultivars, 'Carlos' had the highest total phenolics and ORAC value in whole grapes, while 'Black Beauty' had the lowest level of total phenolics and ORAC value. As expected the whole grapes of the black cultivars 'Black Beauty', 'Ison', 'Nesbitt', 'Southern Home', and 'Supreme' had appreciable levels of total anthocyanins while the bronze

Table 7. Nutraceutical analysis from the dried seeds and skins of muscadine grape cultivars grown at the Southwest Research and Extension Center, Hope, Ark., in 2003.

Cultivar	Total phenolics ^a [mg·kg ⁻¹ (ppm)]	Total anthocyanins ^b [mg·kg ⁻¹ (ppm)]	ORAC ^c (μmol·g ⁻¹ TE)
<i>Seeds</i>			
Black Beauty	80007 a ^w CD ^y	31 b A	735 a D
Carlos	99186 a A	151 a A	1044 a B
Granny Val	76856 a D	110 a A	679 a D
Ison	95185 a AB	91 b A	797 a CD
Nesbitt	88089 a BC	80 b A	951 a BC
Southern Home	81047 a CD	27 b A	733 a D
Summit	79503 a CD	103 a A	667 a D
Supreme	104244 a A	44 b A	2350 a A
<i>Skins</i>			
Black Beauty	31427 b D	5362 a D	376 b C
Carlos	37165 b BC	48 a E	382 b C
Granny Val	30793 b D	48 a E	303 b C
Ison	50882 b A	13174 a A	512 b B
Nesbitt	39499 b B	10372 a B	500 b B
Southern Home	34202 b CD	10372 a B	552 b B
Summit	33566 b CD	0 a E	323 b C
Supreme	49132 b A	7029 a C	716 b A

^aTotal phenolics expressed as milligrams per kilogram dry weight.

^bTotal anthocyanins expressed as milligrams per kilogram dry weight.

^cORAC = oxygen radical absorbance capacity expressed as micromoles per gram of Trolox equivalents (TE) dry weight.

^wWithin a column and type, numbers followed by the same uppercase letter(s) are not significantly different by least significant difference test ($P \leq 0.05$).

^yWithin a column, numbers followed by the lower case same letter(s) are not significantly different by least significant difference test ($P \leq 0.05$).

cultivars had very low levels. Among the black cultivars the total anthocyanin content of whole grapes followed the order of 'Supreme' > 'Ison' > 'Nesbitt' > 'Southern Home' = 'Black Beauty'. In the juices, 'Summit' and 'Granny Val' had the highest levels of total phenolics, while 'Carlos' had the lowest level. Among the black cultivars the total anthocyanin content of juices followed the order of 'Ison' = 'Nesbitt' > 'Southern Home' > 'Black Beauty' = 'Supreme'. 'Southern Home' and 'Carlos' had the highest ORAC values in the juices while 'Nesbitt' had the lowest value.

The levels of whole grape total phenolics (fresh weight) in 'Carlos' [9498 mg·kg⁻¹ (ppm)], 'Summit' (6586 mg·kg⁻¹), 'Ison' (4560 mg·kg⁻¹), and 'Supreme' (6072 mg·kg⁻¹) were much higher than the values reported by Pastrana-Bonilla et al. (2003) for 'Carlos' (3079 mg·kg⁻¹), 'Summit' (2189 mg·kg⁻¹) and 'Supreme' (1847 mg·kg⁻¹). The marked differences in total phenolics may be explained by different extraction methods and sampling techniques used in the two studies. Although both studies used acidified methanol to extract phe-

nolics, Pastrana-Bonilla et al. (2003) used a 24-h extraction time following the procedure of Revilla et al. (1998) designed to optimize the extraction of anthocyanins from grapes. The extraction step employed in our study was completed within 15 min. According to Zhu et al. (2002) the flavan-3-ols catechin and epicatechin and related dimeric procyanidins derived from cocoa, which are major phenolics present in grape seeds, are extremely unstable at acidic pH. Hence, the lengthy extraction time used by Pastrana-Bonilla et al. (2003) may have promoted degradation of nonanthocyanin phenolic compounds, especially flavan-3-ols and their derivatives. In terms of sampling, Pastrana-Bonilla et al. (2003) measured levels of total phenolics in seeds, skin and pulp and used the percentage of each fruit part to calculate the total phenolic content of the whole fruit. In our study the whole grapes (stored frozen, then thawed) were blended to a puree and analyzed for total phenolic content. Freezing the grapes may have also aided in the breakdown of cellular components enhancing the release of phenolic compounds (Flora, 1976).

In contrast to marked differences

in total phenolics in the grapes, the levels of total anthocyanins (fresh weight) in 'Carlos' (5 mg·kg⁻¹), 'Summit' (5 mg·kg⁻¹), 'Ison' (612 mg·kg⁻¹), and 'Supreme' (737 mg·kg⁻¹) were comparable to the previously reported values for 'Carlos' (9 mg·kg⁻¹), 'Summit' (13 mg·kg⁻¹), 'Ison' (695 mg·kg⁻¹), and 'Supreme' (652 mg·kg⁻¹) (Pastrana-Bonilla et al., 2003).

The dried seeds had much higher levels of total phenolics and ORAC values than their corresponding dried skins (Table 7), while the skins obtained from the black cultivars had much higher levels of total anthocyanins than the seeds. Although the phenolic data and ORAC values of seeds and skins are expressed on dry weight basis, the press materials clearly had much higher levels of phenolics and antioxidant capacity than the whole grapes and juice. Consistent with our findings, Lee and Talcott (2004), Pastrana-Bonilla et al. (2003), and Yilmaz and Toledo (2004) reported that total phenolics and ORAC levels were higher in seeds and skins than in pulp.

In comparing cultivars, 'Supreme' and 'Carlos' had the highest levels of total phenolics in the seeds, while 'Granny Val' had the lowest level. Low levels of total anthocyanins were detected in the seeds, which is most likely due to the skins containing anthocyanins coming into contact with the seeds during processing. Seeds from 'Supreme' had the highest ORAC value, followed by 'Carlos' and 'Nesbitt'. The ORAC value for 'Ison' seeds (797 μmol·g⁻¹ TE dry weight) was much higher than the previously reported ORAC value for 'Ison' seeds (246 μmol·g⁻¹ TE dry weight) (Yilmaz and Toledo, 2004). The 3.2-fold difference in ORAC values is most likely due to different fluorescent probes used in the ORAC assays. Yilmaz and Toledo (2004) used β-phycoerythrin as fluorescent probe, whereas we used fluorescein. Fluorescein typically yields a 1.6 to 3.5-fold higher ORAC value than β-phycoerythrin, due to greater photostability and lack of nonspecific binding of polyphenols with protein (Ou et al., 2001).

In skins, the black cultivars Supreme and Ison had the highest levels of total phenolics. Among the black cultivars, the total anthocyanin content of skins followed the order of 'Ison' > 'Nesbitt' = 'Southern Home' > 'Supreme' > 'Black Beauty'. Skins

from 'Supreme' had a much higher ORAC value than the other cultivars, and the ORAC values of black cultivars were generally higher than those of the bronze cultivars, with the exception of 'Black Beauty'. Our results are consistent with previous studies that found that the skin of black muscadines had higher antioxidant capacity than those of bronze muscadines (Ector et al., 1996, Lee and Talcott, 2004; Pastrana-Bonilla et al., 2003).

Conclusions

Evaluation of selected muscadine cultivars during a 5-year period (1999–2003) indicated that 'Black Beauty', 'Carlos', 'Fry', 'Granny Val', 'Nesbitt', 'Southern Home', 'Summit', and 'Supreme' exhibited superior viticulture performance. These cultivars are recommended for use by commercial growers in southwestern Arkansas and areas of similar climate.

Selected cultivars were processed into juice in 2002 and 2003. In addition, press materials were collected and analyzed for nutraceutical content in 2003. Dried skins and seeds were found to be rich sources of total phenolics and antioxidant capacity. Utilization of muscadine seeds and skins for production of nutraceutical products would provide an additional market beyond the traditional markets such as fresh consumption, juice production, wine production, etc.

Recent economic analysis indicates that muscadine grape production can be a profitable enterprise for growers (Noguera et al., 2005). However, the extent to which growers are able to exploit this opportunity is related to the availability of potential markets. Expanded marketing potential would play a significant role in increased commercial muscadine production and acreage in southwestern Arkansas. The development and marketing of value-added nutraceutical products from muscadine press fractions could be an important component of expanded market potential for muscadines.

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