Feasibility of Growing Pierce's Disease Tolerant American and French-American Hybrid Bunch Grape Cultivars and Advanced Grape Selections in Alabama

by

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A thesis submitted to the Graduate Faculty of
Auburn University
in partial fulfillment of the
requirements for the Degree of
Master of Science

Auburn, Alabama
May 4, 2013

Keywords: American and French-American hybrid bunch grape cultivars, seedless table grapes, vegetative growth, cropping potential, fruit quality, *Xylella fastidiosa,*

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Abstract

Eleven Pierce's Disease (PD) tolerant American and French-American hybrid bunch grape cultivars including 'Black Spanish', 'Blanc du Bois', 'Champanel', 'Conquistador', 'Cynthiana', 'Favorite', 'Lake Emerald', 'Stover', 'Villard Blanc', 'Seyval Blanc' and 'Seyval Blanc' grafted on Coudrec 3309 rootstock ('Seyval Blanc'/3309C) were planted at the Sand Mountain Research and Extension Center (SMREC) in Crossville, AL in 2008 to study the feasibility of growing PD tolerant hybrid bunch grape cultivars in the Alabama environment. Our results indicate that 'Champanel' had the most vigorous vegetative growth, while 'Seyval Blanc' had the weakest. 'Stover' had the earliest shoot development, while 'Champanel' and 'Cynthiana' had the latest. 'Stover' and 'Seyval Blanc' flowered earliest, while 'Cynthiana' and 'Lake Emerald' flowered late in the season. 'Seyval Blanc' and 'Seyval Blanc'/3309C had the earliest fruit maturity, while 'Lake Emerald' matured late. 'Villard Blanc' produced the largest yield of 12.7 kg/vine and had the largest mean cluster weight of 287.1 g in 2011 and 2012. 'Champanel' produced the largest berries of 4.8 g. 'Cynthiana' and 'Lake Emerald' had the highest soluble solids content (SSC) with 19.8% and 18.8%, respectively, while 'Champanel' had the SSC of 13.1% at harvest**.** 'Blanc du Bois' and 'Stover' had the highest pH of 3.58 and 3.49, respectively. There were no significant differences in titratable acidity (TA) among cultivars tested which ranged from 0.56 to 1.36 g/100 ml. 'Villard Blanc', 'Cynthiana', and 'Black Spanish' were the best performing cultivars combining vigorous vegetative growth, high yields, and good fruit quality at the SMREC in the two study years.

Three recently released seedless table grape cultivars from the University of Arkansas breeding program, ‘Faith’ (‘A2412’), ‘Joy’ (‘A2494’), and ‘Gratitude’ (‘A2505’); eight advanced grape selections ‘A2817’, ‘A2245’, ‘A2359’, ‘A2467’, ‘A2574’, ‘A2602’, ‘A2632’, and ‘A2786’; two previously released seedless cultivars ‘Mars’, and ‘Neptune’, as well as two standard cultivars ‘Conquistador’, and ‘Stover’, were planted at the North Alabama Horticultural Research Center (NAHRC) in Cullman, AL in 2008 to study the feasibility of growing advanced table and processing grape selections in Alabama environment. Vegetative growth, cropping potential and fruit quality of the tested cultivars and selections were evaluated during the 2011 and 2012 seasons. Our results indicate that ‘Joy’ had the most vigorous vegetative growth, while ‘A2786’ had the weakest. ‘Stover’ had the earliest shoot and flower development in both seasons. Selection ‘A2359’ had the greatest number of clusters per shoot. ‘Mars’ and ‘Faith’ were early ripening and maturing, while ‘Conquistador’ developed late in the season. The highest yielding selections and cultivars in our study were ‘A2574’, ‘A2359’, ‘Neptune’, ‘A2245’, and ‘Conquistador’, which produced over 12.0 kg/vine in both seasons. Table grape cultivars ‘Gratitude’ and ‘Neptune’ had the largest average cluster size of 490 g. ‘Gratitude’ and selection ‘A2817’ produced the largest berries. ‘A2632’, ‘Stover’, ‘Faith’, and ‘Joy’ had high SSC at harvest, while ‘Conquistador’ had relatively low sugar content. Selection ‘A2467’ had the highest TA of 1.34 g/100 ml. The remaining cultivars and selections had TA levels ranging from 0.52 to 0.79 g/100 ml. Selection ‘A2817’ had the largest number of seed traces (3.2), while ‘Gratitude’ had the fewest seed traces. ‘Neptune’, ‘Gratitude’, and ‘A2817’ performed best at NAHRC during study due to their superior cropping potential, fruit quality, and combined vegetative growth.

Acknowledgments

I would like to thank my major advisor, Dr. Elina Coneva, for her patience, guidance, as well as the opportunity to conduct my research. Additionally I would like to thank the members of my advisory committee: Dr. J. Raymond Kessler, and Dr. Jay Spiers. Their expertise was crucial to the completion of my research as well as this thesis. I would like to thank Edgar Vinson for his help both with field work as well as data collection. I would like to express thanks to Dr. Floyd Woods for the training and instruction he provided to complete my fruit quality evaluation lab work. I would like to extend very special thanks to Mr. Arnold Caylor, Ms. Joyce Ducar and the entire staff at the North Alabama Horticulture Research Center, Cullman, AL, and the Sand Mountain Research and Extension Center, Crossville, AL for maintaining the experimental plots as well as their help with harvesting of the research plots and sample collections over the past two years. Additionally, I would like to thank Dr. Kassie Conner for her help with pest identification and ELISA results interpretation in the plant pathology lab. I am extremely grateful to my friends and family, and particularly to my husband, Song Chen, without him this would not be possible.

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CHAPTER ONE

Cultivation and Horticultural Characteristics of American and French-American Hybrid Bunch Grape (*Vitis spp.*) Cultivars:

Literature Review

Classification of Grapes

Grape, which belongs to the botanical family Vitaceae*,* is an important fruit crop in the world. Vitaceae*,* made up of approximately 1000 species assigned to 17 genera (Keller, 2010), is widely distributed in tropical and subtropical climate zones with ranges extending into the temperate regions (Einset and Pratt, 1975). All cultivated grapes of economic importance belong to either the genus *Muscadinia* (2n = 40 somatic chromosomes) or the genus *Vitis* (2n = 38 somatic chromosomes) (Keller, 2010). The genus *Muscadinia* is native from the southeastern United States to Mexico. Members of this genus usually have glabrous leaves, simple tendrils, non-shredding bark, nodes without diaphragms, and hard wood (Munson, 1909; Mullins et al., 1992). This genus has only three species, all of which are very similar (Mullins et al., 1992; Olien, 1990). *Muscadinia rotundifolia*, known as muscadine grape, is grown for use as a table grape, or processed into juice, jelly, or wine. The species is indigenous to Florida and the south coast of the U. S. (Einset and Pratt, 1975). Muscadine grapes have distinctive aromas and flavors; the wines produced from them are considered a specialty product (Winkler et al., 1974). The species has resistance to or tolerance of some of the major grapevine diseases and pests native to North America, including fungal pathogens such as powdery mildew [*Uncinulata necator* (Schw.) Burr], black rot [*Guignardia bidwellii* (Ellis) Viala and Ravaz], and downy mildew

[*Plasmopara viticola* (Berk. and Curt.) Berl. and de Toni]; bacteria such as *Xylella fastidiosa*, which causes Pierce's disease; the phylloxera insect (*Daktulosphaira vitifoliae* Fitch); and the nematode (*Xiphinema spp*.) that transmits the grapevine fanleaf virus, but is sensitive to winter frost and lime-induced chlorosis (Alleweldt and Possingham, 1988). Currently, there are many cultivated varieties of muscadine grapes; most of them have pistilate flowers, while others, those of more recent origin, have perfect flowers. 'Scuppernong' is the oldest cultivated North American cultivar of muscadine grape, which was found in North Carolina and has pistilate flowers (Winkler et al., 1974). The perfect-flowered muscadine cultivars are used primarily as pollinizers for the pistilate cultivars. Their pollen has high germination ability, and they produce good crops of fair quality fruits. However, they are more susceptible to diseases and pests than the pistilate cultivars (Winkler et al., 1974). *Muscadinia munsoniana* Small (Simpson) is another species in the *Muscadinia* genus that is native to Florida and the Bahamas, but it is not cultivated (Keller, 2010). Information about southern Mexico species *Muscadinia popenoei* is relatively unknown (Keller, 2010).

The genus *Vitis* occurs prevalently in temperate and subtropical climate regions (Mullins et al., 1992; Wan et al., 2008). All members of this genus are perennial vines or shrubs with tendril-bearing shoots, hairy leaves with five main veins, forked tendrils, shredding bark when mature, nodes with diaphragms, and soft secondary wood (Keller, 2010). All species within the genus are separated only by geographic, phenologic, and ecologic barriers (Einset and Pratt, 1975), and can readily interbreed to form fertile interspecific crosses called hybrids (Keller, 2010). The genus is often divided into two major groups: the American group and the Eurasian group. The dominant species of the two groups differ greatly in their useful agronomic traits. The grapes from the Eurasian group have good fruitfulness, fruit quality, propagation capacity, and lime tolerance, but poor phylloxera tolerance and disease resistance, while the American group has good phylloxera tolerance and disease resistance, but poor fruitfulness and fruit quality (Keller, 2010).

The American group contains 8 to 34 species, of which several have become economically important wine or juice grapes. *Vitis labrusca* (L.) is one of the most important species. It is a vigorous climber known as northern fox grape that is native to the eastern U.S. from Georgia to southeastern Canada. Some of the *V. labrusca* cultivars, such as 'Concord' and 'Niagara', are commercially grown in the U.S. for juice, jam, jelly, and wine production. This species is cold tolerant and resistant to powdery mildew and crown gall (*Rhizobium radiobacter*), but it is susceptible to phylloxera, downy mildew, black rot, and Pierce's disease and has poor lime tolerance (Keller, 2010). *Vitis aestivalis* (Michaux), also known as summer grape, is another important species from the American group. The vine is a vigorous climber native to eastern North America, growing in dry upland forests and bluffs. It is very cold hardy, drought tolerant, and also tolerates wet and humid summers. It is resistant to important economical diseases including powdery and downy mildew and Pierce's disease (Keller, 2010). *Vitis riparia* (Michaux) is widespread in North America from Canada to Texas and from the Atlantic Ocean to the Rocky Mountains. This species climbs on trees and shrubs along riverbanks and thus is known as a bank grape. It is very cold hardy, tolerant to phylloxera, and resistant to fungal diseases, but susceptible to Pierce's disease (Keller, 2010). *Vitis rupestris* (Scheele) is native to the southwestern U.S. from Texas to Tennessee. It is found in rocky creek beds (rock grape) with permanent water. This species tolerates phylloxera and is resistant to powdery and downy mildew, but is susceptible to anthracnose [*Elsinoe ampelina* (de Bary) Shear.] (Keller, 2010). *Vitis berlandieri* (Planchon) is native to central Texas and eastern Mexico. It is one of very few

American *Vitis* species that has good tolerance to lime (Winkler et al., 1974). It is somewhat tolerant to phylloxera and resistant to fungal diseases and Pierce's disease (Mullins et al., 1992). *Vitis candicans* (Engelmann) is a very vigorous climber native to the southern U.S. and northern Mexico. This species has drought tolerance, phylloxera tolerance, and resistance to powdery and downy mildew and Pierce's disease, but it is difficult to propagate (Keller, 2010).

Approximately 40 known species of grapes belong to the Eurasian group, and most of them are confined to eastern Asia (Keller, 2012). Chinese species are particularly diverse, growing in the dry southwest, the northern and southern foothills of the Himalayas, the very cold northeastern area, and the hot and humid southeastern part (Wan et al., 2008). Most Eurasian species are not resistant to the North American grapevine diseases. *Vitis vinifera* is the most well known species in the Eurasian group because it gave rise to most of the cultivated grape cultivars grown around the world (Keller, 2010). *Vitis sylvestris* (or *silvestris*) (Gmelin) Hegi is native to an area ranging from central Asia to the Mediterranean region, growing mainly in damp woodlands on alluvial soils of riverbanks and hillsides, thus it is considered the "forest grape". These wild grapes are thought to be cold tolerant and resistant to leafroll and fanleaf viruses (Keller, 2010). *Vitis amurensis* (Ruprecht) is native to northeastern China and Russian Siberia ("Amur grape"), and it is considered to be the cold hardiest of all *Vitis* species (Alleweldt and Possingham, 1988; Wan et al., 2008). It is resistant to downy mildew, but susceptible to phylloxera (Du et al., 2009). *Vitis coignetiae* (Pulliat) is native to Japan, and used locally for jam production. The species strongly resemble the American *V. labrusca* (Mullins et al., 1992).

Cultivation and Cultivar Development

Grape cultivation began in Asia Minor, in the region between, and to the south of the Black and Caspian seas (Winkler et al., 1974). That region is the home of the Old World grape, *Vitis vinifera*, from which all cultivated grape cultivars derived before the discovery of North America. From there, culture of the grape spread both west and east. Viticulture was brought to the western shores of the Americas by the conquistadors. In western North America during the seventeenth and eighteenth centuries, the spread of grape and wine production was largely associated with the church. Grape growing and wine making became established in California and rapid expansion occurred from 1860 to 1900 (Einset and Pratt, 1975). The Jesuit missionaries planted the first cultivar of *Vitis vinifera* in California at the San Diego Mission in the late eighteenth century. The cultivar was 'Mission', which was the principal cultivar in California until about 1870 (Winkler et al., 1974). The 'Mission' grape was very vigorous, productive, and hardy. The fruit of 'Mission' attained a high sugar concentration, but was deficient in acid and color (Winkler et al., 1974). Tapia et al. (2007) reported that they found a perfect match for 'Mission' in a little-known Spanish cultivar called 'Listan Prieto'. With the development of the industry, especially the production of grapes for fresh consumption and for raisins, the need for different and better cultivars became apparent. Many cultivars were imported from Europe. The cultivars imported included 'Muscat of Alexandria', 'Tokay, 'Sauvignon blanc', etc. (Winkler et al., 1974). Colonists landed on the eastern shore of North America 150 years before the San Diego mission was established. Several trials with *V. vinifera* cultivars in the eastern part of the U.S. were attempted, but the ventures did not succeed (Hedrick, 1907). In 1821, thousands of grapevines were planted on the Tombigbee River in Alabama by former Napoleonic officers, but the result was a record of misfortune, probably owing to Pierce's disease (Hedrick, 1907). The climate of the areas east of the Rocky Mountains with rainfalls throughout the year and cold winters, and some native North American pests such as the phylloxera and other diseases prevented the successful growing of *Vinifera* cultivars in the eastern U.S. (Clark, 2003). The grapes now grown successfully in the eastern U.S. are either cultivars selected from the native species, such as ‘Concord’, or hybrids of native species, such as ‘Clinton’, which are categorized as “American hybrids”, and hybrids of native species with *vinifera* cultivars, which are called “French-American hybrids” or “French hybrids”, such as ‘Delaware’ (Winkler et al., 1974; Hedrick, 1907). These American and French-American hybrid cultivars combine environmental adaption and good fruit quality (Winkler et al., 1974).

Major Grape Production Practices

Grapevine pruning comprises the removal of living canes, shoot, leaves, and other vegetative parts of the vine (Winkler et al., 1974). The principal pruning is done when the vine is dormant, between leaf fall in autumn and the bud break in spring. Lider et al. (1973) developed pruning methods based on the weight of previous year’s cane growth that provided a better balance of crop and growth. A common balanced pruning formula for French or American hybrids suggests retaining of 20 buds for the first 0.45 kg of wood prunings, plus another 10 buds for each additional 0.45 kg of prunings, up to a maximum of 50 buds per vine. For native American cultivars, the optimum pruning formula suggests to leave 30 buds for the first 0.45 kg of prunings, plus another 10 buds for each additional 0.45 kg of prunings, up to a maximum of 60 buds per vine (Rombough, 2002).

Thinning is removal of flower clusters and includes, immature clusters, or parts of immature clusters (Winkler et al., 1974). Shoot thinning has been reported to decrease yield and open the canopy to improve the fruit quality (Reynolds et al., 1986). Cluster thinning has been reported to result in fewer clusters per vine but provides greater individual cluster weight (Reynolds et al., 1986). Hummell and Ferree (1998) also reported that cluster thinning could impact fruit quality of ‘Seyval Blanc’. Berkey et al. (2011) found that shoot thinning and cluster thinning reduced yield, but improved soluble solids content of ‘Seyval Blanc’ in 2009.

Grapevines are adaptable to a wide range of soil fertility. The roots are active from early spring to late fall and explore the subsoil and the surface soil to absorb the required nutrients. The leaves contain 90% or more of the plant nutrients. The requirements for fertilizing vineyards have been limited (Winkler et al., 1974). Four elements are the most critical to grapevine growth, including nitrogen, potassium, zinc and boron (Winkler et al., 1974).

Grape Nutrition and Production

Recent nutraceutical studies have revealed the benefits of grape or wine consumption to human health and disease prevention. There are strong epidemiological evidences favoring the view that light to moderate consumption of alcoholic drinks reduces mortality and cardiovascular risk in humans, when compared to zero or more than moderate intake (Ronksley et al., 2011). Polyphenols, such as resveratrol, also provide health benefits. Resveratrol could alter molecular mechanisms in blood vessels to reduce susceptibility to vascular damage, decrease the activity of angiotensin to reduce blood pressure, and increase production of the vasodilator hormone (Opie and Lecour, 2007).

According to the Food and Agriculture Organization of United Nations (FAOUN), 75,866 km^2 of the world are dedicated to grapes (FAOUN, 2010). Approximately 71% of world grape production is used for wine, 27% for fresh fruit, and 2% for dried fruit. China was the largest grape producer with 8,651,831 metric tons in 2010, followed by Italy and United States with 7,787,800 metric tons and 6,220,360 metric tons, respectively. According to the world wine consumption rank provided by the wine institute in California, the U.S. was the largest wine consumption nation in the world with 2,912,041,000 liters in 2010, which increased 5.8% from the 2007 consumption rate and 5.4% from the 2009 wine consumption rate. The U.S.A. wine consumption was 12.54% of the world consumption (World Wine Consumption, 2010). According to the 2007 Census of Agriculture-State Data, there were 284 farms producing grapes in Alabama that represented a 53% increase from 2002. The area in grape production in Alabama was 1.89 km^2 that constitutes a 45% increase in 2007, in comparison to 2002 (USDA-NASS, 2007).

Grape Cultivation Constraints in the Southeast - Pierce's Disease

The most important limitation for grape production in Alabama and other southeastern states is the Pierce's disease (PD). PD is a deadly grapevine disease. PD eliminated commercial viticulture in the Los Angeles Basin of California in the 1880s, and was discovered in 1892 by Newton B. Pierce (Pierce, 1892). It is caused by *Xylella fastidiosa* (*X.f.*), which is a gram-negative, xylem-limited bacterium that was first associated with PD of grapevines in 1973 (Hopkins and Mollenhauer, 1973). *X.f.* is transmitted into grape xylem by sharpshooters, particularly the glassy-winged sharpshooters (Hill and Purcell, 1997). Once it is in the xylem, the bacteria uses the xylem sap as a nutrient source to multiply, spread, and increase to concentrations that block the xylem vascular tissue and can eventually cause PD in susceptible grape cultivars (Rombough, 2002).

Infection of virulent strains of *X.f.* is fatal in some grape cultivars such as most *V. vinifera* grapes. General PD symptoms include chlorotic spots on leaves and leaf scorching (Rombough, 2002). PD is associated with distinctive visible symptoms including leaf "matchsticks" and "green islands" (Stevenson et al., 2005). Matchstick exhibits when dried leaves can fall off their petioles, while the petioles remain attached to the canes. The petioles then dehydrate and have a burnt appearance on their distal tips (Stevenson et al., 2005). Green islands appear on stems of infected plants in an intermediate zone between the uniformly green stem in apical regions and the uniformly browned (matured) stem parts in basal regions. In the intermediate zone, small spots of both exclusively green and darkened stem can be found, instead of a typical even transition between the two (Stevenson et al., 2005).

Diseases caused by *X.f.* are mainly tropical or subtropical (Hopkins and Purcell, 2002). PD is typical for the Gulf Coastal Plain states of South Carolina, Georgia, Alabama, Mississippi, Louisiana, and Texas. It seems to be rare or absent from parts of North America with cold winters. Feil and Purcell (2001) discovered that temperatures below 10°C gradually reduced, but did not eliminate populations of the bacterium in grape. *X.f.* has maximum growth at a temperature of 33°C.

The PD transition from areas of severe to rare or no PD is gradual rather than abrupt (Hopkins and Purcell, 2002). The incidence of PD in the eastern U.S. diminishes from the highest levels near the Gulf of Mexico to low levels or absence in the southern mid-western states (Hopkins, 1976; Purcell, 1980). According to a study conducted by Sutton (2005), the number of days with temperature ≤ -12.2 °C or ≤ -9.4 °C are important in defining the regions where PD is not likely to be a problem because *X.f.* populations in grape xylem were shown to decline under cool conditions, and the vines recovered following freezing temperatures. The increase in winter temperatures during the period 1997-2005, compared to the previously studied period 1972-1997, amplified PD occurrence in the Southeast. Up until 2005, areas north of Birmingham, AL were not considered high PD risk locations, but with the increased winter temperatures in recent years, the entire state of Alabama is considered a high PD risk zone. Ma et al. (2010) confirmed the spread of *X.f.* infection in major fruit crops, including hybrid bunch grapes, muscadine grapes, peaches, plums, blueberries, and Satsuma mandarins, throughout Alabama. The study also found the highest PD pressure in the Gulf Coast area of Alabama.

Selected PD Tolerant Cultivars Description

Because Alabama is located in a high PD risk zone, it is critical to select and plant grape cultivars with PD tolerance for sustainable grape production. Several American and French-American hybrid bunch grape cultivars are found to have PD tolerance.

'Seyval Blanc' is a French-American hybrid cultivar, developed as a cross between Siebel 5656 and Seibel 4986 by the French hybridizers Seyve and Villard (NGR). Wilson et al. (2010) studied the performance of 'Seyval Blanc' grown in Kentucky. It produced an average cluster weight of 219 g, an average berry weight of 1.94 g, and the fruit soluble solids content (SSC) was 23.7%. Another long-term study investigated productivity and fruit quality of 'Seyval Blanc' in the Ozark region of Missouri. Based on overall productivity (yield, pruning weight, juice composition), it was one of the wine cultivars best suited for the region (Kaps and Odneal, 2010). The average yield per vine of 'Seyval Blanc' for the period 1989 to 1994 was 11.5 kg. 'Seyval Blanc' combined higher yield with a good balance in wine quality, and it has become widely planted in Missouri. Vine pruning weights were generally low to moderate because the shallow soil profile typical of the Ozark region restricted vine growth. The average pruning weight per vine was 1.1 kg. The average cultivar cluster weight was 300 g for ‘Seyval Blanc’, which represented the largest clusters among the cultivars tested. This cultivar required crop thinning to balance fruit production and vine growth in high crop load years. ‘Seyval Blanc’s fruit produced SSC of 19.8%, which is acceptable for wine production according to a study conducted by Kaps and Odneal (2001).

‘Villard Blanc’ is a French-American hybrid cultivar developed by crossing Seibel 6468 and Seibel 6905 (NGR). ‘Villard Blanc’ was planted on the Texas South Plains during 1974-1986 (Lipe and Davenport, 1988). It has a SSC of 20.7%, and a berry size of 2.56 g.

‘Black Spanish’, also known as ‘Lenoir’, is a cultivar of the American *Vitis aestivalis* species of grape vine native to Texas (Rombough, 2002). ‘Black Spanish’ is a vigorous vine with large, dark green foliage and small black berries (Munson, 1909). It has resistance to phylloxera and PD (Rombough, 2002). It does not lose acidity in the heat, so it makes a decent quality red wine in hot areas (Rombough, 2002).

‘Favorite’ is a clone of ‘Black Spanish’ developed by John Neiderauer in Brenham, Texas. This grape has higher yields and is even more disease resistant than ‘Black Spanish’ (Rombough, 2002).

According to Hedrick (1907), ‘Cynthiana’ (*Vitis aestivalis* Michx) was found growing in the wild in Arkansas. ‘Cynthiana’ prefers sandy or gravelly loam soils. It has phylloxera resistance and is also used as a rootstock. Fruit ripens very late and keeps well on the medium and small clusters. Berries are small, having no value as table grapes, but ‘Cynthiana’ is considered good for table wine production (Hedrick, 1907). Reisch et al. (1993) reported that there is no significant differences between ‘Norton’ and ‘Cynthiana’ via isozyme and botanical analyses and suggested that ‘Norton’ and ‘Cynthiana’ might be cultivars derived from the same clonal source.

‘Champanel’ is an American hybrid cultivar of *V. champini* and *V. labrusca*. It has exceeding high resistance to heat and drought. ‘Champanel’ produces large, black and juicy berries (Munson, 1909). It is reported to have resistance to anthracnose (Mortensen, 1981) and tolerance of PD (Kamas et al., 2000).

According to Stover (1954), ‘Lake Emerald’ was developed at the University of Florida breeding program by crossing native ‘Pixiola’ (*V. simpsoni*) and ‘Golden Muscat’ (hybrids from *V. labrusca* and *V. vinifera*), so it is an American hybrid cultivar having *vinifera* background. It produces average clusters of 184 g and berries with 18% sugar content (Halbrooks and Mortensen, 1989). ‘Lake Emerald’ is resistant to black rot, downy mildew, and tolerant of PD.

‘Stover’ is another hybrid cultivar developed by the University of Florida breeding program. It is resistant to PD, downy mildew, and moderately resistant to black rot, but susceptible to anthracnose and powdery mildew in Florida (Mortensen, 1968). Clusters are medium size and the sugar content is 17-18% with a mild taste.

‘Conquistador’ is a multipurpose, self-fertile Florida hybrid cultivar having *V. aestivalis* and ‘Concord’ parentage (Mortensen, 1983). Vine growth is moderate. The clusters are 118 g and the slipskin type berries are 2.5 g. Unevenly ripened berries appear in bunches occasionally, and some bunches mature later than others (Mortensen, 1983). ’Conquistador’ is resistant to PD and somewhat resistant to anthracnose, downy mildew, and black rot.

Mortensen (1987) describes Florida-grown ‘Blanc du Bois’ as an early ripening French-American hybrid cultivar for wine making with a cluster size of 133 g, and a berry weight of 2.9 g. Berries are round, light green, slipskin, juicy, with a muscat flavor. The number of seeds per berry is 3.2. ‘Blanc du Bois’ is reported to have resistance to PD, rarely showing symptoms. It is also resistant to downy mildew and grape leaf folder (*Desmia funeralis* Hubner). ‘Blanc du Bois’ is susceptible to anthracnose, black rot and ripe rot, but could be managed by spraying preventively with fungicides.

Cultivars and Selections Developed by the University of Arkansas Breeding Program

The University of Arkansas breeding program was begun at 1964 with a focus on the development of table grape cultivars. The table grape is defined as a grape developed exclusively for the table market with major characteristics of seedlessness, crisp texture, and edible skin that can be consumed easily without discarding the skins or other inedible component (Clark, 2010). Released from the program are the seedless table grape cultivars ‘Venus’ (1977), ‘Reliance’ (1983), ‘Mars’ (1985), ‘Saturn’ (1989), ‘Jupiter’ (1999), ‘Neptune’ (1999) (Clark, 2003), ‘Faith’, ‘Hope’, ‘Joy’, and ‘Gratitude’ (Clark, 2012). The major objectives in eastern table grape improvement programs include improving the textures of both slipskin and non-slipskin grape types, which provide different mouth sensation to customers; development of seedless cultivars; fruit cracking resistance and winter hardiness; wider flavor pallet combined with crisp texture; and more elongated fruit shape (Clark, 2010).

‘Mars’ is a hybrid of *V. labrusca* and *V. vinifera*. It has demonstrated outstanding resistance to black rot, anthracnose, powdery and downy mildew under minimum chemical disease control at the Arkansas Agricultural Experiment Station in Clarksville, AR (Moore, 1985). The ripening date of ‘Mars’ is July 22nd in central Arkansas. Fruit skins are medium thick and do not adhere to the flesh (non-slipskin). The fruit color is blue at maturity. The berry size is

3.5 g, which is considered large for a seedless grape cultivar. The flavor is strong and typically resembles *labrusca* species characteristics. Soluble solids content (SSC) of the fruit is medium (16%), but acid content is low and the fruit tastes sweet. Fruit clusters, are medium in size, well-filled, and compact.

'Neptune' is a hybrid of *V. labrusca* and *V. vinifera*, and is the first advanced seedless white table grape developed by the University of Arkansas breeding program. The vines and fruit have demonstrated good resistance to black rot, anthracnose, and powdery mildew (Clark and Moore, 1999). The ripening date of 'Neptune' is August 4^{th} in central Arkansas. The fruit is yellow-green in color at maturity. Fruit skin is moderately thick and non-slipskin. The berry size is medium and the berry weight is 2.5 g with a fruity flavor. Fruit SSC are 19.7%. Fruit clusters are usually borne two per shoot, have a conical shape and very often have a small shoulder. They are large in size (345g), and well-filled.

'Faith' (A2412) is a blue, non-slipskin, seedless table grape with early ripening, late July to early August in Arkansas (Clark, 2012). Cluster weight ranges from 150 to 250 g, and berries are 4 g. SSC is 19% with a neutral flavor. Some berries matured unevenly in some years.

'Joy' (A2494) is a blue, non-slipskin, seedless table grape with average harvest date of August 11^{th} in Arkansas (Clark, 2012). Cluster weight is usually 300 g, and berries are 3 g. The flavor is exceptional fruity. Shatter of mature berries occurred in some years.

'Gratitude' (A2505) is a white, non-slipskin, seedless table grape (Clark, 2012). Cluster weight is up to 500 g, and berries are 3.5 g. SSC is 19% with exceptional crisp texture. The flavor is neutral, similar to *Vitis vinifera* table grapes.

Other selections have not been tested outside of Arkansas and information on their performance is not available. These cultivars and selections were not exposed to PD during development or testing, so we are not aware of their PD resistance.

The demand for high quality, locally produced table and wine grapes from consumers, grape growers and winemakers is increasing. Science based information is lacking on the performance of American and French-American hybrid bunch grape cultivars and newly released or existing seedless table grapes in Alabama's high PD risk environment. Data about cultivar growing requirements, cropping potential, and fruit quality in Alabama would be very beneficial to the grape growing industry in the state and the entire southeastern region.

We hypothesized that American and French-American hybrid cultivars and table grapes will perform differently in terms of their vegetative growth, cropping potential and fruit quality in response to the environmental condition present in Alabama.

The main objective of the current study was to evaluate the performance of PD tolerant American and French-American hybrid grape cultivars and seedless table grapes in Alabama's environment to gain science based empirical information on their productivity, fruit quality, PD resistance and longevity; and to provide grape growers with recommendations on cultivar selection as a means to expand and sustain the grape growing industry in the southeastern region of the U.S.

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Chapter Two

Feasibility of Growing Pierce's Disease Tolerant American and French-American Hybrid Bunch Grape Cultivars in North Alabama

Abstract

Eleven Pierce's disease (PD) tolerant American and French-American hybrid bunch grape cultivars including 'Black Spanish', 'Blanc du Bois', 'Champanel', 'Conquistador', 'Cynthiana', 'Favorite', 'Lake Emerald', 'Stover', 'Villard Blanc', 'Seyval Blanc' and 'Seyval Blanc' grafted on Coudrec 3309 rootstock ('Seyval Blanc'/3309C) were planted at the Sand Mountain Research and Extension Center (SMREC) in Crossville, AL in 2008 to study the feasibility of growing PD tolerant hybrid bunch grape cultivars in the Alabama environment. Our results indicate that 'Champanel' had the most vigorous vegetative growth, while 'Seyval Blanc' had the weakest. 'Stover' had the earliest shoot development, while 'Champanel' and 'Cynthiana' had the latest. 'Stover' and 'Seyval Blanc' flowered earliest, while 'Cynthiana' and 'Lake Emerald' flowered late in the season. 'Seyval Blanc' and 'Seyval Blanc'/3309C had the earliest fruit maturity, while 'Lake Emerald' matured late. 'Villard Blanc' produced the largest yield of 12.7 kg/vine and had the largest cluster weight of 287.1 g. 'Champanel' produced the largest berries of 4.8 g. 'Cynthiana' and 'Lake Emerald' had the highest soluble solids content (SSC) with 19.8% and 18.8%, respectively, while 'Champanel' had the SSC of 13.1% at harvest**.** 'Blanc du Bois' and 'Stover' had the highest pH of 3.58 and 3.49, respectively. There were no

significant differences in titratable acidity (TA) among cultivars tested which ranged from 0.56 to 1.36 g/100 ml. ‘Villard Blanc’, ‘Cynthiana’, and ‘Black Spanish’ were the best performing cultivars combining vigorous vegetative growth, high yields, and good fruit quality at the SMREC in the two study years.

Introduction

The climate of areas east of the Rocky Mountains with rainfalls year around and cold winters, and some native North American pests such as the phylloxera (*Daktulosphaira vitifoliae* Fitch) and other diseases prevent *Vitis vinifera* species from developing and surviving in the eastern U.S. (Clark, 2003). The grapes now grown successfully in the eastern U.S. are cultivars selected from native species, such as ‘Concord’; hybrids of native species, such as ‘Clinton’; and hybrids of native species with varieties of *vinifera*, such as ‘Delaware’ (Winkler et al., 1974; Hedrick, 1907).

Although the quality of wine produced from hybrid grape cultivars is generally inferior to the wine produced from *V. vinifera* cultivars, the hybrid grapes have a distinct application in the eastern U.S., because they are adaptable to the climate and resistant to some native pests and diseases, such as Pierce’s disease (PD).

Grape Cultivation Constraints in the Southeast - Pierce's Disease

The most important limitation for grape production in Alabama and other southeastern states is Pierce's disease (PD). PD is a deadly grapevine disease. PD eliminated commercial viticulture from the Los Angeles Basin of California in the 1880s, and was discovered in 1892 by Newton B. Pierce (Pierce, 1892). It is caused by *Xylella fastidiosa* (*X.f.*), which is a gram-negative, xylem-limited bacterium that was first associated with PD of grapevines in 1973 (Hopkins and Mollenhauer, 1973). *X.f.* is transmitted into grape xylem by sharpshooters, particularly the glassy-winged sharpshooters (Hill and Purcell, 1997). Once it is in the xylem, the bacteria uses the xylem sap as a nutrient source to multiply, spread, and increase to concentrations that block the xylem vascular tissue and can eventually cause PD in susceptible grape cultivars (Rombough, 2002).

Infection of virulent strains of *X.f.* is fatal in some grape cultivars such as most *V. vinifera* grapes. General PD symptoms include chlorotic spots on leaves and leaf scorching (Rombough, 2002). PD is associated with distinctive visible symptoms including leaf "matchsticks" and "green islands" (Stevenson et al., 2005). Matchstick symptom is observed when dried leaf blades fall off their petioles, while the petioles remain attached to the stems. The petioles then dehydrate and have a burnt appearance on their distal tips (Stevenson et al., 2005). Green islands appear on stems of infected plants in an intermediate zone between the uniformly green stem in apical regions and the uniformly browned (matured) stem parts in basal regions. In this intermediate zone, small spots of both exclusively green and darkened stem can be found, instead of a typical even transition between the two (Stevenson et al., 2005).

Diseases caused by *X.f.* are mainly tropical or subtropical (Hopkins and Purcell, 2002). PD is typical for the Gulf Coastal Plain states of South Carolina, Georgia, Alabama, Mississippi, Louisiana, and Texas. It seems to be rare or absent from parts of North America with cold winters. Feil and Purcell (2001) discovered that temperatures below 10°C gradually reduced, but did not eliminate populations of the bacterium in grape. *X.f.* exhibits maximum growth at a temperature of 33°C.

The PD transition from areas of severe to rare or no PD is gradual rather than abrupt (Hopkins and Purcell, 2002). The incidence of PD in the eastern U.S. diminishes from the highest incidences near the Gulf of Mexico to the lowest incidences or absence in the southern mid-western states (Hopkins, 1976; Purcell, 1980). According to a study conducted by Sutton (2005), the number of days with temperature ≤ -12.2 °C or ≤ -9.4 °C are important in defining the regions where PD is not likely to be a problem because *X.f.* populations in grape xylem were shown to decline under cool conditions, and the vines recovered following freezing temperatures. The increase in winter temperatures during the period 1997-2005, compared to the previously studied period 1972-1997, amplified PD occurrence in the Southeast. Up until 2005, areas north of Birmingham, AL were not considered high PD risk locations, but with the increased winter temperatures in recent years, the entire state of Alabama is considered a high PD risk zone. Ma et al. (2010) confirmed the spread of *X.f.* infection in major fruit crops, including hybrid bunch grapes, muscadine grapes, peaches, plums, blueberries, and Satsuma mandarins, throughout Alabama. The study also found the highest PD pressure in the Gulf Coast area of Alabama.

Selected PD Tolerant Cultivars Description

Because Alabama is located in a high PD risk zone, it is critical to select and plant grape cultivars with PD tolerance for sustainable grape production. Several American and French-American hybrid bunch grape cultivars are found to have PD tolerance.

‘Seyval Blanc’ is a French-American hybrid cultivar, developed as a cross between Siebel 5656 and Seibel 4986 by the French hybridizers Seyve and Villard (NGR). Wilson et al. (2010) studied the performance of ‘Seyval Blanc’ grown in Kentucky. It produced a cluster weight of 219 g, and the berry weight of 1.94 g, and the fruit soluble solids content (SSC) was 23.7%. Another long-term study investigated ‘Seyval Blanc’s productivity and fruit quality in the Ozark region of Missouri. Based on overall productivity (yield, pruning weight, juice composition), it was one of the wine cultivars best suited for the region (Kaps and Odneal, 2010). Yield per vine of ‘Seyval Blanc’ for the period 1989 to 1994 was 11.5 kg. ‘Seyval Blanc’ combined higher yield with a good balance in wine quality, and it has become widely planted in Missouri. Vine pruning weights were generally low to moderate in the Ozark region because the shallow soil profile typical for this region restricted vine growth. Pruning weight per vine was 1.1 kg. ‘Seyval Blanc’ average cluster weight was 300 g, which represented the largest clusters among the cultivars tested. This cultivar required crop thinning to balance fruit production and vine growth in high crop load years. 'Seyval Blanc's fruit produced SSC of 19.8%, which is acceptable for wine production according to a study conducted by Kaps and Odneal (2001).

'Villard Blanc' is a French-American hybrid cultivar developed by crossing Seibel 6468 and Seibel 6905 (NGR). 'Villard Blanc' was planted on the Texas South Plains during 1974-1986 (Lipe and Davenport, 1988). It had a SSC of 20.7%, and a berry size of 2.56 g.

'Black Spanish', also known as 'Lenoir', is a cultivar of the American *Vitis aestivalis* Michx species of grape vine native to Texas (Rombough, 2002). 'Black Spanish' is a vigorous vine with large, dark green foliage and small black berries (Munson, 1909). It has resistance to phylloxera and PD (Rombough, 2002). It does not lose acidity in the heat, so it makes a decent quality red wine in hot areas.

'Favorite' is a clone of 'Black Spanish' developed by John Neiderauer in Brenham, Texas. This grape has higher yields and is even more disease resistant than 'Black Spanish' (Rombough, 2002).

According to Hedrick (1907), 'Cynthiana' (*V. aestivalis*) was found growing in the wild in Arkansas. 'Cynthiana' prefers sandy or gravelly loam soils. It has phylloxera resistance and is also used as a rootstock. Fruit ripens very late and keeps well on the medium and small clusters. Berries are small, having no value as table grapes, but 'Cynthiana' is considered good for table wine production (Hedrick, 1907). Reisch et al. (1993) reported that there is no significant difference between 'Norton' and 'Cynthiana' via isozyme and botanical analyses and suggested that 'Norton' and 'Cynthiana' might be cultivars derived from the same clonal source.

‘Champanel’ is an American hybrid cultivar of *V. champini* and *V. labrusca*. It has high resistance to heat and drought. ‘Champanel’ produces large, black and juicy berries (Munson, 1909). It is reported to have resistance to anthracnose (Mortensen, 1981) and tolerance of PD (Kamas et al., 2000).

According to Stover (1954), ‘Lake Emerald’ was developed by the University of Florida breeding program by crossing native ‘Pixiola’ (*V. simpsoni*) and ‘Golden Muscat’ (hybrids from *V. labrusca* and *V. vinifera*), so it is an American hybrid cultivar having *vinifera* background. It produces clusters of 184 g and berries with 18% sugar content (Halbrooks and Mortensen, 1989). ‘Lake Emerald’ is resistant to black rot, downy mildew, and tolerant of PD.

‘Stover’ is another hybrid cultivar developed by the University of Florida breeding program. It is resistant to PD, downy mildew, and moderately resistant to black rot, but susceptible to anthracnose and powdery mildew in Florida (Mortensen, 1968). Clusters are medium size and the sugar content is 17-18% with a mild taste.

‘Conquistador’ is a multipurpose, self-fertile Florida hybrid cultivar having *V. aestivalis* and ‘Concord’ parentage (Mortensen, 1983). Vine growth is moderate. The clusters are 118 g and the slipskin type berries are 2.5 g. Unevenly ripened berries appear in bunches occasionally, and some bunches mature later than others. ‘Conquistador’ is resistant to PD and somewhat resistant to anthracnose, downy mildew, and black rot.

Mortensen (1987) describes Florida-grown ‘Blanc du Bois’ as an early ripening French-American hybrid cultivar for wine making with a cluster size of 133 g, and a berry weight of 2.9

g. Berries are round, light green, slipskin, juicy, with a muscat flavor. The number of seeds per berry is 3.2. ‘Blanc du Bois’ is reported to have resistance to PD, rarely showing symptoms. It is also resistant to downy mildew and grape leaf folder (*Desmia funeralis* Hubner). ‘Blanc du Bois’ is susceptible to anthracnose, black rot and ripe rot, but these could be managed by spraying preventively with fungicides.

Science based information is lacking on the performance of American and French-American hybrid bunch grape cultivars in Alabama. Data about their growing requirements, cropping potential, and efficient pest control management in Alabama would be very beneficial to the grape growing industry in the state and the entire southeastern region, as the consumers’ demand for high quality, locally produced table and wine grapes is increasing.

The main objective of this study was to evaluate the performance of PD tolerant American and French-American bunch grape cultivars in Alabama’s environment to gain science-based empirical information on their productivity, fruit quality, PD resistance and longevity, and to provide grape growers with recommendations on cultivar selection as a means to expand and sustain the grape growing industry.

Materials and Methods

An experimental vineyard was established in 2008 at the Sand Mountain Research and Extension Center (SMREC) in Crossville, AL (lat. 34.287449 N, long. -85.972073E), USDA Plant Hardiness Zone 7A (USDA Plant Hardiness Zone Map, 2012). It consists of 11 American and French-American hybrid bunch grape cultivars including: ‘Black Spanish’, ‘Blanc du Bois’, ‘Champanel’, ‘Conquistador’, ‘Cynthiana’, ‘Favorite’, ‘Lake Emerald’, ‘Seyval Blanc’, ‘Seyval Blanc’ grafted on Coudrec 3309 rootstock (‘Seyval Blanc’/3309C), ‘Stover’, and ‘Villard Blanc’. All experimental vines were two-year-old rooted cutting, except ‘Seyval Blanc’ which was also two-year-old grafted on Couderc 3309 rootstock. The soil in the SMREC is Hartsells fine sandy loam (USDA Web Soil Survey, 2012). The experimental design for this vineyard was a randomized complete block design with 4 blocks and 4 individual plants per cultivar, per block. Standard commercial practices were implemented for the planting and maintenance of the vines (Poling, 2007). Supplemental irrigation was installed to ensure a successful plant establishment and production using drip tape. Irrigation was provided during the growing season according to the weather conditions. The emitters delivered water rate at 3.785 liters per hour, and the system operated between two and four hours per day as needed. The irrigation was still operated at veraison stage, because the cultivars had different veraison progression. The irrigation was maintained to make sure the experiment condition was uniform.

Cultivar shoot development was determined by counting the number of fully developed leaves per shoot after bud break. In 2011, the number of fully developed leaves per shoot per vine was visually rated on March 27th and April 5th. In 2012, six shoots per vine were chosen and the number of fully developed leaves per shoot were counted on March 21st, March 26th, April 1st, and April 8th. After bud break, six shoots were chosen and flagged on each vine as follows: two shoots located at the distant part of each cordon, two shoots located in the middle part of each cordon, and two shoots located in the basal part of each cordon.

In 2011, the percentage of open flowers per vine was rated visually on May 14th and May 20th. In 2012, six clusters per vine were chosen and the number of open flowers per cluster were counted on April 23rd, April 29th, and May 8th to determine flowering progression. A flower was considered fully open when the pistil and stamens were observed. Six clusters were chosen and flagged on each vine as follows: two clusters located at the distant part of each cordon; two clusters located in the middle part of each cordon, and two clusters located in the basal part of each cordon.

To determine the cultivar vegetative growth and vigor characteristics, vine pruning weight, trunk cross sectional area (TCSA), leaf area and leaf chlorophyll levels were measured. Dormant pruning was done at bud break on March 1st, 2011 and March 7th, 2012, respectively. Each experimental vine was pruned to sever spurs per cordon with two buds on each spur for a total number of 30 buds per vine (Rombough, 2002). Pruned wood per vine was collected and the individual pruning weight per vine was recorded by using an Adam CPWplus-35 scale (Adam Equipment Inc, Danbury, CT, USA). The vine trunk diameter was measured at 20 cm above the ground level using a digital caliper (Serial No. 0107312, Mitutoyo Corporation, Kawasaki, Japan) to determine the TCSA.

To determine the leaf area per vine, 10 recently mature leaves per vine were collected in mid-July and measured with a Licor LI-3100 area meter (Lincoln, NB, USA). Mature leaves located at least 5 nodes back from the terminal bud of the shoot apex were used. The relative amount of chlorophyll was measured with a SPAD-502 Plus chlorophyll meter (Konica Minolta Sensing, INC, Osaka, Japan) on 10 leaves per experimental vine to evaluate the cultivar chlorophyll content.

To determine the number of fruiting clusters per shoot, six shoots per vine were marked and the number of clusters per shoot were counted. Six shoots were chosen on each vine as follows: two shoots located at the distant part of each cordon, two shoots located in the middle part of each cordon, and two shoots located in the basal part of each cordon.

Veraison progression was determined by visual rating the percentage of berries per vine turning color on July 6th, July 15th, July 25th, and August 1st in 2011; and on June 19th, June 22nd, July 2nd, July 8th, July 13th, July 20th, and July 27th in 2012, respectively.

Experimental vines were hand-harvested during August in 2011 and from mid-July to late August in 2012. Total yield per vine was measured for each experimental vine on each harvest date using an Adam CPWplus-35 scale.

A subsample of five clusters per vine was collected at harvest to determine cluster weight using an Adventurer Pro digital scale (Adventurer Pro AV4101, Ohaus Corporation, Pine Brook, NJ, USA). A subsample of 50 berries was also collected from each experimental vine to determine berry weight using an Adventurer Pro digital scale. The berries were placed in a cooler and kept at 4 °C until further analysis was performed.

Fruit quality analysis was performed by measuring berry soluble solids content (SSC), titratable acidity (TA), and pH. SSC was determined by squeezing the juice from ten berries per vine and filtering the liquid with Veratec Graphic Arts cheesecloth (BBA Nonwovens, Simpsonville, SC, USA). The extracted juice was analyzed using a digital refractometer (Pal-1 Atago, Co., Tokyo, Japan) to determine the percent brix at room temperature.

Titratable acidity (TA) was measured by using a DL 15 Titrator (Mettler-Toledo, LLC, Columbus, OH). One milliliter of grape juice was diluted to 40 ml of solution, titrated by 0.1 N NaOH, with an endpoint of pH 8.2. Results were expressed as grams of tartaric acid equivalent per 100 ml extracted juice. The juice pH was measured in the initial titration procedure.

PD symptom expressions, including leaf scorching, ‘matchstick’, and ‘green island’, were visually rated after harvest using the following scale in 2011: 0 = no symptoms; 1 = 1 to 20% leaves with scorching; 2 = 21 to 40% leaves with scorching; 3 = 41 to 60% leaves with scorching; 4 = 61 to 80% leaves with scorching; 5 = 81 to 100% leaves with scorching. In 2012, 10 petioles per vine were collected from the basal part of each cordon to conduct serological tests to determine *Xylella fastidiosa* infections. Samples were submitted to the Auburn University Plant Diagnostic Lab and ELISA test was conducted using Agdia ELISA kits (Agdia, Inc, USA), and following manufacturer’s recommendations. Follow-up PCR tests were utilized to confirm positive *X.f.* infections.

Analysis of variance was performed on all data using PROC GLIMMIX in SAS version 9.2 (SAS Institute, Cary, NC). The experimental design was a randomized complete block design. The homogeneity of variance assumption for ANOVA was tested for all responses using the COVTEST statement. Appropriate correction for heterogeneity of variance was applied where needed using the GROUP option on the RANDOM statement in PROC GLIMMIX. For data collected in 2011 and 2012 including pruning weight, TCSA, leaf area, leaf chlorophyll level, the number of fruiting clusters per shoot, yield per vine, average cluster weight, mean berry weight, SSC, TA and pH, the two years and blocks were analyzed as random variables. Where data were collected over time including shoot development, seasonal flowering, and veraison progression, a factorial treatment design was used with cultivars and time as main effects. Differences among cultivars were determined using the Simulate mean separation test because of missing data. Linear and quadratic polynomial contrasts were used to determine trends over weeks. All data presented are least squares means. All significances were at $\alpha=0.05$.

Results

Experimental cultivars studied showed differences in vine pruning weights in both seasons (Table 1). 'Champanel' had the highest pruning weight of 3.0 kg/vine. 'Seyval Blanc' had the lowest pruning weight of 0.3 kg/vine. The remaining cultivars had the pruning weights ranging from 0.4 to 1.6 kg/vine.

The cultivars differed in trunk cross sectional area (TCSA) (Table 1). 'Champanel' had the largest TCSA with 9.5 cm^2, followed by 'Villard Blanc' of 8.8 cm^2, and 'Stover' of 7.6 cm^2. These cultivars also had higher pruning weight. 'Seyval Blanc' had the smallest TCSA with 4.4 cm^2, which also corresponded to its low pruning weight.

The cultivars differed in leaf chlorophyll content (Table 2). 'Favorite' and 'Black Spanish' had the highest leaf chlorophyll levels of 41.5 and 40.7, respectively. 'Seyval Blanc' and 'Seyval Blanc'/3309C had the lowest chlorophyll levels of 33.4. The remaining cultivars had leaf chlorophyll levels ranging from 34.0 to 38.1.

The cultivars differed in leaf area (Table 2). 'Favorite' and 'Cynthiana' had the largest leaf area of 142.8 cm^2 and 141.1 cm^2, respectively. 'Blanc du Bois', 'Stover', 'Seyval Blanc', and 'Seyval Blanc'/3309C had the smallest leaf area ranging from 79.3 to 88.9 cm^2. The remaining cultivars had the leaf area ranging from 93.3 to 136.8 cm^2.

The cultivars had differences in early season shoot development in 2011 (Figure 1). 'Stover' had the earliest shoot development with 2.5 fully developed leaves on March 27th. It also had the greatest number of fully developed leaves on April 5th. 'Champanel' and 'Cynthiana' had relatively late shoot development.

The cultivars differed in early season shoot development in 2012 (Figure 2). 'Stover' and 'Conquistador' had the earliest shoot development on March 21st, with 2.8 and 2.4 fully developed leaves, respectively. 'Champanel' and 'Cynthiana' had relatively late shoot development, which started on March 26th. All the cultivars had more than 4 fully developed leaves on April 8th.

The flowering season differed among cultivars in 2011 (Figure 3). 'Stover', 'Seyval Blanc' and 'Seyval Blanc'/3309C had early flowering with more than 72% open flowers on May 14rd, and they developed 100% open flowers on May 20th. For 'Cynthiana', 'Blanc du Bois', and 'Lake Emerald', the flowering season started later and vines only developed 11-17% open flowers on May 20th.

The flowering season differed among cultivars in 2012 (Figure 4). 'Seyval Blanc' and 'Stover' had early flowering with 25% and 23% open flowers on April 23rd, and they developed 93% and 96% open flowers on April 29th. For 'Cynthiana' and 'Lake Emerald', the flowering season started after April 29th.

The cultivars varied in number of fruiting clusters per shoot (Table 3). 'Villard Blanc', 'Cynthiana', 'Lake Emerald', and 'Stover' had the highest number of clusters per shoot ranging from 2.3 to 2.4. 'Blanc du Blois' had the lowest number of fruiting clusters per shoot (1.3). The remaining cultivars produced between 1.8 and 2.0 fruiting clusters per shoot.

The cultivars differed in veraison progression in 2011 (Figure 5). 'Blanc du Bois', 'Seyval Blanc', and 'Seyval Blanc'/3309C had early veraison progression. They had 80% veraison on July 15th. 'Cynthiana' and 'Lake Emerald' were the late ripening cultivars.

The American and French-American cultivars differed in veraison progression in 2012 (Figure 6). 'Seyval Blanc'/3309C and 'Seyval Blanc' started veraison early, on June 19th with veraison progression of 31% and 37%, respectively, and they reached 100% veraison on July 8th. 'Lake Emerald' was the latest cultivar starting veraison on July 27th with 10% berries changing color.

The season of maturity varied for cultivars in our test in 2011 (Figure 7). 'Seyval Blanc' and 'Seyval Blanc'/3309C were very early ripening cultivars that matured on August 1st in 2011. 'Blanc du Bois', 'Stover' and 'Villard Blanc' matured early, on August 8th and August 10th, respectively in 2011. 'Black Spanish', 'Cynthiana', and 'Lake Emerald' ripened late, and were harvested on August 30th.

Period of ripening varied in 2012 (Figure 8). 'Seyval Blanc' and 'Seyval Blanc'/3309C matured very early and were harvested on July 18th. Due to the unusual warm spring season in 2012, grape ripening was advanced by about two weeks, but cultivars followed a similar ripening pattern as in 2011. 'Seyval Blanc' and 'Seyval Blanc'/3309C had the earliest ripening in both seasons, while 'Cynthiana' and 'Lake Emerald' had a consistently late maturity. The remaining cultivars matured in mid-August.

The cultivars differed in total yield per vine in both study seasons (Table 4). The highest yielding cultivar was ‘Villard Blanc’ with 12.7 kg/vine. The lowest yielding cultivar was ‘Conquistador’ of 2.0 kg/vine. The remaining cultivars were intermediate in yield, between 2.9 and 7.6 kg/vine. ‘Seyval Blanc’ and ‘Seyval Blanc/3309C’ had an estimated 30% yield loss due to green June beetle (*Cotinis nitida* Linnaeus) damage in both seasons. Green June beetle damage was recorded for ‘Blanc du Bois’ in 2011, resulting in about 30% yield loss. Additionally, bunch rot [*Botryotinia cinerea* (De Bary) Whezel] damage occurred on ‘Blanc du Bois’ clusters during the flowering period that resulted in complete crop loss in 2012. The low crop of ‘Conquistador’ was mainly due to powdery mildew damage that occurred prior to harvest in 2011. Rainy weather delayed ‘Conquistador’ harvest in 2012 and also resulted in 80% loss due to over ripe fruit.

The cultivars differed in cluster weight (Table 4). ‘Villard Blanc’ produced the largest clusters with weight of 287.06 g. ‘Seyval Blanc’, ‘Seyval Blanc’/3309C, ‘Black Spanish’, and ‘Favorite’ had cluster weights between 153.28 and 180.04 g. The remaining cultivars produced smaller clusters ranging from 73.8 to 113.95 g.

PD tolerant hybrid cultivars differed in berry weight (Table 4). ‘Champanel’ produced the largest berries with a weight of 4.8 g, followed by ‘Blanc du Bois’ (3.3 g) and ‘Villard Blanc’ (3.1 g). ‘Cynthiana’ (1.5 g) and ‘Conquistador’ (1.4 g) produced the smallest berries.

Our results suggested that cultivars differed in fruit pH (Table 5). 'Blanc du Bois' and 'Stover' had the highest pH of 3.58 and 3.49, respectively. 'Champanel' had the lowest juice pH of 3.25.

The cultivars also differed in soluble solids content (SSC) (Table 5). 'Cynthiana' had the highest SSC of 19.8% at harvest, while 'Champanel' had the lowest sugar content of 13.1%.

No differences were found in fruit titratable acidity (TA) among the cultivars (Table 5). The TA ranged from 0.56 to 1.36 g/100 ml.

PD symptoms were not observed in 2011 (data not shown). In 2012, PD symptoms, including leaf scorching, matchsticks, and green islands were found on several cultivars (Table 6). ELISA tests showed that three vines of 'Lake Emerald', and one vine of 'Champanel' were positive for *Xylella fastidiosa* infection. PCR (Polymerase Chain Reaction) is much more sensitive than ELISA (about 100 times). When developing a protocol for a specific pathogen, all organisms in existence cannot be tested for cross-reaction (especially those that have not been identified), so a certain amount of false positives can be expected. A false positive is when the test picks up a non-target organism. We had several positive samples, so the test was picking up the enzyme of another organism very similar to *Xylella fastidiosa* either on, or in the plant tissue. PCR is a very sensitive method of detection because it is designed to identify a specific segment of the organisms DNA/RNA that is targeted because this segment is unique only to the target organism. The follow-up PCR analysis revealed that there were no *Xylella fastidiosa* infected vines in our study.

Discussion

‘Champanel’ had the largest pruning weight and the largest TCSA, which suggested ‘Champanel’ had the most vigorous vegetative growth among all studied cultivars in both seasons. ‘Seyval Blanc’ had the lowest pruning weight and its vines also produced the smallest TCSA, which indicated ‘Seyval Blanc’ had the weakest vine vigor. Kaps and Odneal (2010) also found that Missouri - grown ‘Seyval Blanc’ had a low to moderate pruning weight of 1.1 kg/vine. Modification of pruning for an optimal crop load and vigor will be needed for ‘Seyval Blanc’. Reynolds et al. (1986) reported that ‘Seyval Blanc’ vines should be thinned to a density in the range of 12-19 shoots/months of row to obtain a desirable canopy.

‘Stover’ had the earliest shoot development in both 2011 and 2012. This observation is in agreement with Mortensen (1968) who suggested that ‘Stover’ responded to warmer spring temperatures prior to other cultivars and had the highest number of fully expanded leaves per shoot early.

Cultivars in our study were harvested depending on fruit color, sugar accumulation, and flavor development. ‘Seyval Blanc’ and ‘Seyval Blanc/3309C’ had the earliest ripening in both seasons, while ‘Cynthiana’ and ‘Lake Emerald’ were late ripening cultivars. Wolf (2008) also stated that ‘Seyval Blanc’ had early ripening in New York.

Information about the horticultural characteristics and performance of ‘Villard Blanc’ in various environments is recently very scarce. Our research suggested that ‘Villard Blanc’ had good vegetative growth and excellent crop productivity, producing the highest yield and largest cluster size in the North Alabama environment.

'Champanel' produced the largest berries in both 2011 and 2012 in comparison to all the other American and French-American hybrid grape cultivars tested. Similarly, Munson (1909) also reported that 'Champanel' had large berries.

For wine processing cultivars, a SSC of 20 to 24 % after fermentation yields an acceptable alcohol level for a good quality table wine (Amerine et al., 1980). A titratable acidity (TA) of 0.65 to 0.80 g/100 ml is also desirable for producing a good table wine depending on the color and style. A grape juice pH of 3.4 or below at these SSC and TA levels is desirable to obtain microbial stability in wine. In our study, the pH of tested cultivars was around 3.4, which suggested all cultivars produced fruit with an acceptable pH level, but had a relatively low SSC when compared to the desirable level. The reason for low SSC perhaps was the rainy weather prior to harvest in Alabama. 'Blanc du Bois', 'Seyval Blanc', and 'Seyval Blanc'/3309C produced fruit with TA within the desirable range.

Empirical information on the performance of American and French-American hybrid bunch grape cultivars in Alabama's high PD risk environment was obtained in this study. 'Black Spanish' and 'Favorite' performed similarly in our study, but vineyard management for 'Favorite' was more difficult than 'Black Spanish' because 'Favorite' had thicker canopy and more root suckers, which required additional labor for proper canopy management. 'Black Spanish' 'Cynthiana', and 'Villard Blanc', were the best performing cultivars in our study based on vegetative growth and fruit productivity and quality. Multiple years' observations are needed to fully evaluate the selected cultivars before sound recommendations can be made to the grape industry. More detailed studies will be needed to investigate cultivar vine canopy management and adjust the crop load, and to assess the cultivar PD tolerance.

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Table 1. Comparison of vine pruning weight and trunk cross sectional area (TCSA) of Pierce's disease tolerant American and French-American hybrid bunch grape cultivars grown at the SMREC, Crossville, AL, in 2011 and 2012 combined[z].

Cultivar	Pruning weight (kg/vine)	TCSA (cm^2)
Champanel	3.0[y] a[x]	9.5 a
Lake Emerald	1.6 ab	6.9 cd
Blanc du Bois	1.4 ab	6.2 cde
Villard Blanc	1.4 ab	8.8 ab
Stover	1.3 ab	7.6 abc
Conquistador	1.0 ab	4.6 ef
Favorite	0.8 ab	6.9 cd
Cynthiana	0.8 ab	5.4 def
Black Spanish	0.8 ab	7.2 bc
Seyval Blanc/3309C	0.4 ab	7.5 bc
Seyval Blanc	0.3 b	4.4 f

[z]Year was analyzed as a random variable.
[y]All data presented are least squares means.
[x]Differences among cultivars were determined using the Simulate test at $\alpha = 0.05$.

Table 2. Comparison of leaf chlorophyll content and leaf area of Pierce's disease tolerant American and French-American hybrid bunch grape cultivars grown at the SMREC, Crossville, AL, in 2011 and 2012 combined[z].

Cultivar	Leaf chlorophyll content	Leaf area (cm^2)
Favorite	41.5[y] a[x]	142.8 a
Black Spanish	40.7 a	136.8 ab
Conquistador	38.1 b	119.3 bc
Cynthiana	37.8 b	141.1 a
Lake Emerald	36.6 bc	110.3 cd
Champanel	35.8 cd	129.9 ab
Blanc du Bois	34.6 de	88.9 e
Villard Blanc	34.0 de	93.3 de
Stover	34.0 de	84.9 e
Seyval Blanc	33.4 e	79.3 e
Seyval Blanc/3309C	33.4 e	80.7 e

[z]Year was analyzed as a random variable.
[y]All data presented are least squares means.
[x]Differences among cultivars were determined using the Simulate test at $\alpha = 0.05$.

Table 3. Comparison of number of fruiting clusters per shoot of Pierce's disease tolerant American and French-American hybrid bunch grape cultivars grown at the SMREC, Crossville, AL, in 2011 and 2012 combined[z].

Cultivar	Number of fruiting clusters per shoot
Villard Blanc	2.4[y] a[x]
Cynthiana	2.3 a
Lake Emerald	2.3 a
Stover	2.3 ab
Conquistador	2.0 bc
Seyval Blanc/3309C	2.0 cd
Sevyal Blanc	2.0 cd
Favorite	2.0 cd
Black Spanish	1.9 cd
Champanel	1.8 d
Blanc du Bois	1.3 e

[z]Year was analyzed as a random variable.
[y]All data presented are least squares means.
[x]Differences among cultivars were determined using the Simulate test at $\alpha = 0.05$.

Table 4. Comparison of yield per vine, cluster weight, and berry weight of Pierce's disease tolerant American and French-American hybrid bunch grape cultivars grown at the SMREC, Crossville, AL, in 2011 and 2012 combined[z].

Cultivar	Yield (kg/vine)	Cluster weight (g)	Berry weight (g)
Villard Blanc	12.7[y] a[x]	287.06 a	3.1 b
Black Spanish	7.6 b	155.41 b	1.8 ef
Favorite	7.6 b	153.28 b	1.7 fg
Seyval Blanc	6.1 bc	180.04 b	2.0 de
Cynthiana	5.7 bcd	113.95 c	1.5 g
Stover	5.5 bcd	80.19 c	2.5 c
Seyval Blanc/3309C	5.2 cd	163.65 b	2.0 d
Champanel	4.0 cde	109.36 c	4.8 a
Lake Emerald	3.0 de	100.76 c	1.6 fg
Blanc du Bois	2.9 de	105.78 c	3.3 b
Conquistador	2.0 e	73.81 c	1.4 g

[z]Year was analyzed as a random variable.
[y]All data presented are least squares means.
[x]Differences among cultivars were determined using the Simulate test at $\alpha = 0.05$.

Table 5. Comparison of fruit pH, soluble solids content (SSC), and titratable acidity (TA) of Pierce's disease tolerant American and French-American hybrid bunch grape cultivars grown at the SMREC, Crossville, AL, in 2011 and 2012 combined[z].

Cultivar	pH	SSC (% Brix)	TA (g/100 ml)
Blanc du Bois	3.58[y] a[x]	16.7 c	0.77
Stover	3.49 a	17.3 bc	0.56
Black Spanish	3.44 ab	18.3 b	1.36
Conquistador	3.43 ab	16.7 c	0.90
Cynthiana	3.43 ab	19.8 a	1.01
Sevyal Blanc	3.42 ab	16.5 c	0.74
Lake Emerald	3.35 ab	18.8 ab	1.13
Favorite	3.34 ab	18.5 b	1.28
Villard Blanc	3.33 ab	16.3 c	0.85
Seyval Blanc/3309C	3.32 ab	17.4 bc	0.75
Champanel	3.25 b	13.1 d	1.06

[z]Year was analyzed as a random variable.
[y]All data presented are least squares means.
[x]Differences among cultivars were determined using the Simulate test at $\alpha = 0.05$.

Table 6. Comparison of Pierce's disease symptoms of Pierce’s disease tolerant American and French-American hybrid bunch grape cultivars grown at the SMREC, Crossville, AL, in 2012.

	Leaf scorching scale[z]	Matchsticks[y]	Green islands
Blanc du Bois	0	N	N
Black Spanish	1	Y	Y
Champanel	1	Y	Y
Conquistador	1	Y	N
Cynthiana	0	N	N
Favorite	1	Y	Y
Lake Emerald	1	Y	Y
Seyval Blanc/3309C	0	N	N
Seyval Blanc	0	N	N
Stover	1	Y	N
Villard Blanc	1	Y	N

[z]0 = no symptoms;
1 = 1 to 20% leaves with scorching;
2 = 21 to 40% leaves with scorching;
3 = 41 to 60% leaves with scorching;
4 = 61 to 80% leaves with scorching;
5 = 81 to 100% leaves with scorching;

[y]Y=Yes
N=No

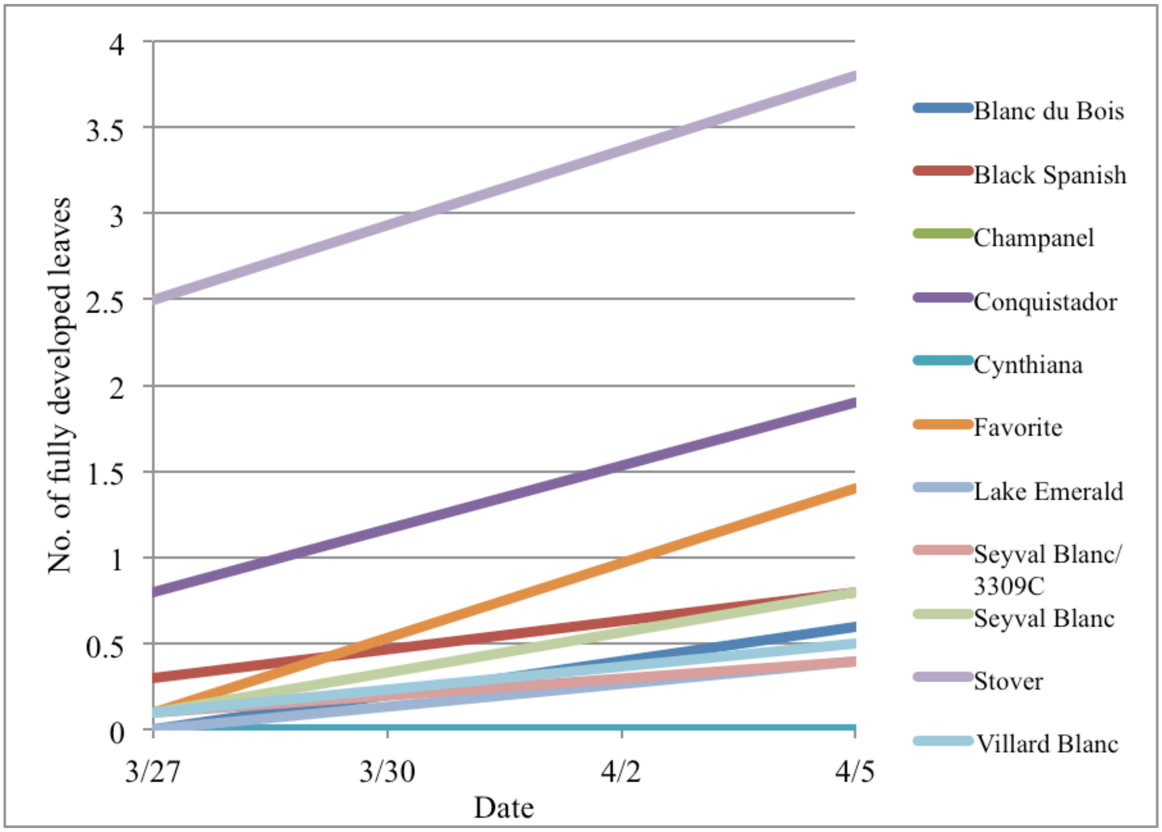

Figure 1. Comparison of early season shoot development of Pierce's disease tolerant American and French-American hybrid bunch grape cultivars grown at the SMREC, Crossville, AL, in 2011.

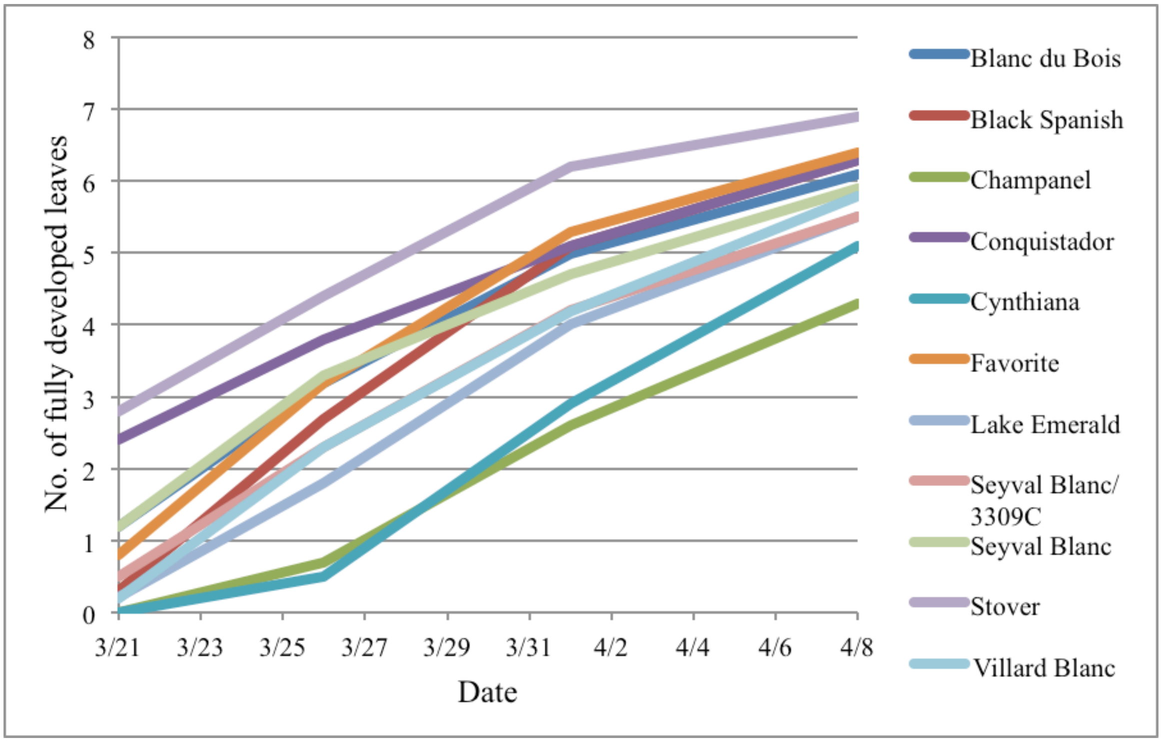

Figure 2. Comparison of early season shoot development of Pierce's disease tolerant American and French-American hybrid bunch grape cultivars grown at the SMREC, Crossville, AL, in 2012.

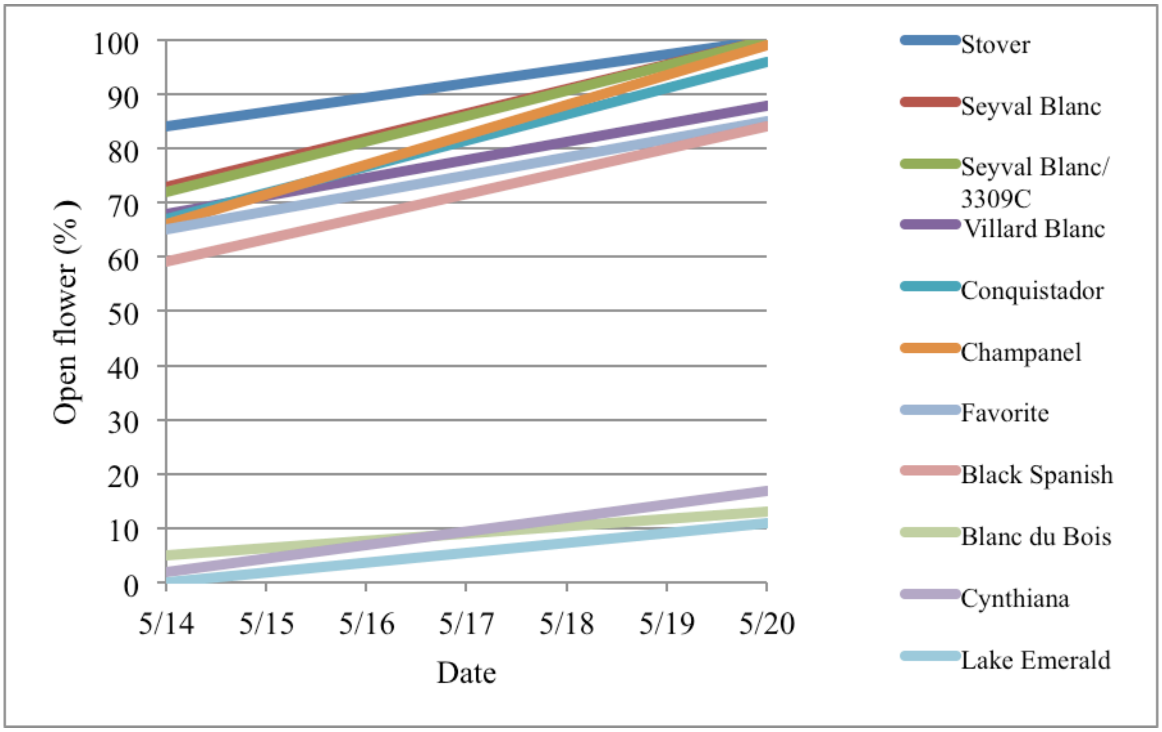

Figure 3. Comparison of percent open flowers of Pierce's disease tolerant American and French-American hybrid bunch grape cultivars grown at the SMREC, Crossville, AL, in 2011.

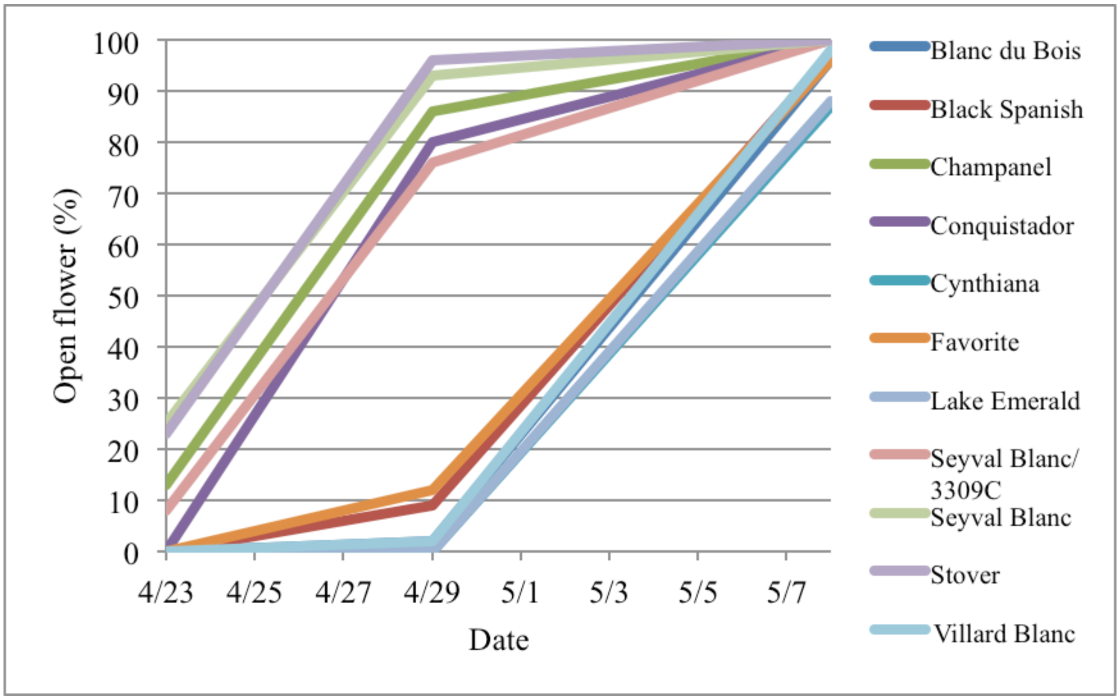

Figure 4. Comparison of percent open flowers of Pierce's disease tolerant American and French-American hybrid bunch grape cultivars grown at the SMREC, Crossville, AL, in 2012.

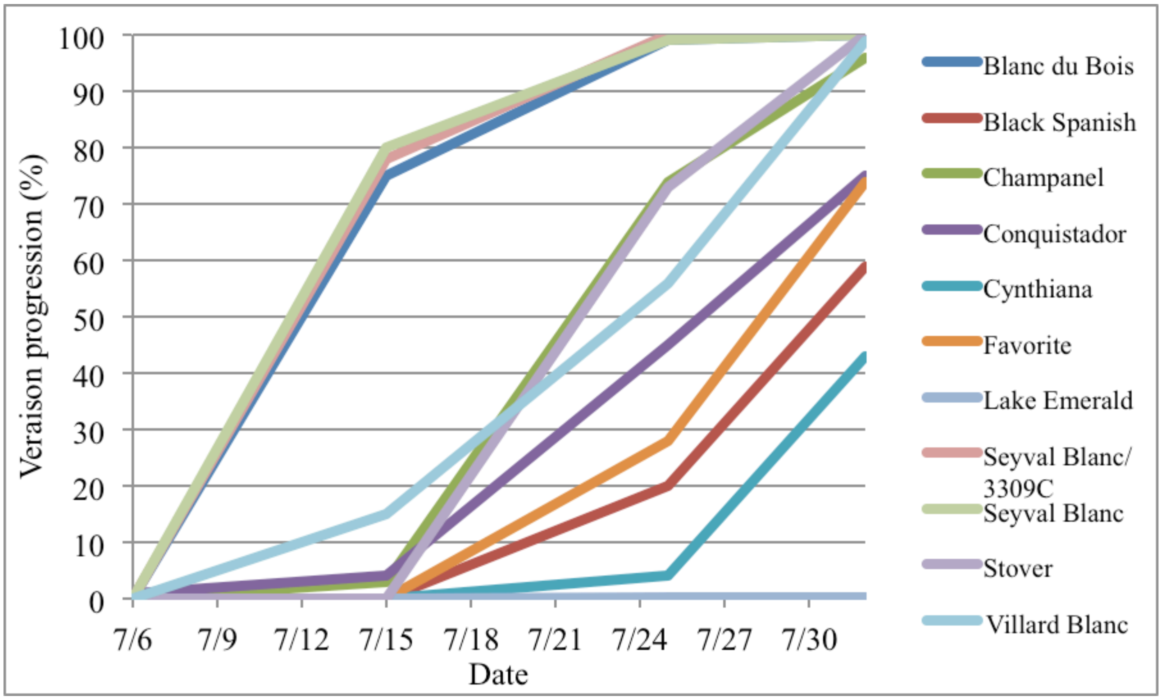

Figure 5. Comparison of veraison progression (percent) of Pierce's disease tolerant American and French-American hybrid bunch grape cultivars grown at the SMREC, Crossville, AL, in 2011.

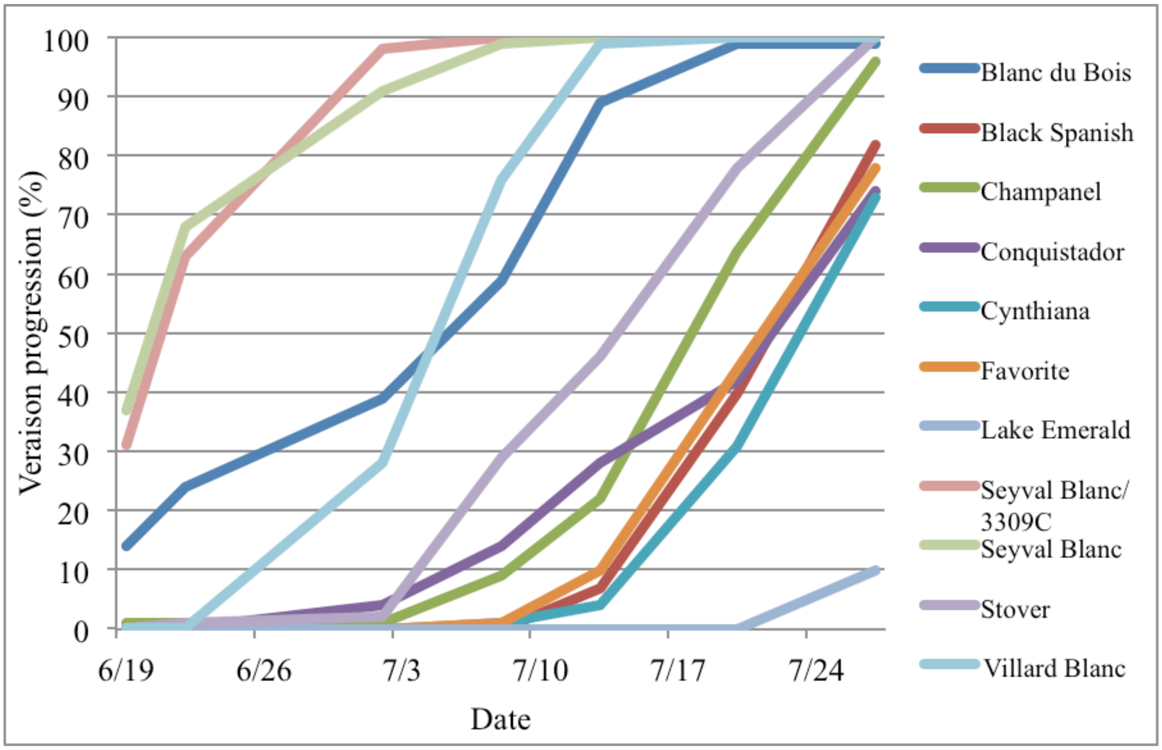

Figure 6. Comparison of veraison progression (percent) of Pierce's disease tolerant American and French-American hybrid bunch grape cultivars grown at the SMREC, Crossville, AL, in 2012.

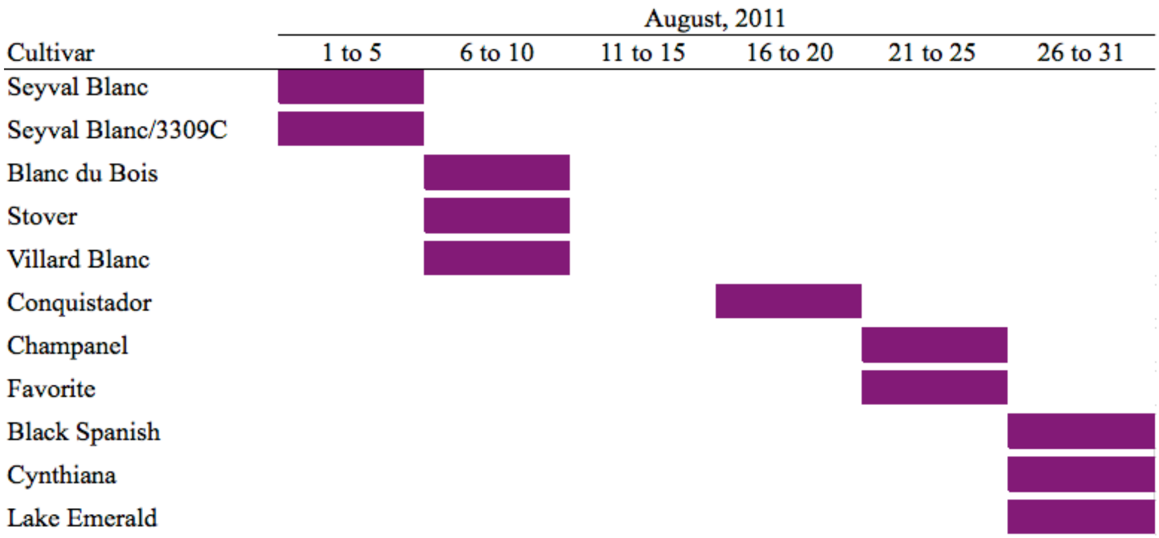

Figure 7. Season of ripening of Pierce's disease tolerant American and French-American hybrid bunch grape cultivars grown at the SMREC, Crossville, AL, in 2011.

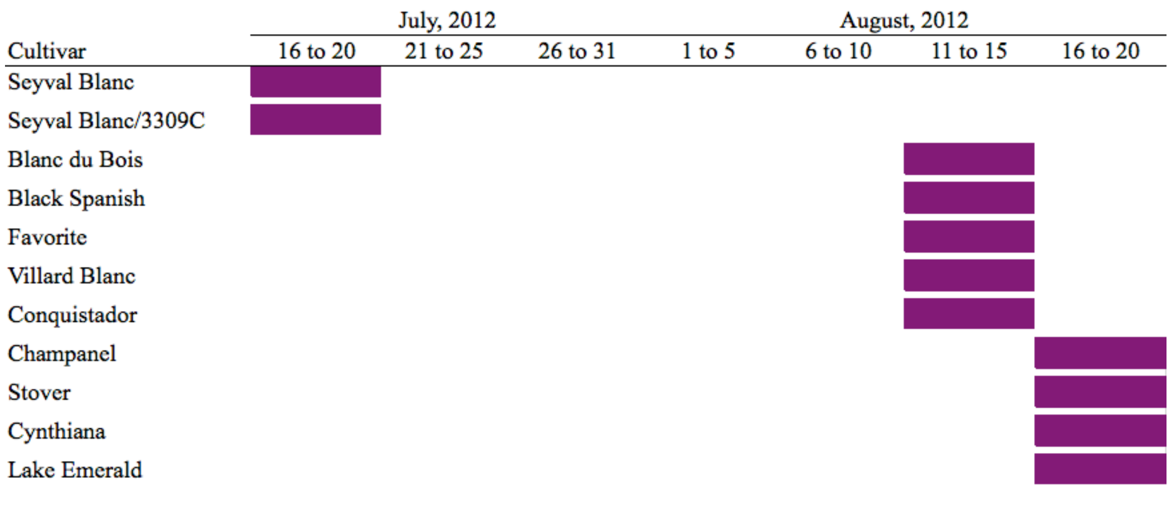

Figure 8. Season of ripening of Pierce’s disease tolerant American and French-American hybrid bunch grape cultivars grown at the SMREC, Crossville, AL, in 2012.

Chapter Three:

Feasibility of Growing Advanced Grape Selections Developed by the University of Arkansas Breeding Program in Alabama

Abstract

Three recently released seedless table grape cultivars ‘Hope’, ‘Joy’, and ‘Gratitude’; two previously released cultivars ‘Mars’, and ‘Neptune’; and eight advanced grape selections from the University of Arkansas breeding program ‘A2817’, ‘A2245’, ‘A2359’, ‘A2467’, ‘A2574’, ‘A2602’, ‘A2632’, and ‘A2786’ were planted at the North Alabama Horticultural Research Center (NAHRC) in Cullman, AL in 2008 to study the feasibility of growing advanced table and processing grape selections in the Alabama environment. Two Pierce’s disease (PD) tolerant cultivars ‘Conquistador’ and ‘Stover’ were also included as controls. Vegetative growth, cropping potential and fruit quality of the tested cultivars and selections were evaluated during 2011 and 2012 seasons. Our results indicate that ‘Joy’ (A2494) had the most vigorous vegetative growth, while ‘A2786’ had the least. ‘Stover’ had the earliest shoot and flower development in both seasons. Selection ‘A2359’ had 3.5 fruiting clusters per shoot that was the highest fruiting cluster number among all the cultivars and selections. ‘Mars’ and ‘Faith’ were early ripening and early maturing, while ‘Conquistador’ started to develop late in the season. The highest yielding selections and cultivars recorded were ‘A2574’, ‘A2359’, ‘Neptune’, ‘A2245’, and ‘Conquistador’ that produced 12.0 kg/vine or higher in both experimental years. Seedless table grape cultivars ‘Gratitude’ and ‘Neptune’ had the largest cluster size of 490 g. ‘Gratitude’ and ‘A2817’ produced the largest berries of 4.9 g. ‘A2632’ had the highest soluble solids content, while ‘Conquistador’ had the lowest sugar concentration at harvest. Fruit pH level of all cultivars

and selections ranged from 3.28 to 3.95. ‘A2817’ had the highest number of seed traces, 3.2, while ‘Gratitude’ had the lowest number of seed traces. ‘A2602’, ‘A2817’ and ‘Mars’ were found to have positive infection for *Xylella fastidiosa* (*X.f.*) when ELISA assay was employed, but the follow-up PCR tests did not confirm *X.f.* infected vines. Based on our results, ‘Neptune’ and ‘Gratitude’ were the best performing seedless table grape cultivars based on their vegetative growth, cropping potential, and fruit quality.

Introduction

The continental climate of areas east of the Rocky Mountains with hot, wet summers and cold, dry winters, and some native North American pests such as the phylloxera (*Daktulosphaira vitifoliae* Fitch) and bacterial diseases have prevented *Vitis vinifera* cultivars from developing and surviving in the eastern United States (Clark, 2003). The grapes now grown successfully in the eastern United States are cultivars selected from the native species, such as ‘Concord’; hybrids of native species, such as ‘Clinton’; and hybrids of native species with varieties of *V. vinifera*, such as ‘Delaware’ (Winkler et al., 1974; Hedrick, 1907).

The University of Arkansas breeding program was begun in 1964 with a focus on the development of table grape cultivars. The table grape is defined as a grape developed exclusively for the table market with the major characteristics such as seedlessness, crisp texture, and edible skin that can be consumed easily with no discarding of skins or other inedible components (Clark, 2010). Released from the program were the seedless table grape cultivars ‘Venus’ (1977), ‘Reliance’ (1983), ‘Mars’ (1985), ‘Saturn’ (1989), ‘Jupiter’ (1999), ‘Neptune’ (1999) (Clark, 2003), ‘Faith’, ‘Hope’, ‘Joy’, and ‘Gratitude’ (Clark, 2012). The major objectives in this eastern table grape improvement program includes improving the textures of both slipskin and non-slipskin grape types that provide different mouth sensation to customers, development of seedless cultivars, fruit cracking resistance and winter hardiness, wider flavor pallet combined with crisp texture, and more elongated fruit shape (Clark, 2010).

'Mars' is a hybrid of *V. labrusca* and *V. vinifera*. It has demonstrated outstanding resistance to black rot, anthracnose, powdery mildew and downy mildew under minimum chemical disease control at the Arkansas agricultural experiment station in Clarksville, AR (Moore, 1985). The average ripening date of 'Mars' is July 22nd in central Arkansas. Fruit skins are medium thick and do not adhere to the flesh (non-skipskin). Fruit color is blue at maturity. The berry size is 3.5 g, which is considered large for a seedless grape cultivar. The flavor is strong and typically resembles *V. labrusca* species. Soluble solids content (SSC) of the fruit is medium (16%), but acid content is low and the fruit tastes sweet (Moore, 1985). Fruit clusters are medium in size, well-filled, and compact. Kaps and Odneal (2001) conducted a study to evaluate 'Mars' in the Ozark region of Missouri. According to the authors 'Mars' was one of the table grape cultivars best suited for the region based on overall productivity (yield, pruning weight, juice composition). According to the annual data from 1989 to 1994, the yield per vine of 'Mars' was 5.0 kg, which was considered an intermediate yield. The pruning weight of 'Mars' was 1.6 kg, and the cluster weigh was 143 g, which is considered a medium size cluster. 'Mars' had a SSC of 16.2%. Early ripening blue colored 'Mars' berries were found to be susceptible to bird feeding before SSC was high enough for harvesting the crop.

'Neptune' is a hybrid of *V. labrusca* and *V. vinifera*, and is the first advanced seedless white table grape developed by the University of Arkansas breeding program. 'Neptune' has demonstrated good resistance to black rot, anthracnose, and powdery mildew (Clark and Moore, 1999). The average ripening date of 'Neptune' is August 4th in central Arkansas. The fruit is yellow-green in color at maturity, and berries within a cluster are evenly colored. Fruit skin is moderately thick, and the pulp adheres to the skin of the berry, providing a non-slipskin texture. The berry size of 'Neptune' was medium and the berry weight was 2.5 g. The flavor is fruity and sweet. Fruit SSC was 19.7%. Fruit clusters were large in size (345 g), and well-filled (Clark and Moore, 1999). Wilson et al. (2010) reported that Kentucky-grown 'Neptune' grapes were harvested on September 8, 2010, and produced a cluster weight of 340 g. Fruit sugar concentration of 'Neptune' was 21.8%, and the berry weight was 5.83 g.

'Faith' (A2412) is a blue, non-slipskin, seedless table grape with early ripening, late July to early August in Arkansas (Clark, 2012). Cluster weight ranged from 150 to 250 g, and berries were 4 g. SSC was 19% with neutral flavor. Some berries matured unevenly in some years.

'Joy' (A2494) is a blue, non-slipskin, seedless table grape that was harvested date on August 11th in Arkansas (Clark, 2012). Cluster weight was 300 g, and berries were 3 g. The flavor is exceptional fruity. Shatter of mature berries occurred in some years.

'Gratitude' (A2505) is a white, non-slipskin, seedless table grape (Clark, 2012). Cluster weight was up to 500 g, and berries were 3.5 g. Soluble solids content was 19% with exceptional crisp texture. The flavor is neutral, similar to *Vitis vinifera* table grapes.

Newly developed grape selections have not been tested outside of Arkansas and information on their performance is not available. It is unknown if these newly released cultivars and selections possess resistance to the major grape pest in the southeast – Pierce's disease (PD).

The demand for high quality, locally produced table and wine grapes from consumers, grape growers and winemakers is increasing. Science based information is lacking on the performance of recently released or existing seedless table grapes in Alabama's high PD risk environment. Data about cultivar growing requirements, cropping potential, and fruit quality in

Alabama would be very beneficial to the grape growing industry in the state and the entire southeastern region.

We hypothesized that seedless table grapes will respond differently in terms of their vegetative growth, cropping potential and fruit quality due the climatic conditions in Alabama.

The main objective of the current study was to evaluate the performance of seedless table grapes in Alabama's environment to gain science based empirical information on their productivity, such as fruit quality, PD resistance and longevity, and to provide grape growers with recommendations on cultivar selection as a means to expand and sustain the grape growing industry in the southeastern region of the nation.

Materials and Methods:

An experimental vineyard was established in 2008 at the North Alabama Horticulture Research Center (NAHRC) in Cullman, AL (long. 34.193559N, lat. -86.794975E), USDA Plant Hardiness Zone 7B (USDA Plant Hardiness Zone Map, 2012). Thirteen cultivars and advanced table and processing grape selections developed by the University of Arkansas breeding program, and another two PD tolerant American and French-American hybrid bunch grape cultivars were used in this study. The soil in the NAHRC is Hartsells sandy loam (USDA Web Soil Survey, 2012). The experimental design was a randomized complete block design with 4 blocks and 2 individual plants per cultivar, per block. The vines from were obtained as stem cuttings from the University of Arkansas and rooted at the Auburn University Paterson greenhouse, Auburn, AL under mist conditions. After 8 weeks, the rooted cutting were transported to the NAHRC in Cullman, transplanted in 2-gallon pots, and grown for the reminder of the season before planted in the open field in the fall. Standard commercial practices were implemented for the planting and maintenance of the vines (Poling, 2007). Supplemental irrigation was installed to ensure a successful plant establishment and production using drip tape. Irrigation was provided during the growing season according to the weather conditions. The emitters delivered water rate at 3.785 liters per hour, and the system operated between two and four hours per day as needed. The irrigation was still operated at veraison stage, because the cultivars had different veraison progression. The irrigation was maintained to make sure the experiment condition was uniform.

Newly released seedless table grape cultivars ‘Faith’ (A2412), ‘Joy’ (A2494), and ‘Gratitude’ (A2505); one advanced selection ‘A2817’; and two previously released seedless table grape cultivars ‘Mars’, and ‘Neptune’ were used. Processing grape selections were ‘A2245’, ‘A2359’, ‘A2467’, ‘A2574’, ‘A2602’, ‘A2632’, and ‘A2786’. Processing cultivars ‘Conquistador’ and ‘Stover’ were included as standards.

In 2011, the average number of fully developed leaves per shoot per vine was rated visually on March 27th, April 5th, and April 17th. In 2012, six shoots per vine were chosen and the number of fully developed leaves per shoot were counted on March 21st, March 26th, April 2st, and April 8th to determine shoot development. After the bud brake, six shoots per vine were chosen and flagged as follows: two shoots located at the distal part of each cordon; two shoots located in the middle part of each cordon, and two shoots located in the basal part of each cordon.

Grape flowering was determined by visual rating the percentage of fully open flowers. In 2011, the percentage of fully open flowers per vine was visually rated on May 11th and May 20th. In 2012, six clusters per vine were chosen and the percentage of fully open flowers per cluster was recorded on April 23rd, April 29th, and May 8th to determine flowering progression. A flower was considered fully open when the pistil and stamens were observed. Six clusters were chosen and flagged on each vine as follows: two clusters located at the distal part of each cordon; two clusters located in the middle part of each cordon, and two clusters located in the basal part of each cordon.

To determine cultivar vegetative growth and vigor characteristics, vine pruning weight, trunk cross sectional area (TCSA), vine leaf area and leaf chlorophyll content were measured. Dormant pruning was done at bud break on March 18th in 2011 and March 6th in 2012. Each vine was pruned to seven spurs per cordon with two buds on each spur for a total number of 30 buds per vine (Rombough, 2002). Pruned wood was collected and the individual pruning weight per vine was recorded by using an Adam CPWplus-35 scale (Adam Equipment Inc, Danbury, CT, USA). The vine trunk diameter was measured at 30 cm above the ground level using a digital caliper (Serial No. 0107312, Mitutoyo Corporation, Kawasaki, Japan), and was used to determine the TCSA.

To determine the leaf area per vine, 10 recently matured leaves were collected in mid-July and measured with a Licor LI-3100 area meter (Lincoln, NB, USA). Mature leaves located at least five nodes back from the terminal bud of the shoot were used. Leaf chlorophyll content were taken on 10 leaves per vine with a SPAD-502 Plus chlorophyll meter (Konica Minolta Sensing, INC, Osaka, Japan) to evaluate the cultivar chlorophyll content.

To determine the number of fruiting clusters per shoot, six shoots per vine were marked and the number of clusters per shoot was counted. Six shoots were chosen on each vine as follows: two shoots located at the distal part of each cordon; two shoots located in the middle part of each cordon, and two shoots located in the basal part of each cordon.

Veraison progression was determined by periodical visual rating of the percentage of berries per vine turning their color. Percentage of berries turning their color was evaluated on

July 11th in 2011; and on June 12th, June 22nd, July 2nd, July 8th, July 13th, July 20th, and July 27th in 2012.

Vines were hand-harvested from mid-July until late August in both years. Total yield was measured for each experimental vine on each harvest date using an Adam CPWplus-35 scale.

Five cluster subsamples per vine were collected at harvest to determine cluster weight using a digital scale (Adventurer Pro AV4101, Ohaus Corporation, Pine Brook, NJ, USA). Fifty berry subsamples were collected from each vine to determine the mean berry weight using a digital scale (Adventurer Pro AV4101, Ohaus Corporation, Pine Brook, NJ, USA). The berries were placed in a cooler and kept at 4 °C for no more than 2 days before analysis.

Fruit quality analysis was performed by measuring berry soluble solids content (SSC), titratable acidity, and pH. SSC was determined by squeezing the juice from 10 berries per vine and filtering the liquid with Veratec Graphic Arts cheesecloth (BBA Nonwovens, Simpsonville, SC, USA). The extracted juice was analyzed using a digital refractometer (Pal-1 Atago, Co., Tokyo, Japan) to determine the percent brix at a room temperature.

Titratable acidity was measured by using a DL 15 Titrator (Mettler-Toledo, LLC, Columbus, OH). One milliliter of grape juice was diluted to 40 ml solution, titrated by 0.1 N NaOH, with an end point of pH 8.2. Results were expressed as grams of tartaric acid equivalent per 100 ml extracted juice. Juice pH was measured in the initial titration procedure.

Pierce's disease symptom expressions, including leaf scorching, 'matchstick', and 'green island', were visually rated after harvest using the following scale in 2011: 0 = no symptoms; 1 = 1 to 20% leaves with scorching; 2 = 21 to 40% leaves with scorching; 3 = 41 to 60% leaves with scorching; 4 = 61 to 80% leaves with scorching; 5 = 81 to 100% leaves with scorching. In 2012, 10 petioles per vine were collected from the basal part of each cordon to conduct serological tests to determine *Xylella fastidiosa* infections. Samples were submitted to the Auburn University Plant Diagnostic Lab and ELISA test was conducted using Agdia ELISA kits (Agdia, Inc, USA), and following manufacturer's recommendations. Follow-up PCR tests were utilized to confirm positive *X.f.* infections.

Analysis of variance was performed on all data using PROC GLIMMIX in SAS version 9.2 (SAS Institute, Cary, NC). The experimental design was a randomized complete block design. The homogeneity of variance assumption for ANOVA was tested for all responses using the COVTEST statement. Appropriate correction for heterogeneity of variance was applied where needed using the GROUP option on the RANDOM statement in PROC GLIMMIX. For data collected in 2011 and 2012 including pruning weight, TCSA, leaf area, leaf chlorophyll level, the number of fruiting clusters per shoot, yield per vine, average cluster weight, mean berry weight, SSC, TA and pH, the two years and blocks were analyzed as random variables. Where data were collected over time including shoot development, seasonal flowering, and veraison progression, a factorial treatment design was used with cultivars and time as main effects. Differences among cultivars were determined using the Simulate mean separation test because of missing data. Linear and quadratic polynomial contrasts were used to determine trends over weeks. All data presented are least squares means. All significances were at α=0.05.

Results

The cultivars and selections showed differences in vine pruning weights (Table 1). Seedless table grape cultivar 'Joy' had the highest pruning weight of 3.0 kg/vine, followed by 'A2245' (2.7 kg/vine), 'A2632' (2.7 kg/vine), and 'Gratitude' (2.6 kg/vine). Selection 'A2786' had the lowest pruning weight of 0.9 kg/vine. The remaining cultivars and selections had the pruning weights ranging from 1.1 kg/vine to 2.4 kg/vine.

The cultivars and selections differed in TCSA (Table 1). 'Stover' had the largest TCSA with 9.7 cm^2, followed by 'A2467', 'A2359', 'A2245', 'A2602', and 'A2632' ranging from 7.3 cm^2 to 8.5 cm^2. These selections also had high pruning weights. 'A2786' had the smallest TCSA of 4.6 cm^2, which also corresponded to its lowest pruning weight among all the cultivars and selections studied.

The table and processing cultivars and selections differed in leaf area (Table 2). 'Faith', 'Mars', and 'Conquistador' had the largest leaf area of 168.4 cm^2, 158.9 cm^2, and 148.8 cm^2, respectively. 'A2602' and 'A2359' had the smallest leaf area of 87.6 cm^2 and 82.4 cm^2, respectively. The remaining cultivars and selections had the leaf area ranging from 91.8 cm^2 to 128.1 cm^2.

Newly developed cultivars and selections differed in leaf chlorophyll content (Table 2). 'Conquistador' and 'A2632' had the highest leaf chlorophyll level of 43.0 and 42.5, respectively. 'A2817' had the lowest chlorophyll level of 31.5.

The cultivars and selections had differences in early shoot development in 2011 (Figure 1). 'Stover' had the earliest shoot development with 0.8 fully developed leaves on March 27th. 'Stover' also had the largest number of fully developed leaves on April 5th and April 17th of 2.2

and 5.9, respectively. ‘Joy’, ‘Gratitude’, ‘A2632’, ‘A2786’, ‘A2817’, ‘Conquistador’, and ‘Mars’ had relatively late shoot development beginning after April 5^{th} and grew the fewest number of fully developed leaves on April 17^{th}.

Differences in early shoot development were evident for the cultivars and selections tested in 2012 (Figure 2). ‘Stover’, ‘A2574’, and ‘Faith’ had the earliest shoot development on March 21^{st}, with 2.8, 2.5, and 2.2 fully developed leaves, respectively. ‘Stover’ also had a high number of fully developed leaves on March 26^{th}, April 2^{rd}, and April 8^{th}. ‘Joy’, ‘Gratitude’, ‘A2632’, ‘A2786’, and ‘A2817’ had relatively late shoot development and the lowest number of fully developed leaves on April 8^{th} ranging from 4.6 to 5.1.

Seedless and processing grape selections and cultivars differed in season of flowering in 2011 (Figure 3). ‘Stover’, ‘Faith’, and ‘A2574’ had early flowering with 77%, 72%, and 72% open flowers on May 11^{th}. ‘A2786’ and ‘Conquistador’ flowered late with 1% and 8% open flowers on May 20^{th}.

Differences in the percentage of open flowers were found among the selections and cultivars in 2012 (Figure 4). ‘Stover’ and ‘A2574’ flowered early in the season with 15% and 11% open flowers on April 23^{rd}, and these two cultivars developed more than 80% open flowers on April 29^{th}. ‘A2602’ flowered late with 50% open flowers on May 8^{th}, while the remaining selections and cultivars reached the stage of over 75% open flowers.

Table and processing cultivars and selections varied in number of fruiting clusters per shoot (Table 3). ‘A2359’ had the highest number of clusters per shoot with 3.5, followed by ‘A2574’ with 3.1 fruiting clusters per shoot. ‘Gratitude’ had the lowest number of fruiting clusters per shoot with 1.5. The number of fruiting clusters per shoot of the remaining cultivars and selections ranged from 1.6 to 2.9.

Differences were observed among studied selections and cultivars in the percentage of veraison progression in 2011 (Table 4). ‘Mars’ had the most advanced veraison with 97% berries turning red on July 11th, followed by ‘Faith’ and ‘A2467’ with 60% and 56% maturing berries, respectively. Veraison started late in the season, on July 11th, for ‘Conquistador’, and ‘Stover’.

Cultivars and selections showed differences in veraison progression in 2012 (Figure 5). ‘A2467’ was the first selection to start maturing fruit with 13% of berries turning red on June 12th, but the process was extended over a long period of time and the selection did not achieve 100% veraison until July 20th. Veraison was the most advanced for the seedless table grape ‘Faith’, which reached 98% veraison on July 2nd. ‘Gratitude’, ‘Mars’, and ‘Neptune’ also developed early in the season reaching 94% or higher fruit maturity on July 8th. Veraison occurred late for ‘Conquistador’, which had 63% of its berries turning red on July 27th.

In 2011, ‘Faith’, ‘A2467’, and ‘Mars’ were early maturing grapes that were harvested in mid-July (Figure 6). ‘A2602’ and ‘Conquistador’ were late maturing and harvested in late August. The remaining cultivars and selections were harvested from late July to early August. A tornado occurred on April 27th, 2011 that damaged the selections ‘Joy’, ‘A2632’, and ‘A2786’. These three selections had complete yield loss in 2011. In 2012, ‘Faith’ and ‘Mars’ ripened early in the season and were harvested in mid July (Figure 7). ‘A2245’, ‘A2359’, ‘A2602’, ‘A2632’, ‘Conquistador’, and ‘Stover’ were late season cultivars and were harvested in mid August. The remaining cultivars and selections had intermediate ripening and were harvested at early August.

Differences were found for total yield per vine among the cultivars and selections in 2011 and 2012 (Table 5). The highest yielding selections and cultivars were ‘A2574’, ‘A2359’, ‘Neptune’, ‘A2245’, and ‘Conquistador’ with a yield ranging from 12.0 to 13.7 kg/vine. The lowest yielding cultivars and selections were ‘A2632’, ‘A2786’, ‘A2602’, and ‘Stover’ with yield ranging from 1.5 to 4.3 kg/vine. The remaining cultivars were intermediate in yield, between 5.3 and 9.7 kg/vine. Individual clusters from the vines of ‘A2786’ did not ripe uniformly and some vines had over ripe fruit at harvest resulting in a 50% yield loss in 2012.

Advanced grape selections and cultivars differed in cluster weight (Table 5). Seedless table grapes ‘Gratitude’ and ‘Neptune’ had the largest cluster weight of 495.6 and 492.0 g, respectively. Processing grapes ‘Stover’ and ‘A2602’ produced the smallest clusters of 69.8 and 74.5 g, respectively. The remaining cultivars and selections produced clusters ranging from 157.2 to 360.9 g. In general, the table grape selections produced larger clusters, while the processing selections produced smaller clusters, which is a desirable characteristic for each market group.

Studied grape cultivars and selections differed in berry weight (Table 5). ‘Gratitude’ and ‘A2817’ produced the largest berries of 4.9 g, respectively. ‘A2467’ produced the smallest berries of 1.4 g. The remaining selections and cultivars produced berries with sizes ranging from 1.8 to 3.6 g. In general, seedless table grape selections produced larger berries, while processing selections produced smaller size berries.

Selections and cultivars differed in SSC and TA (Table 6). ‘A2632’ had the highest SSC of 21%, while ‘Conquistador’ had the lowest sugar content of 13% at harvest. ‘A2467’ had the highest TA of 1.34 g/100 ml. The TA for the remaining cultivars and selections was similar and ranged from 0.52 to 0.79 g/100 ml. No difference was found among the studied grapes in juice pH levels and pH ranged from 3.28 to 3.95.

Seedless table grape differed in number of seed traces per berry (Table 7). ‘A2817’ had the highest number of seed traces of 3.2, while ‘Gratitude’ had the lowest number of seed traces of 1.5. The seed traces were not noticeable when eating the fruit. The berry texture of all the table grapes was described as non-slipskin.

Pierce's disease symptoms were not observed in 2011 (data not shown). In 2012, PD symptoms, including leaf scorching, "matchsticks", and "green islands" were found in several cultivars and selections (Table 8). 'A2602', 'A2817' and 'Mars' were found to be *Xylella fastidiosa* infected when an ELISA test was performed. PCR (Polymerase Chain Reaction) is much more sensitive than ELISA (about 100 times). When developing a protocol for a specific pathogen, all organisms in existence cannot be tested for cross-reaction (especially those that have not been identified), so a certain amount of false positives can be expected. A false positive is when the test picks up a non-target organism. We had several positive samples, so the test was picking up the enzyme of another organism very similar to *Xylella fastidiosa* either on, or in the plant tissue. PCR is a very sensitive method of detection because it is designed to identify a specific segment of the organisms DNA/RNA that is targeted because this segment is unique only to the target organism. The follow-up PCR analysis revealed that there were no *Xylella fastidiosa* infected vines in our study.

Discussion

'Joy' had the largest pruning weight indicating it had the most vigorous vegetative growth. 'A2786' had the smallest pruning weight and TCSA indicating it had the weakest vegetative growth in both 2011 and 2012. According to balanced crop pruning (Rombough, 2002), 'A2786' perhaps would benefit from a pruning that leaves fewer buds after dormant pruning.

'Stover' had early shoot development and flowering development in 2011 and 2012. This was in agreement with Mortenson (1968) who stated 'Stover' started developing in early spring.

According to our results, 'Mars' was an early ripening cultivar in 2011 and 2012. This result is similar to studies conducted by other authors in different locations. Moore (1985) reported that the average ripening date for 'Mars' is July 22^{nd} in central Arkansas. Kaps and Odneal (2001) also found that 'Mars' had early ripening in Missouri.

'Neptune' had high yield with large clusters and medium berry size in our study. This result is similar to trials in Arkansas and Kentucky (Clark and Moore, 1999; Wilson et al. 2010).

Newly released cultivar 'Faith' had early ripening, medium cluster weight and berry size. SSC of "Faith' fruit was 18% with a non-slipskin texture. This is in agreement with results from a study conducted in Arkansas (Clark, 2012). In our research, maturing berries of 'Joy' had a tendency to shatter, which is also similar to the breeder's report (Clark, 2012).

'Gratitude' fruit provided the largest cluster weight and berry weight among tested cultivars. According to Clark (2012), this cultivar had similar characteristics when grown in Arkansas.

Science based information on the performance of newly released cultivars and advanced selections developed by the University of Arkansas breeding program in Alabama's high PD risk environment was obtained through our study. Due to the tornado in 2011, 'Joy', 'A2632', and 'A2786' only had one-year yield data, so the result for these cultivar and selections were not conclusive. 'Neptune' and 'Gratitude' were the best performing seedless table grape cultivars combining a good vegetative growth, cropping potential and fruit quality. Multiple years of observations are needed to fully evaluate the selected cultivars and selections before sound recommendations can be made to the grape industry. Vineyard management, such as cultivar specific pruning and thinning, should be further explored.

The cultivars and selections developed by University of Arkansas breeding program were not breed for PD before, so it is uncertain that if they have PD tolerance or not. According to the PCR results, there were no *Xylella fastidiosa* infected vines in our study in 2011 and 2012, but further research is needed to explore PD tolerance in the future before making a sound conclusion.

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Table 1. Comparison of vine pruning weight and trunk cross sectional area (TCSA) of newly grape released cultivars and advanced grape selections grown at the NAHRC, Cullman, AL, in 2011 and 2012 combined[z].

Cultivar	Pruning Weight (kg/vine)	TCSA (cm^2)
Joy	3.0[y] a[x]	6.5 bcd
A2245	2.7 a	7.5 abcd
A2632	2.7 a	7.3 abcd
Gratitude	2.6 a	6.4 bcd
Faith	2.4 ab	5.7 bcd
A2602	2.4 ab	7.4 abcd
Mars	2.4 ab	6.5 bcd
Stover	2.4 ab	9.7 a
Conquistador	2.1 ab	6.7 bcd
A2467	1.8 ab	8.5 ab
A2359	1.7 abc	7.9 abc
A2574	1.7 abc	5.6 bcd
A2817	1.6 abc	5.5 bcd
Neptune	1.1 bc	5.1 cd
A2786	0.9 c	4.6 d

[z]Year was analyzed as a random variable.
[y]All data presented are least squares means.
[z]Differences among cultivars were determined using the Simulate test at $\alpha = 0.05$.

Table 2. Comparison of leaf area and leaf chlorophyll content of newly released grape cultivars and advanced grape selections grown at the NAHRC, Cullman, AL, in 2011 and 2012 combined[z].

Cultivar	Leaf area (cm^2)	Chlorophyll content
Faith	168.4[y] a[x]	34.5 efg
Mars	158.9 a	38.1 cd
Conquistador	148.8 ab	43.0 a
Joy	128.1 bc	36.3 def
A2786	122.7 bcd	39.5 bc
Neptune	122.3 bcde	37.2 cde
Gratitude	120.7 bcde	34.1 fg
A2245	113.7 cdef	36.6 cdef
A2574	111.3 cdef	34.8 ef
A2817	111.1 cdef	31.5 g
A2467	104.3 cdef	35.1 def
A2632	93.1 def	42.5 ab
Stover	91.8 ef	35.4 def
A2602	87.6 f	36.3 def
A2359	82.4 f	34.5 efg

[z]Year was analyzed as a random variable.
[y]All data presented are least squares means.
[x]Differences among cultivars were determined using the Simulate test at $\alpha = 0.05$.

Table 3. Comparison of the number of fruiting clusters per shoot of newly released grape cultivars and advanced grape selections grown at the NAHRC, Cullman, AL 2011 and 2012 combined[z].

Cultivar	No. of fruiting clusters per shoot, (No.)
A2359	3.5[y] a[x]
A2574	3.1 ab
Conquistador	2.9 bc
Stover	2.6 cd
A2245	2.4 de
Faith	2.3 de
Joy	2.2 e
Neptune	2.1 ef
A2817	2.1 ef
A2467	2.1 ef
Mars	2.0 ef
A2632	2.0 ef
A2786	1.8 fgh
A2602	1.6 gh
Gratitude	1.5 h

[z]Year was analyzed as a random variable.
[y]All data presented are least squares means.
[x]Differences among cultivars were determined using the Simulate test at $\alpha = 0.05$.

Table 4. Comparison of veraison progression (percent) of newly released grape cultivars and advanced grape selections grown at the NAHRC, Cullman, AL, in 2011.

Cultivar	Veraison grogression (%), July 11st, 2011
Mars	96.9[z] a[y]
Faith	60.0 b
A2467	56.4 b
Gratitude	36.3 c
A2817	18.8 cd
Neptune	18.8 cd
A2786	6.3 d
Joy	1.3 d
A2245	0.1 d
A2359	0.0 d
A2574	0.0 d
A2602	0.0 d
A2632	0.0 d
Conquistador	0.0 d
Stover	0.0 d

[z]All data presented are least squares means.
[y]Differences among cultivars were determined using the Simulate test at $\alpha = 0.05$.

Table 5. Comparison of yield per vine, cluster weight, and berry weight of newly released grape cultivars and advanced grape selections grown at the NAHRC, Cullman, AL, in 2011 and 2012 combined[z].

Cultivar	Yield (kg/vine)	Cluster weight (g)	Berry weight (g)
A2574	13.7[y] a[x]	250.9 bc	1.8 ef
A2359	13.6 a	177.4 cd	2.3 de
Neptune	12.9 a	492.0 a	3.5 b
A2245	12.8 a	251.4 bc	2.4 cde
Conquistador	12.0 a	168.3 cd	2.9 bc
A2817	9.7 ab	360.9 b	4.9 a
A2467	9.1 ab	215.7 c	1.4 f
Mars	6.3 bc	235.1 c	3.3 b
Joy	6.2 bc	205.4 cd	2.5 cd
Faith	6.0 bc	217.1 c	3.2 b
Gratitude	5.3 bc	495.6 a	4.9 a
Stover	4.3 c	69.8 d	2.4 cd
A2602	2.7 c	157.2 cd	2.3 de
A2786	1.7 c	189.0 cd	3.6 b
A2632	1.5 c	74.5 d	2.1 de

[z]Year was analyzed as a random variable.
[y]All data presented are least squares means.
[x]Differences among cultivars were determined using the Simulate test at $\alpha = 0.05$.

Table 6. Comparison of fruit pH, soluble solids content (SSC), and titratable acidity (TA) of newly released grape cultivars and advanced grape selections grown at the NAHRC, Cullman, AL, in 2011 and 2012 combined[z].

Cultivar	pH	SSC (%)	TA (g/100 ml)
A2632	3.82	21.0[y] a[x]	0.78 b
Stover	3.81	18.1 ab	0.52 b
Faith	3.95	17.5 abc	0.62 b
Joy	3.54	16.7 abcd	0.70 b
A2574	3.56	16.7 bcd	0.66 b
A2602	3.83	15.8 cd	0.59 b
A2245	3.62	15.4 cd	0.66 b
A2359	3.55	15.2 cd	0.55 b
Gratitude	3.57	14.7 cde	0.70 b
Neptune	3.35	14.7 de	0.79 b
A2786	3.54	14.6 de	0.65 b
Mars	3.34	14.6 de	0.75 b
A2817	3.44	14.1 de	0.55 b
A2467	3.28	13.4 de	1.34 a
Conquistador	3.65	13.0 e	0.66 b

[z]Year was analyzed as a random variable.
[y]All data presented are least squares means.
[x]Differences among cultivars were determined using the Simulate test at $\alpha = 0.05$.

Table 7. Comparison of the number of seed traces of newly released grape cultivars and advanced table seedless grape selections grown at the NAHRC, Cullman, AL, in 2011 and 2012 combined[z].

Cultivar	Seed traces
A2817	3.2[y] a[x]
Neptune	2.0 b
Joy	1.8 bc
Mars	1.7 bc
Faith	1.7 bc
Gratitude	1.5 c

[z]Year was analyzed as a random variable.
[y]All data presented are least squares means.
[x]Differences among cultivars were determined using the Simulate test at $\alpha = 0.05$.

Table 8. Comparison of Pierce's disease symptoms of newly released grape cultivars and advanced grape selections grown at the NAHRC, Cullman, AL, in 2012.

Cultivar	Leaf scorching[z]	Matchsticks[y]	Green islands
A2245	0	N	N
A2359	1	Y	Y
Faith	0	N	N
A2467	0	N	N
Joy	1	Y	Y
Gratitude	0	N	N
A2574	0	N	N
A2602	1	Y	Y
A2632	0	N	N
A2786	1	N	N
A2817	1	Y	Y
Conquistador	0	N	N
Mars	1	N	N
Neptune	1	N	Y
Stover	0	N	N

[z]0 = no symptoms;
1 = 1 to 20% leaves with scorching;
2 = 21 to 40% leaves with scorching;
3 = 41 to 60% leaves with scorching;
4 = 61 to 80% leaves with scorching;
5 = 81 to 100% leaves with scorching

[y]Y=Yes
N=No

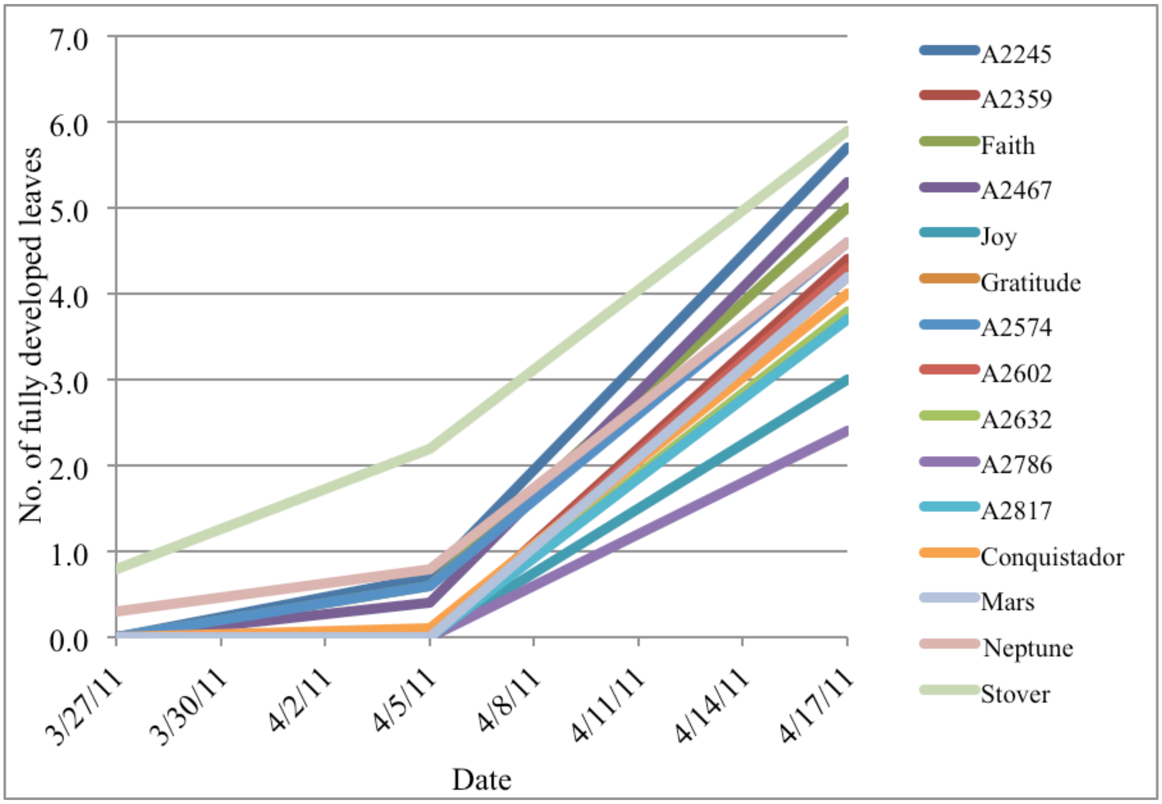

Figure 1. Comparison of early season shoot development of newly released grape cultivars and advanced grape selections grown at the NAHRC, Cullman, AL, in 2011.

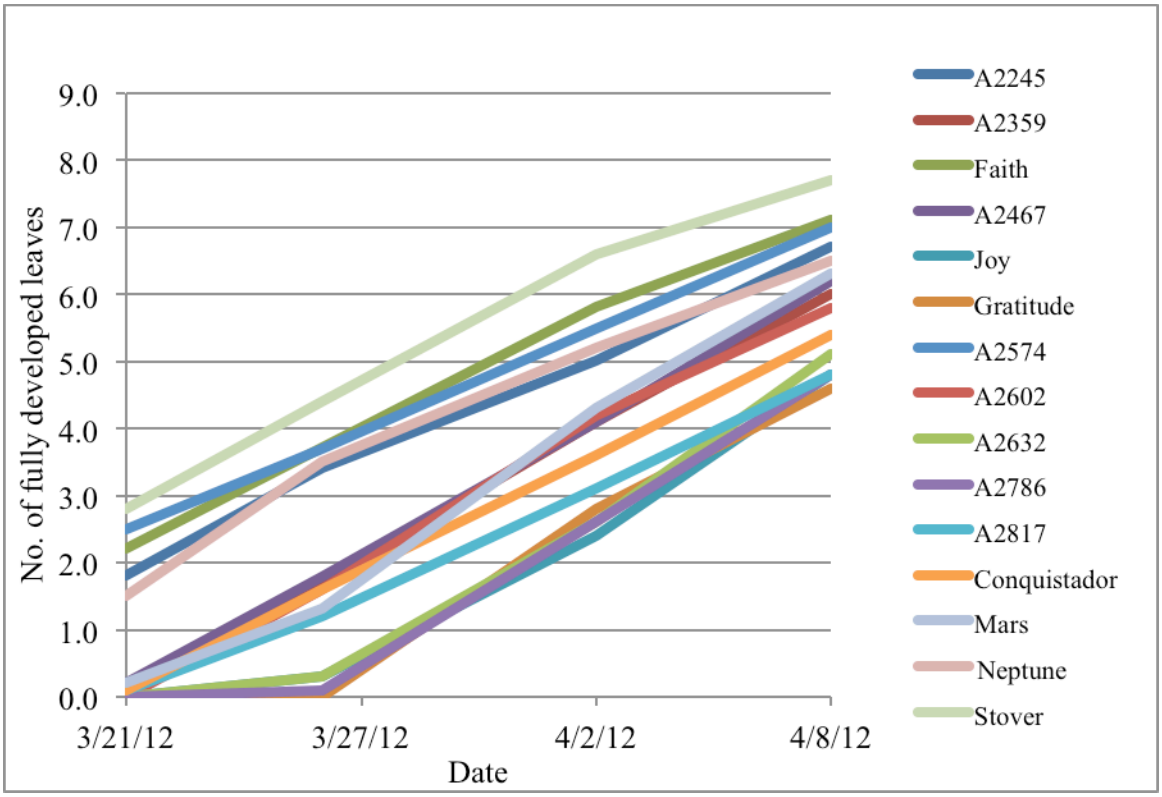

Figure 2. Comparison of early season shoot development of newly released grape cultivars and advanced grape selections grown at the NAHRC, Cullman, AL, in 2012.

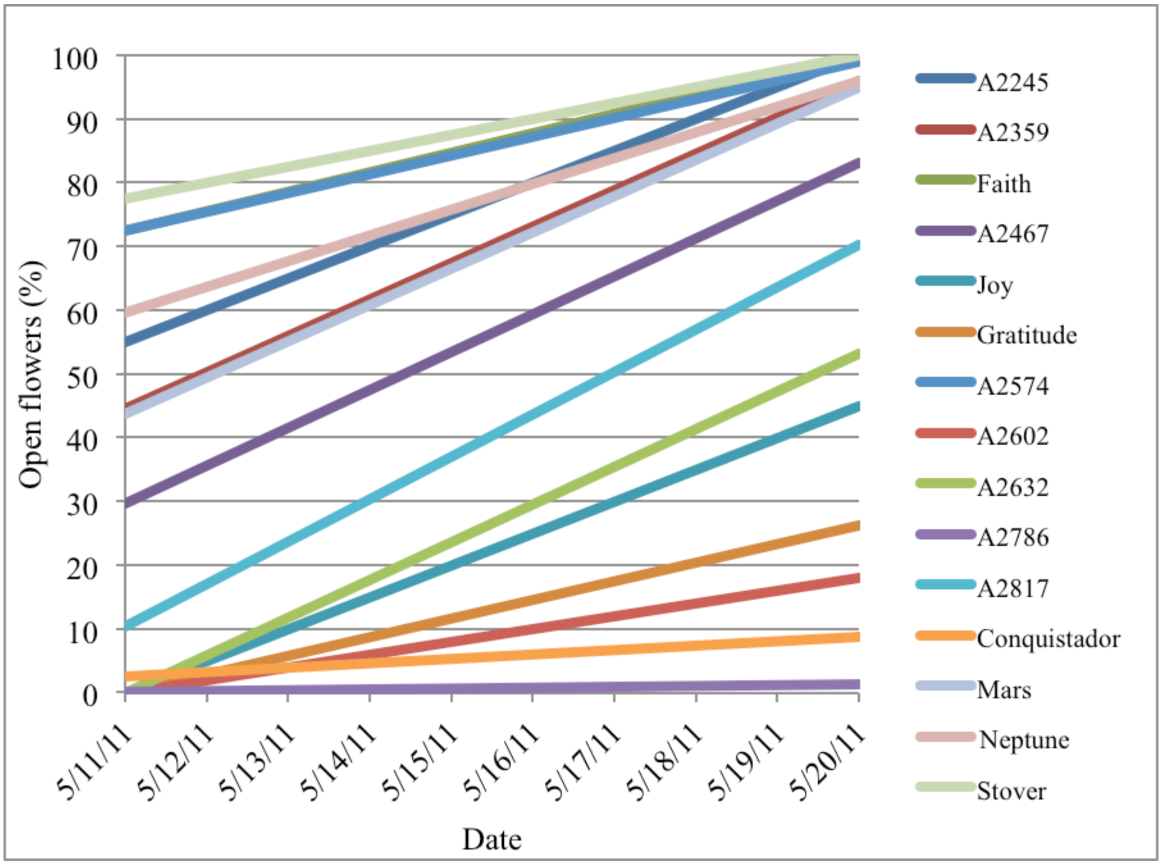

Figure 3. Comparison of percent open flowers of newly released grape cultivars and advanced grape selections grown at the NAHRC, Cullman, AL, in 2011.

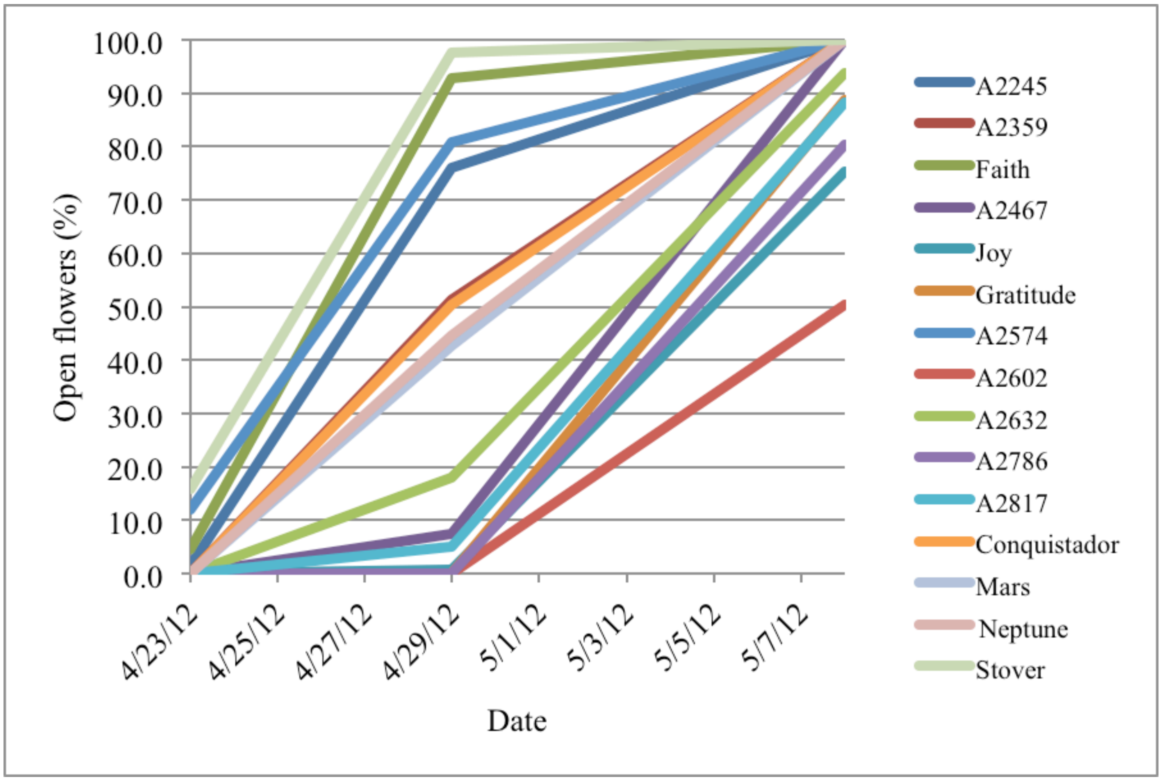

Figure 4. Comparison of percent open flowers of newly released grape cultivars and advanced grape selections grown at the NAHRC, Cullman, AL, in 2012.

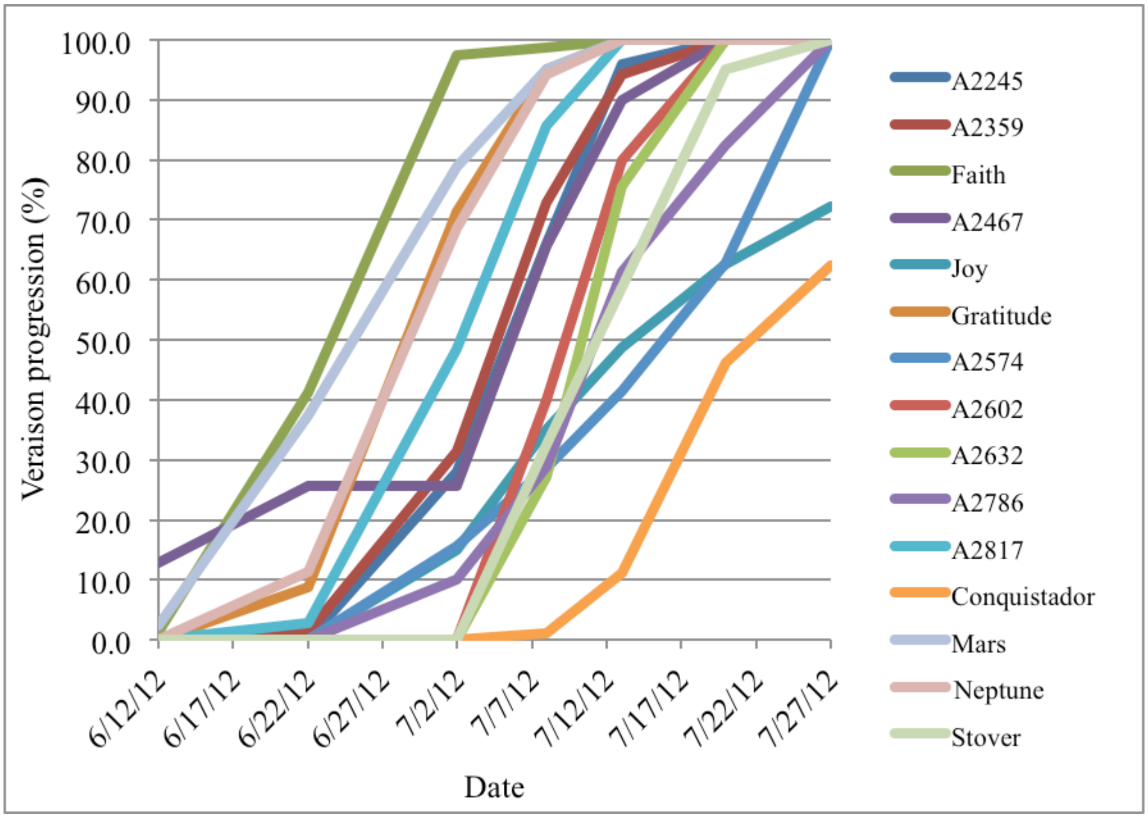

Figure 5. Comparison of veraison progression (percent) of newly released grape cultivars and advanced grape selections grown at the NAHRC, Cullman, AL, in 2012.

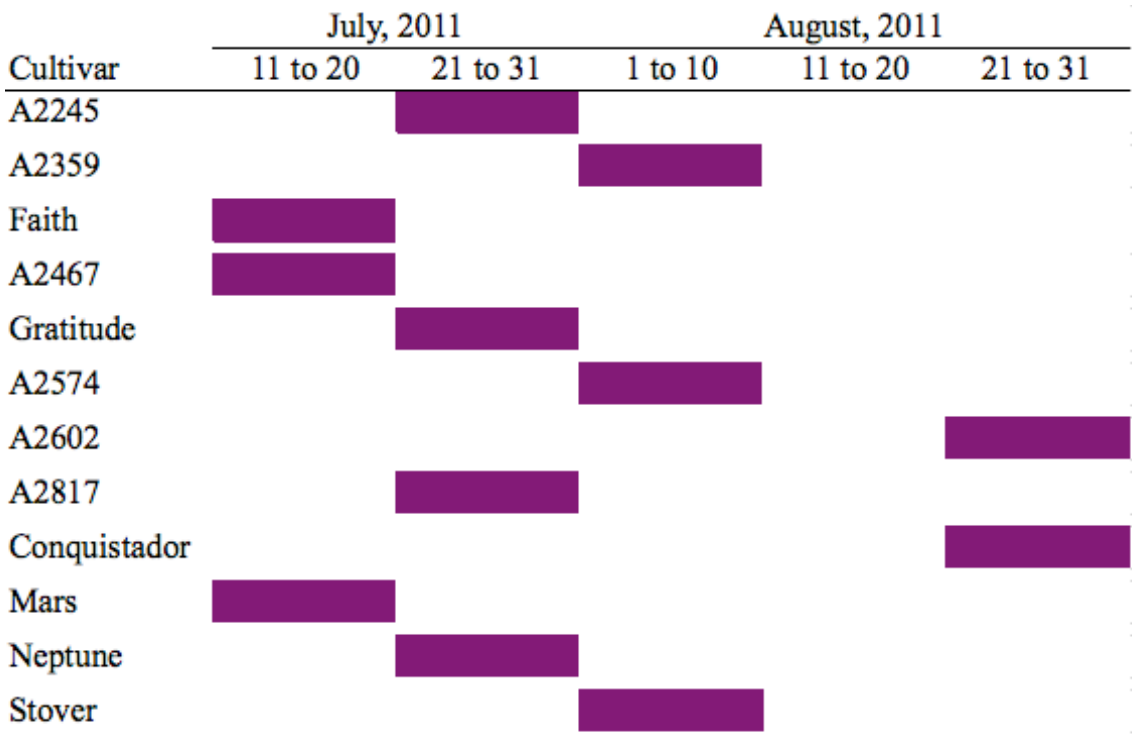

Figure 6. Season of ripening of newly released grape cultivars and advanced grape selections grown at the NAHRC, Cullman, AL, in 2011.

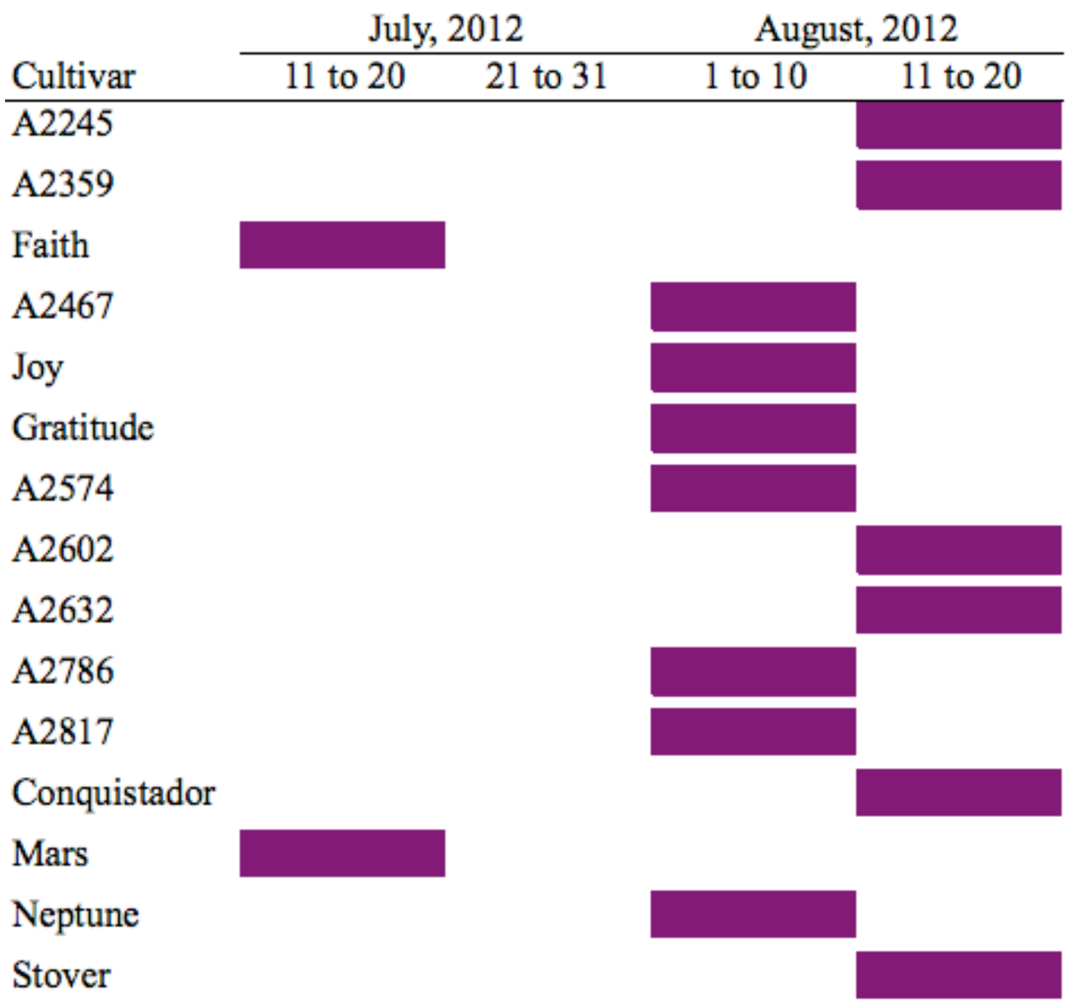

Figure 7. Season of ripening of newly released grape cultivars and advanced grape selections grown at the NAHRC, Cullman, AL, in 2012.