Title: Vegetative and Reproductive Traits of Two Southern Highbush Blueberry Cultivars Grafted onto *Vaccinium arboreum* Rootstocks

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This adapted study is intended for education use for student preparation on conducting an agriscience fair report/project in School-based Agricultural Education. Educational commentary provided by Dr. Andrew C. Thoron, Associate Professor of Agricultural Education & Isabella Damiani, graduate assistant in the Department of Agricultural Education & Communication at the University of Florida, Gainesville, FL. For access to the full study, please see the citation below.

Abstract

Acres of blueberry production in Florida has continued to increase over the past decade. Florida soil conditions present producers with challenges due to north central Florida soil being higher in pH and having less organic matter. *Vaccinium arboreum (V. arboretum)* Marsh is a wild species adapted to high pH (above 6.0) and low organic matter soils (below 2.0%). The use of *V. arboreum* rootstocks may be a viable option to increase soil adaptation of southern highbush blueberry (SHB; *V. corymbosum* interspecific hybrid) under marginal soil conditions. The purpose of this study was to increase berry weight and maintain overall plant health. The study utilized a two-group experimental design between own rooted and grafted blueberry cultivars under amended soil conditions. The objective of this research was to evaluate the vegetative traits and cumulative yield of 'Farthing' and 'Meadowlark' SHB own-rooted or grafted onto *V. arboreum* grown in pine-bark amended or non-amended soil. Own-rooted and grafted cultivars grown in unamended soil acted as the control. Results indicated that grafted cultivars (*V. arboretum)* rootstock generally induced the same effects in both cultivars. Grafted cultivars in both soil treatments had reduced canopy growth. Fruit yield was lower in grafted cultivars compared with own-rooted cultivars the first fruiting year (2 years after field planting). In conclusion grafted cultivars will have a decreased plant canopy volume and decreased yield in their first fruiting year. It is recommended that fruit yield and plant canopy volume be measured over the course of multiple years because grafting causes significant stress on the plant and may require subsequent fruiting years to reach optimal production.

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Introduction

In 2012, 6,179 acres of tame blueberries were harvested in Florida. Florida represented 7.5% of the total harvested blueberries in the United States (USDA, 2012). Southern highbush blueberries are mainly grown in Florida, Georgia, and southern California due to the milder climates of these regions. Several cultivars of southern highbush blueberries have been adapted specifically to be grown in Florida. Blueberries are primarily grown in northern and central Florida because in other regions of Florida, there are not enough chilling hours for the blueberries. Chilling hours are the number of hours that are at or below 45°F that a fruit bearing plant needs to blossom (Linvill, 1990). Southern highbush blueberries planted in Florida need between 200 and 400 hours of chilling $\leq$45°F (Bielinski, Santos, & Salame-Donoso, 2012). Thus, north and central Florida are the only regions of Florida that blueberries can be grown efficiently.

Northern Florida and central Florida are unique due to their climate and their soil composition. Blueberries require specific soil conditions to have optimal growth. Blueberries require acidic soils with a pH between 4.0 and 5.5 and an organic matter content of about 2-3% (Williamson, Olmstead, England, & Lyrene, 2014). These conditions are not commonplace among Florida, and thus soil amendments are used to reach these required conditions. Granulated sulfur and dilute sulfuric acid applications can be used to decrease soil pH. However, many fertilizes have acids as components and over time, the accumulation of these acids lowers the soil pH (Williamson et al., 2014). Two common soil amendments are used in Florida to increase organic matter content. Peat moss is mixed into soil prior to planting, and pine bark is either

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Florida soils require these amendments because of the composition. This leads to solving the problem of maintaining the health of blueberry plants with quality yields. North Florida soils are low in organic matter. However, due to the subsoil layers, most soils in northern Florida are susceptible to increased water holding capacity. Per se, soil amendments and planting adaptations must be done when planting blueberries.

Florida produced 7.5% of the United States total blueberries in 2012 (USDA, 2012). They have an additional advantage of early market. The cultivars that have been bread specifically to be grown in Florida, require less chilling hours, and are able to ripen and be ready for sale in early April (Williamson, Olmstead, & Lyrene, 2012.). This allows for these producers to have the highest market price. It is important to maintain this success to maintain the Florida blueberry industry.

The specific objectives were to evaluate the effects of soil treatment (pine-bark amended or non-amended soil) and root system (own-rooted or grafted plants) on plant growth, and fruit yield in two southern highbush cultivars through experimental design.

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Literature Review

Cultivated *Vaccinium* species require specific soil conditions for establishment, vigorous plant growth, and fruit production. Soil adaptation of blueberry plants has been the subject of research over many years (Burkhard, Lynch, Percival, & Sharifi, 2009; Krewer, G., M. Tertuliano, P. Andersen, O. Liburd, G. Fonsah, H. Serri, and B. Mullinix, 2009; Strik & Buller, 2014). Soils suitable for blueberry production must be acidic (pH 4.0 to 5.5), well aerated with good drainage, high in organic matter (Williamson et al., 2012), and have readily available iron (Fe) and ammonium (Darnell & Hiss, 2006). In order to grow cultivated blueberry, including southern highbush blueberry (SHB), on typical agricultural soils (i.e., higher pH and lower organic matter), soil amendments are required.

In the southeastern United States, pine bark beds or pine bark incorporated into the top layer of the soil and sulfur application (Williamson et al., 2012) are used to increase (a) organic matter, (b) lower pH, and (c) increase Fe and nitrogen (N) availability. Without soil amendments, plants exhibit decreased growth (Krewer et al., 2009), possibly due to decreases in Fe and/or N uptake (Poonnachit & Darnell, 2004). Increased N uptake by blueberries grown in amended soil promotes greater growth and yield compared to plants grown in non-amended soil (Burkhard et al., 2009). However, soil amendments are expensive (Julian et al., 2012) and may not be ecologically sound. The high costs associated with soil amendments decrease the profitability and sustainability of the blueberry industry.

Grafting is a well-established horticultural practice commonly used in perennial fruit crops and more recently in annual horticulture crops. Grafting has several benefits to plants, such

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as (a) control of biotic and abiotic stresses (Liu et al., 2014), (b) increased soil adaptation (Penella et al., 2015), and (c) improved horticultural traits (Marra et al., 2013). Rootstocks may potentially impart several advantages to blueberries. Galleta and Fish Jr. (1971) reported that highbush cultivars grafted onto rabbiteye blueberry (*V. virgatum* Ait.) rootstocks exhibited (a) greater plant height, (b) flower bud number per shoot, and (c) survival compared with own-rooted highbush cultivars (*V. corymbosum* L.). Kuniyake et al. (2006), through an experimental design, tested different combinations of blueberry rootstocks (*V. bracteatum* Thunb. and *V. virgatum*) and scions (*V. corymbosum*). The researchers found that grafted plants had high survival rates and no signs of incompatibility between the rootstock and scion. Therefore, Kuniyake et al. (2006), concluded that blueberry grafting is possible for several varieties. An additional study found that 'Sharpblue' SHB grafted onto Wufanshu (*V. bracteatum*) had greater plant height and yield than non-grafted plants. However, no differences were found for berry weight or fruit quality. This study demonstrated the effective grafting techniques to ensure survival and demonstrated how the grafted plant has both the characteristics and adaptations of both the rootstock and scion individual cultivars (Xu et al., 2014).

Vaccinium arboreum is a wild blueberry relative that is native to the southeastern United States. This wild blueberry relative grows in (a) calcareous, (b) sandy or sandy-clay upland soils, (c) tolerates soil pH up to 6.5, (d) low organic matter (Lyrene, 1997), (e) low iron availability, and (f) nitrogen in the form of nitrate (Darnell & Hiss, 2006). These are conditions that the scion (*V. corymbosum*) tolerates poorly. Studies have found that nitrate and iron uptake are greater in rootstock (*V. arboretum*) compared with scion (*V. corymbosum)* (Darnell & Hiss, 2006;

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Poonnachit & Darnell, 2004). The rootstock of *V. arboretum* can more easily absorb and translocate nutrients throughout the plant system than *V. corymbosum.* This is vital during grafting recovery as the plant is experiencing high levels of stress and those vessel connections are fragile and forming during the healing process. Additionally, this rootstock has a deep root system, which increases drought tolerance, and aids in stability (Lyrene, 1997).

Because of the wide soil adaptation and poor overall fruit quality of *V. arboreum* (Vander Kloet, 1988), previous experimental studies have examined the use of *V. arboreum* as a rootstock for highbush blueberry. Ballington (1996), compared ‘Premier’ rabbiteye blueberry own-rooted vs. grafted onto *V. arboreum* and found that grafted plants had greater yield and fruit size than own-rooted plants, with no differences in fruit quality. In a later study also utilizing *V. arboreum*, Ballington (1998) reported increased plant growth, fruit yield, and berry size of grafted cultivars compared with own-rooted cultivars.

Vaccinium arboreum has the potential for use as a rootstock to expand blueberry production to soils with higher pH and low organic matter. While there is information about soil adaptation of *V. arboreum,* as well as information on the use of *V. arboreum* as a rootstock in research trials, little is known about its performance when used as a rootstock in commercial field settings, under amended vs. non-amended soil conditions. This led for the need to conduct a study that investigated the effects that grafting, and soil amendments have on overall fruit yield of two cultivars of southern highbush blueberries.

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Materials and Methods

Methods

Through a two-group experimental design grafted and own-rooted 'Farthing' and 'Meadowlark' southern highbush blueberry (SHB) were tested. Both cultivars are high-yielding (Williamson et al., 2014), but they differ in plant architecture; 'Farthing' is bushy with many laterals (Lyrene, 2008), while 'Meadowlark' is tall and upright (Lyrene, 2010).

Prior to grafting, *V. arboreum* rootstocks were selected and blocked for uniform vigor and stem diameter. Plants are selected for uniform vigor branching degree, leaf number, and size. Stem diameter was measured in millimeters. Grafted plants were veneer-grafted. Grafted plants were similar in size to the canopy of the own-rooted plants. Plants were spaced 0.9 m in the row by 3.0 m. Soil was an Arredondo sand with low organic matter (~1.4%) with a pH of approximately 6.0. Each scion/rootstock combination was grown in one of two soil treatments: 1) pine bark amended soil and 2) non-amended soil. The amended soil treatment consisted of a homogeneous mixture of pine bark and native soil, where a 10 cm layer of pine bark was rototilled into the top 20 cm of the native soil. The non-amended treatment consisted of native soil. The experiments were arranged in plots side by side with soil treatments as one section, and the scion/rootstock combinations as another. Each scion/rootstock plot consisted of eight plants, with guard plants on each side and two data plants**.** The guard plants were placed to preserve the integrity of the data plants. The guard plants protect the data plants from (a) weather conditions, (b) harvesting damage, and (c) potential animal predation.

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Irrigation, fertilization through drip-irrigation, and pest management followed the recommended guidelines for blueberry production in Florida (Williamson & Lyrene, 1995; Williamson et al., 2013). Soil pH was kept between 5.0 and 6.0 using sulfuric acid 38% injected through the irrigation system. Plants had overhead irrigation for frost protection, which was used as necessary to protect buds, flowers, and developing fruit from freeze damage. On average, plants received an annual fertilizer rate of 213N–21P–89K $kg{\cdot}ha^{-1}$ and 762 L of irrigation water.

Fruit yield was estimated from March to June. Berries were hand-harvested twice per week to avoid over-ripening and loss of berries. The cumulative total yield was determined at the end of the harvest season.

The hypothesis tested in this research was that SHB plants grafted onto *V. arboreum* rootstocks exhibit increased vegetative growth and yield compared with own-rooted SHB plants when grown in non-amended soil.

A Tukey's HSD (Honest Significant Difference) test was conducted to analyze the data. The test has a *p*- value of significance of $p \leq 0.05$.

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Materials Needed	**Amount**
Logbook	1
Grafting Shears	1
Grafting Tape	3 rolls
Harvesting Tubs	3
Digital Scale	1
Fertilizer	213N–21P–89K kg·ha^{-1}
Drip Irrigation System	762L per plant
Overhead Irrigation System	As needed for frost protection
Pine Bark	1:2 ratio with soil
Sulfuric Acid 38%	As needed
Overhead Irrigation for Frost Production	One system
V. corymbosum Blueberry Scions	32
V. arboreum Blueberry Rootstocks	32

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Results

Total yield of ‘Farthing’ and ‘Meadowlark’ cultivars are shown in Table 1. In 2014, the root by soil interaction was not significant for either *V. corymbosum* or *V. arboreum* cultivars. For ‘Farthing’, plants grown in amended soil yielded more (4476 g/plant) than plants grown in non-amended soil (3746 g/plant), while there was no difference in yield between own-rooted (4423 g/plant) and grafted plants (3799 g/plant). ‘Meadowlark’ grown in amended soil also yielded more (4260 g/plant) than in non-amended soil (3216 g/plant). ‘Farthing’, grafted ‘Meadowlark’ plants had greater yields (4095 g/plant) than own-rooted plants (3381 g/plant).

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Table 1

Effect of Root and Soil Treatments on Total Yield in 'Farthing' and 'Meadowlark' Southern Highbush Blueberry in Northern Florida

	Total yield (g/plant)	
	Farthing	Meadowlark
Treatment	2014	
Own-rooted/amended	4837	4052
Own-rooted/non-amended	4008	2710
Grafted/amended	4114	4468
Grafted/non-amended	3484	3722
p values		
Rootx	0.059	0.033
Soil	0.028	0.014
Root x Soil	0.753	0.328

Note. Own-rooted=cultivars grown on their own roots; Grafted=cultivars grafted onto *V. arboreum*; Amended=pine bark amended soil; Non-amended=native soil. Means represent the root x soil interaction. Main effect means for root (own-rooted vs. grafted) and soil (amended vs. non-amended) are not given, but *p* values indicate significance.

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Discussion/Conclusion

The reduction in fruit yield of grafted plants was likely due to the initial reduction in growth due to the recovery time associated with the grafting process. However, after growth recovery from grafting, *V. arboreum* rootstocks induced similar or greater yields in southern highbush blueberry (SHB) than own-rooted SHB regardless of soil treatment or when grown in non-amended soil.

Plants grafted onto *V. arboreum* rootstocks and grown in non-amended soil were larger than own-rooted plants in non-amended soil and similar in size to own-rooted and grafted plants in amended soil. Yield differences between grafted and own-rooted plants were inconsistent. Yields were generally greater in grafted plants vs. own-rooted plants when grown in non-amended soil, while yields were similar when grown in amended soil. These results suggest that grafting SHB onto *V. arboreum* rootstocks may enable a reduction in the use of soil amendments for commercial production systems, without negative impacts on fruit yield or quality. Previous studies have shown that grafting aids in plant's soil adaptation capacity (Penella et al., 2015). Galleta and Fish (1971) reported that grated southern highbush blueberries have a higher survival rate than that of own rooted cultivars. However, additional research is needed to assess the impacts of *V. arboreum* rootstocks on productivity of mature SHB plants and longevity of the plant as a whole.

This supports previous findings that blueberries perform more efficiently with the additional of soil amendments (Krewer et al., 2009), and the potential of grafting to decrease the reliance on soil amendments for southern highbush blueberry cultivars (Lie et al, 2014). Our data

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supports the need for future research into this concern as results and finds based on the hypothesis are inconclusive.

This research is valuable and important for the sustainability of the Florida blueberry industry. The Florida blueberry industry relies on their opportunity to sell during an early market window. The Florida industry must continue to adapt and improve yield to stay productive in the blueberry industry.

In the future, this study could be conducted over the series of years to adequately observe the effects of both grafting and soil amendments. Many of the effects are not observable until the plant is able to recover and grow after the grafting procedure.

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