

Evergreen Production of Southern Highbush Blueberries in Hawai'i

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Abstract

Blueberry is not commercially grown in Hawai'i, though it represents a potential high-value niche-market crop. Many localities with equivalent low chilling environments, such as southern California, Mexico, Spain and Portugal, have successfully begun growing blueberries, but little is known about the adaptability of this crop to Hawai'i. In mid-April 2004, blueberries were planted at the University of Hawai'i. Mealani Agricultural Research Station in Waimea, a mid-elevation vegetable production area on the Island of Hawai'i. Ten plants each of six southern highbush-blueberry (*Vaccinium corymbosum* L.) hybrid cultivars, 'Biloxi', 'Emerald', 'Jewel', 'Misty', 'Sapphire', and 'Sharpblue' were planted in blocks and evaluated from Oct. 2004 through Oct. 2006. The objectives were to compare trends in the production season, potential yields, plant growth, and fruit quality of the cultivars. First production occurred within 6 months of planting. Each of the plants grew and produced reasonable yields of quality berries within two years. 'Biloxi', 'Emerald', 'Sapphire', and 'Sharpblue' produced between 1.70 to 1.87 kg/plant/year during their second year after field establishment. Peak production times, when total berry harvest exceeded 4 kg/week for the 60 plant plot, occurred between mid-Aug. to mid-Sept., and for two weeks in mid-Feb.; individual cultivar harvest peaks were spread throughout the year. 'Jewel' plants were very vigorous and had low annual yield. 'Emerald' had the largest average berry size, exceeding 4 g. Fruit from each of the cultivars of this study had similar total soluble solids and acceptable flavor. Bird damage was prevented by enclosing the planting in net-covered caging. Chinese rose beetle (*Adoretus sinicus* Burmeister) and thrips (*Heliothrips haemorrhoidalis* Bouché) caused some foliar damage, but disease and pest problems were otherwise minimal. Southern highbush blueberries are amenable for culture in Hawai'i.

In 1906, Elizabeth White and Fredrick Coville began selecting and breeding highbush blueberries (*Vaccinium corymbosum* L.) for northern climates in North America (3). By 1930, 81 ha of commercial blueberries were grown, which increased to more than 8094 ha by 1965 (6).

In 1975, the first complex crosses of highbush with low chilling species, such as *V. darrowii* Camp, were released by R. Sharpe and W. Sherman in Florida (4). Plantings of blueberries slowly developed in Florida, from 6 ha in 1978, to commercial export quantities in 1982, and 971 ha in 2003 (6). Southern blueberry production in Georgia covered 2428 ha in 2003 (6). Recently, private companies have expanded blueberry acreage in low chilling environments of California, Mexico, and

in Europe and South America. While Mexico had 38 ha in production in 2003, predictions suggest an increase to more than 800 ha by 2013 (6).

Production techniques in Mexico involve periodic artificial defoliation to substitute for winter dormancy and reduce foliar diseases and pests (M. Hurst, Oregon berry grower, personal comm.) In the Mexican climate, where flowers and fruit occur simultaneously on blueberry plants, this technique allows plants to accumulate reserves for increased production on specified dates (D. Brazelton, Oregon nurseryman, personal comm.).

Sugarcane acreage and production in Hawai'i has been declining for the past two decades (7). Alternative and diversified niche market crops are being sought for available land that previously produced sugar. Proper

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crop selection and targeted marketing of alternative crops are key factors to the survival and success of small farmers on the islands. With the success of new blueberry plantings in many low chill environments, we wondered if these fruits could provide a crop alternative for Hawai'i.

This preliminary report presents information on an initial trial planting of southern highbush blueberry cultivars at Waimea. The planting was established with blocks of 10 plants for each cultivar. Replicates were not randomized so only production trends will be reported rather than significant differences in cultivar production. Studies with replicated variety trials are in progress. The objectives of this study were to compare trends in the production season and potential yields in this environment, and to compare plant growth and fruit quality of selected cultivars.

We wanted to determine if blueberries from Waimea would produce yields suitable for market, and when production would occur during the year. We also wanted to observe the types of problems, pests, and diseases encountered to guide regional farmers in cultural management issues.

Materials and Methods

Six southern highbush blueberry cultivars ('Biloxi,' 'Emerald,' 'Jewel,' 'Misty,' 'Sapphire,' and 'Sharpblue') were chosen because of their low chilling requirements and high quality fruit when produced in the southeastern United States. These cultivars include Northern highbush, *Vaccinium corymbosum* (L.), and the Florida-native low growing *Vaccinium darrowii* (Camp.) in their pedigree. 'Biloxi' was released by Dr. Craighton Gup-ton, USDA ARS geneticist from Poplarville, Miss., and the other five by Dr. Paul Lyrene, Professor and geneticist from the University of Florida at Gainesville.

The planting site at the University of Hawai'i Mealani Agricultural Research Station in Waimea is located at 853 m elevation. It has a well drained silt loam soil belonging to the Maile series (8). The average annual maximum temperature at the station is 23

°C, average minimum temperature is 10 °C, with a range from 28 °C high to 5.5 °C low. The station receives up to 200 chilling hours per annum. The annual rainfall averages 163 cm. Waimea, located in the major vegetable production area on the Island of Hawai'i, is in close proximity (within 16 km) to potential markets at major hotels and resorts along the Gold Coast from Kohala to Kona.

A 9.14 m × 36.5 m area was tilled one month prior to planting. Peat (0.21 m³), steer manure (0.08 m³), treble superphosphate (0-41-0, 7.71 kg), gypsum (5.4 kg), ammonium sulfate (20.5-0-0-24S, 5.4 kg) and K-mag (0-0-22-22S, 5.4 kg) were spread over each 1 × 9.14 m row and shallow tilled into the soil to lower the pH in the area from pH 6.3 to the preferred pH 4.5 to 5.5. The area was then completely covered with weed mat (Weedbarrier®, Western Landscape, Denver, CO), which provided excellent weed control and sanitation.

Ten plants each of the six cultivars were received from Fall Creek Nursery in Lowell, Ore. on 7 Apr. 2004, and were planted one week later in blocks of ten plants by variety. Plants were not randomized within the planting. Plant spacing was 1.2 m × 1.2m. Holes 0.6 m in diameter were cut into the weed mat for each plant. Additional peat was mixed into each hole at planting. Ridomil Gold ® 480 EC dilution was applied as a soil drench at 0.061 ml·l⁻¹ of water for each planting hole for *Phytophthora* root rot prevention.

The plants were irrigated and fertigated through drip irrigation using 2 emitters per plant at a rate of 1.9 l·hr⁻¹ of water per emitter. The plants were watered three times a week for 45 min. each during the dry season (Nov. to Jan.) and reduced to twice weekly for 45 min. during the wet season (Feb. to Apr.). The plants were fertigated once per month using Miller 4-41-27 soluble fertilizer (452 g in 189 l) formulation for two consecutive months. Cleancrop® 4.5% iron chelate (239 g in 189 l) was added to the fertilizer mix in the third month.

Soil pH was initially tested every three months. When the soil pH was above 5.2, we used ammonium sulfate, and when the

pH was below 5.2, we applied urea at rates recommended by the Northwest berry and grape information network (2007). On 19 Apr. 2005, the plants were top dressed with 142 g of ammonium sulfate, and nitrogen applications were increased from May 2005. The plants were fertigated with 21-7-7 fertilizer (452 g in 189 l) and the following week with a foliar of 4-41-27 (8 g in 38 l). This was done through June and July, equally one application per month.

Fruit evaluations began in Oct. 2004 and continued through Oct. 2006. Fruit were harvested, weighed, and recorded weekly for each cultivar. Cultivars ripened at different dates. On 11 Oct. 2006, height, width, and shoot counts were recorded for each plant. Shoots greater than 2.5 mm diameter were counted. Plants had been pruned prior to this count to remove brushy twiggy growth around the base of each plant. Pruning was performed according to the plant structure but equitably between cultivars. Pruning was also performed to control insects and localized disease infection. At peak ripeness for each cultivar, five replicate berries were randomly selected from five plants. Individual berries were weighed, and the length and width were measured. Total soluble solids (TSS) was measured by placing a drop of juice from each fruit on a hand held refractometer (Misco, Cleveland, OH). One-way analysis of variance (Excel, Microsoft, Redmond, WA) was calculated for fruit weight, length, width and TSS. Fisher's

least significant difference (LSD) at $P < 0.05$ was applied for mean separation.

Results and Discussion

After two and a half years, blueberry plants grew well at the Mealani Station, and their fruit was of high quality (10). Growing blueberries in the tropics had challenges, but the project gave promising results during this initial trial. We did not follow the recommendation that flowers and fruits should be removed for the first two years after planting (6). Although the plants were not vigorous during the first year, they flowered and fruited profusely on short vegetative stems. Sufficient berry production for gathering occurred in Oct. 2004, six months after field planting. Some plants did not grow well initially due to the addition of nitrate based fertilizer applied to the high pH soil (pH 5.4 to 5.9). The vegetative growth and yield if each of the plants improved after ammonium fertilizer was added.

The low chilling hours for vegetative dormancy did not seem to affect the productivity of these southern highbush genotypes. As the year progressed we observed an increase of insect pests, such as thrips, aphids and leafhoppers, without the winter minimum temperatures found in temperate climates to reduce their populations.

Cultivar yields. Each of the cultivars became established, grew, and produced reasonable yields of quality berries (Fig. 1

Table 1. Mean² and standard deviation of plant height, plant width and shoot count of two-year-old southern highbush blueberry plants measured on 11 October 2006.

Cultivar	Plant height (m)	Plant width (m)	Shoot count
Biloxi	1.17 ± 0.1 a	1.35 ± 0.1 b	17.0 ± 4.1 ab
Jewel	1.13 ± 0.1 a	1.66 ± 0.1 a	11.4 ± 3.7 d
Sharpblue	1.04 ± 0.1 b	1.35 ± 0.1 b	15.6 ± 3.9 bc
Emerald	0.99 ± 0.1 c	1.56 ± 0.1 a	14.0 ± 3.7 c
Misty	0.96 ± 0.1 c	1.21 ± 0.1 b	18.6 ± 4.3 a
Sapphire	0.90 ± 0.1 d	1.01 ± 0.1 c	11.0 ± 3.3 d

²Mean of 5 replicates. Means within a column followed by the same letter are not significantly different by Fisher's LSD at $P < 0.05$.

Table 2. Berry weight, berry width, and total soluble solids (TSS) for southern highbush blueberries grown at the Mealani Agricultural Research Station in Waimea, Hawai'i.

Cultivar	Harvest date	Berry weight (g)	Berry width (cm)	TSS (%)
Biloxi	10 August 2006	2.2 ± 0.6 b	1.7 ± 0.2 b	12.3 ± 1.3 ab
Misty	16 February 2006	2.2 ± 0.6 b	1.6 ± 0.2 b	13.3 ± 0.7 ab
Sharpblue	16 February 2006	2.2 ± 0.5 b	1.6 ± 0.1 b	13.2 ± 0.9 ab
Sapphire	21 September 2006	2.1 ± 0.4 b	1.6 ± 0.1 b	12.1 ± 1.3 b
Jewel	9 February 2006	2.5 ± 0.7 b	1.8 ± 0.2 b	12.2 ± 1.1 ab
Emerald	31 August 2006	4.1 ± 0.7 a	2.1 ± 0.1 a	12.3 ± 0.7 ab

^aMean of 5 randomly selected berries from 5 plants per cultivar. Means within a column followed by the same letter are not significantly different by Fisher's LSD at P< 0.05.

and 2). 'Emerald,' 'Sapphire,' 'Sharpblue,' and 'Biloxi' had high yields, ranging from 1.70 to 1.87 kg/plant/year (Fig. 1). 'Misty' and 'Jewel' had low production (Fig. 1), although their second year yield was better than the first year. Eck (4) stated that yields of 'Sharpblue' in Gainesville, Florida, ranged from 1.8 to 2.7 kg/plant/year for 6-year-old bushes. Baptista et al. (2) looked at southern highbush production in Portugal and reported yields for 'Cape Fear' and 'Georgia Gem' of 0.81 and 1.22 kg/plant/year for 5-year-old plants. The yields in Hawai'i were good considering the younger age of the plants.

Production cycle. Time of production appeared to be cyclical with major and

minor peaks through the year (Fig. 2). The major peak production times, when total berry harvest exceeded 4 kg/week for the 60 plant plot, occurred from mid-August to mid-September and for two weeks in mid-February (Fig. 2). Minor production peaks, when total berry harvest was about 2 kg/week or more, occurred in late May-early June and late Nov.-early Dec. (Fig. 2). Individual genotype differences spread harvest peaks to about every 3 months throughout the year (Fig. 2). In very mild climates, like those of this study, 'Sharpblue' flowers and fruits throughout the year; in temperate climates, a larger commercial crop occurs in spring, with a smaller crop in fall.

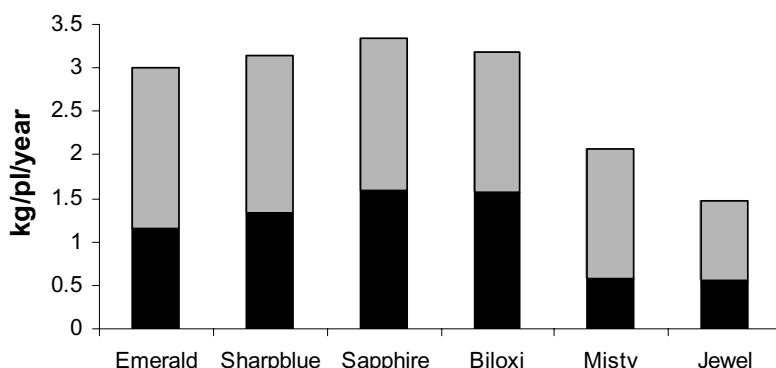


Figure 1. Average annual yield (kg per plant per year), of six southern highbush blueberries (*V. corymbosum* L. hybrid cultivars) grown in Waimea, Hawai'i. Black area represents total from Oct. 2004 through Sept. 2005; striped region represents Oct. 2005 through Sept. 2006. Each value is the mean of 10 replicates.

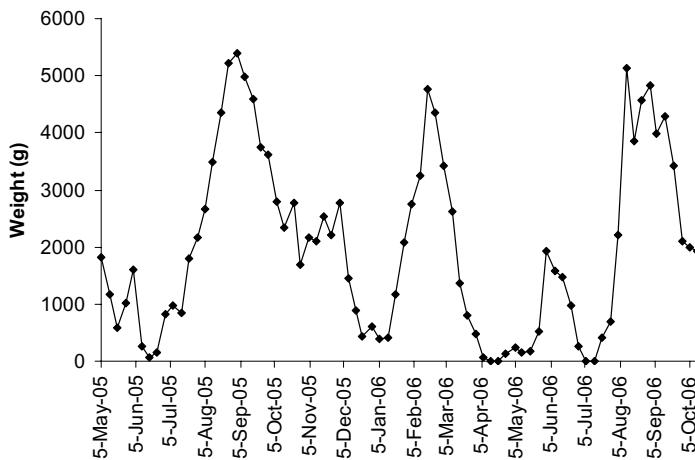


Figure 2. Total weekly harvest of 60 plants (ten replicates of six southern highbush cultivars) between 5 May 2005 and 5 Oct. 2006, at the Mealani Station, Waimea, Hawai'i.

In our study, 'Sapphire', 'Sharpblue', and 'Biloxi' had production peaks on the major cycle, i.e., in mid-August to mid-September and in mid-February. 'Sharpblue' has grown well in climates with practically no chilling hours although originally it was described as needing 500 chilling hours prior to the onset of flowering (1). Care must be taken to harvest frequently during hot weather to maintain high quality (1). 'Misty', 'Jewel', and 'Emerald' tended to have lower peaks and more sustained production throughout the year (data not shown). In Florida, 'Jewel' tends to ripen before 'Sharpblue' (1). In Hawai'i most peak harvest dates were similar for the two cultivars although 'Jewel' had a peak harvest in June 2006 prior to that of 'Sharpblue' in August 2006.

Cultivar differences. Each variety behaved very differently in plant vigor, growth habit, harvest peak, and pest susceptibility. 'Biloxi' and 'Jewel' plants were the most vigorous of the six cultivars (Table 1), while 'Biloxi' produced the second largest total yield (Fig. 1), 'Jewel' was the least productive (Fig. 1). 'Emerald' and 'Jewel' had large berries that exceeded 2.5 g. (Table 2).

Biloxi. Under Hawai'i conditions, 'Biloxi' has upright growth with vigorous shoots and

good fruit set. 'Biloxi' had fewer incidences of thrips, aphids, and rose beetle (*Adoretus sinicus* Burmeister) damage than did other cultivars in this study (Table 3). Fruit has an average TSS of 12.3 % with consistent size and quality (Table 2).

Misty. 'Misty' had an upright growth habit, and the highest shoot count (Table 1). The dark evergreen foliage was especially susceptible to thrips damage and turned rusty brown when infested. 'Misty' showed high quality. Pruning stimulated new shoot growth. In Florida, 'Misty' can be partially to completely evergreen, and tends to produce excessive flower buds. We did not see this tendency during the duration of this study but expect that it will apply in Hawai'i. Winter pruning was recommended to reduce number of flowering shoots (1).

Sharpblue. 'Sharpblue' had an upright growth habit, with vigorous, dense canopy. It was susceptible to thrips infestation. Periodic thinning of the shoots and spray with approved insecticide was needed to control thrips. Fruit varied in size (1.3 to 3.5 g), color (blackish blue to blue), and quality. TSS averaged 13.2% (Table 2).

Sapphire. 'Sapphire' was reported to be less vigorous than 'Sharpblue' (1) and it seemed

to be true in our study (Table 1). In Hawai'i 'Sapphire' had an upright growth with sparse canopy. This cultivar was highly susceptible to rose beetle and thrips. 'Sapphire' could not support a heavy fruit load and needed periodic pruning to maintain plant vigor. The TSS averaged 12.1% (Table 2). The berry qualities were high but gradually declined at the end of the season. In this study, 'Sapphire' had fewer shoots, and plants were significantly shorter and narrower than other cultivars (Table 1). 'Sapphire' had less vegetative growth (Table 1) a high total yield (Fig. 1). Fruit thinning may be required as a quality management strategy for this cultivar.

Jewel. 'Jewel' had a vigorous spreading canopy. Shoot growth was consistent and strong. It was resistant to rose beetle feeding. 'Jewel' had the lowest yield among the six varieties (Fig. 1), and appeared to enter a natural vegetative dormancy and a distinct fruiting season during the trial. This was possibly related to lack of chilling. Berries were large, light blue, with an average TSS of 12.2% (Table 2).

Emerald. 'Emerald' had a vigorous, low, spreading, bushy growth habit (Table 1), and the plant supported a reasonable fruit load (Fig. 1). The foliage was evergreen and resistant to rose beetle and thrips. Fruit was of high quality. Berry color was light to medium blue and had the fewest blemishes. The fruit TSS averaged about 12.3% (Table 2). The fruit had the largest average weight and diameter of the blueberry cultivars in this study.

Fruit quality. Most berries harvested during this trial had dark blue and shiny skin, not the sky blue skin color with waxy bloom, as shown in blueberry nursery catalogues. The windy environment at the Mealani Station may have removed the waxy bloom by physically moving the berries against the leaves and stems (D. Brazelton, personal comm.). Some additional form of wind protection may be needed if lighter sky blue fruit color is preferred for the market.

The southern highbush blueberry cultivars in this trial had similar TSS (Table 2). The flavor of each cultivar was acceptable in

informal taste tests. Both 'Emerald' and 'Misty' had large fruit throughout the study. 'Emerald' had significantly heavier and wider fruit than did any other cultivar in this trial (Table 2), which is in accordance with published descriptions (1).

Problems and pests. Birds were the most serious problem encountered during the two years of growing blueberries at the Mealani Station. Turkeys and pheasants fed on young plants immediately after planting, cardinals and Japanese white eyes (*Zosterops japonicus*) fed on fruits. The larger birds were kept out by enclosing the planting under bird netting on a metal pipe frame. However, the small Japanese white eye was able to enter through the eye of the netting and continue to cause fruit damage. Mylar ribbons and plastic owl scarecrows were totally ineffective. Finer mesh bird netting was highly effective in excluding the Japanese white eye from the planting.

The Mediterranean fruit fly (*Ceratitis capitata* Wiedemann), oriental fruit fly (*Bactrocera dorsalis* Hendel), melon fly (*B. cucurbitae* Coquillett), and Malaysian fruit fly (*B. latifrons* Hendel, are major pests of fruits and vegetables in Hawai'i. Fruit flies were not a problem for the Mealani blueberries during our field trials because farmers in Waimea had adopted the Hawai'i Area-Wide Fruit Fly Integrated Pest Management Program (HAW-FLYPM), a cooperative project by the U.S. Pacific Basin Agricultural Research Center (USDA, ARS) and the University of Hawai'i (9). Our laboratory studies, however, showed that blueberry can be infested by both Mediterranean and oriental fruit flies. Fruit flies will be a serious pest for blueberry production in Hawai'i if no control measures are taken. Therefore, blueberry growers in areas with abundant wild fruit, such as guava (*Psidium guajava* L.), should consider using management strategies to minimize infestation and crop loss caused by fruit flies (J. Armstrong, Research Entomologist, Hilo, personal comm.). Occasionally, aphids were observed on new shoots, but were not a serious problem. The introduction and

Table 3. Disease symptoms observed on southern highbush cultivars (*Vaccinium corymbosum* L. hybrids) at the Mealani Agricultural Research Station in Waimea, Hawai'i, October 2004-2006.

Pathogen	Affected organ	Symptoms	Cultivar
<i>Lasiodiplodia</i> sp. (anamorph of <i>Botryosphaeria</i>)	leaves, stem	Wilting and reddening of leaves. Dead limbs that do not drop their leaves. Internal stem is light brown.	Sharpblue, Jewel, Emerald
<i>Botrytis</i> sp.	leaves, stem	Irregular, brown lesions. Tip dieback	All cultivars in test
<i>Phytophthora</i> sp.	roots, stem	Reddening of leaves. Discoloration of roots and stem	Jewel, Emerald
<i>Pestalotiopsis</i> sp.	leaves	Leaf spots	Emerald

planting of certified virus- or pathogen-negative blueberry planting stock from reputable nurseries is highly recommended. Virus-negative plants would not provide an inoculum source for local aphids.

Chinese rose beetle caused serious foliage damage, especially during field establishment. Physical barriers, such as 1.2 m-tall wire cages with 20 % mesh shade cloth can protect new plants from flying beetles. The cages can be removed and re-used once plants are established.

Two fungi were isolated from leaves and stems of 'Jewel' and 'Emerald'. *Lasiodiplodia* sp. (the anamorph of *Botryosphaeria*) caused stem blight, and *Pestalotiopsis* sp. was associated with leaf spots and a sporadic postharvest rot (Table 3). *Pestalotiopsis* sp. was characterized by black, inky spore masses with a creamy white mycelium. *Botrytis* sp. was found on all six of the varieties. These diseases were not severe, and did not reduce yield during the study. Symptoms ranged from 1 to 2 small lesions per leaf to about 20% of the entire leaf showing symptoms. *Botrytis*-infected leaf samples had brown lesions on the tips; fungal structures were visible by dissecting microscope. The other fungi tended to affect leaves on lateral branches. Most of these pathogens tend to attack weakened tissues, so optimum plant health is very important. Fruit

that is set is generally resistant to infection by these fungi. We recommend eliminating potential inoculum sources by removing dead leaves and providing good air circulation in the canopy. Should these diseases build up, annual defoliation may be needed to invigorate plants.

Conclusions. Southern highbush blueberries showed potential as a new high value crop for Hawai'ian farmers. Pests and diseases seemed manageable. Fruit production could be managed to occur throughout the year through appropriate cultivar choices. The peak production for 'Sapphire', 'Sharpblue' and 'Biloxi' occurred in August-September and mid-February; and for 'Jewel', 'Emerald', and 'Misty' in February and June. In this study, 'Sapphire', 'Biloxi' and 'Sharpblue' had high production and 'Emerald' produced the largest berries. Each of the cultivars produced acceptable fruit with multiple peak production times. The growth and production of the low chilling blueberry cultivars in Hawai'i for the first two years was equivalent to, or better than, in Florida or Portugal. We suggest that blueberries be considered by growers and home gardeners for production for local markets and value-added products.

We add a note of caution concerning production of blueberries relative to native flora. Southern highbush blueberries are hexaploids

($2n = 6x = 72$), while the native Hawai'ian "Ohelo" berries (*V. reticulatum* Sm. and *V. × pahalaе* Skottsb.) are diploid ($2n = 2x = 24$), and will not easily hybridize in nature. Southern highbush blueberry, however, is relished by birds, and has the potential to escape into the Hawai'ian environment.

Hawai'i's climate has an advantage for blueberry production throughout the year. Our study demonstrated that this can be achieved through growing a mix of southern highbush cultivars. Further investigation will examine the cultural management of southern highbush blueberry by pruning techniques to achieve consistent berry production and reduce pest and disease pressure.

Acknowledgement

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