Final Report

Green & Healthy Hawaii: Identifying & Introducing Alternative Ornamental Landscape Plants in Response to Invasive Species Issues

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Abstract

Landscape industry sectors across Hawaii grow, specify and use landscape plants to improve the urban environment. Unfortunately, some plants have the ability to disperse and become invasive. This study identified the 10 most frequently used invasive landscape plants and their possible non-invasive alternatives. After the selection of 43 non-invaisve alternative for evaluation, only 17 native and exotic species were readily available from local nurseries. Plants were cultivated with or without fertilizer at three Research Stations of the University of Hawaii, each representing a distinct environment – Waimanalo (mesic), Poamoho (dry) and Waiakea (wet). There were statistically significant differences of growth rate and visual evaluations. Location seems to be the major factor affecting growth rates and visual appearance of tested plants, while fertilizing treatments affected mostly growth rates of some species. Most of the plants performed better in Waimanalo, representative of a mesic environment, followed by Waiakea (wet), and Poamoho (dry). Most of the trees had satisfactory results in all locations, indicating that the tested trees are suitable to a wide range of environments and would require low maintenance in the landscape after establishment. A field day was organized to share the results with industry representatives and to receive industry feedback. Most of the participants demonstrated strong interest in having this project continued and mentioned that more plants should be tested, including interest on having early field visits to the trial. All participants agreed that a website showing the final results of this research would be helpful to the industry, and some mentioned the importance of public education. Future steps would be to continue the observations on the current plants, as well as adding more species to be included in the evaluations.

Introduction

Staples and Cowie (2001) defined invasive species as: “having certain biological features in common, that predispose them towards invasiveness…: (i) adaptable to and capable of thriving in different habitats; (ii) tolerant of a range of conditions (light, temperature, moisture); (iii) able to eat or survive on a diversity of food resources; (iv) fast growing, thereby able to displace other plants or animals; (v) disturbance-tolerant, able to proliferate in places disturbed by humans or natural events; (vi) easily dispersible to new localities.” In reference to plants, an important consideration is their “reproductive capability…: (i) able to produce many seeds…and begin doing so early in life; (ii) able to reproduce vegetatively as well as by seed...; (iii) has long breeding seasons, or even breed year round; (iv) has seeds…easily dispersible, for instance by animals, wind, or accidental by humans; (v) have seeds with no special germination requirements” (such as dormancy).

The horticulture industry and related community are the principal agents in the movement of species around the world. According to Reichard (1997), most introductions of woody plants in North America were for landscaping use purposes, corresponding to 85% of the total introductions, including for ornamental, wildlife habitat and erosion control uses. Unfortunately, several plant attributes that are favorable for horticultural and landscaping use, such as easy propagation, fast growth, pest and disease tolerance, and tolerance to a wide range of environmental conditions, are the very same features present in potentially invasive species (Reichard, 1997; Staples and Cowie, 2001). In contrast, species presenting low propagation rates, low growth rates and limited tolerance to local environmental conditions are more likely to be classified as species with low risk to become invasive (HWRA, 2009). However, such species require longer time and higher costs for propagation and growth to sizes appropriate to the industry, which discourages their adoption in the landscape industry.

The impact of invasive species, which endanger native species, is well known, being second only to habitat loss or degradation in continental U.S (30% and 90%, respectively). In Hawai´i the impact is even higher. By 1998, as a result of Hawaii geographical isolation and the extensive introduction of exotic species, invasive species contributed to endangering of 99% of the threatened endemic species, while habitat disturbance was related to 66% of the species (Wilcove et al, 1998).

In the State of Hawai´i, landscape industry sectors throughout the state grow, specify and use ornamental plants to improve the urban environment. Unfortunately, some plants have escaped from their designed areas, harming native species and causing a cost for their control, estimated at over $150 million annually (Cox, 2003). This undesirable dispersion may occur due to the plants' propagation structures, such as root-suckers, stolons, or due to seeds easily dispersed by wind, animals and water movement, but it can be accelerated by human activities such as propagules which attach to hikers' gear and disperse along trails, or seeds scarified by automobiles and seeds dispersed along roads (Mortensen, 2009).

Reducing the use of invasive species and promoting non-invasive exotic and native species in the landscape industry is an important step to increase the sustainability of this industry in Hawaii. The objective of this project was to evaluate and promote non-invasive plants in the landscape industry in order to reduce the use of invasive species and their negative impacts.

Problem statement

In the State of Hawaii, landscape industry sectors across the state grow, specify and use landscape plants to improve the urban environment. Unfortunately, some plants have the ability to disperse from their original environments and become invasive. The management of invasive species in Hawaii is estimated at $150 million annually.

Objectives

This study has the objective to identify the most frequently used invasive landscape plants and evaluate possible non-invasive alternatives.

Goals

Specifically, the main goals of this research project are:

- To identify new ornamental plants for Hawai´i's landscape industry that are not an invasive threat to the natural environment, and;
- To produce a reference publication of alternative ornamental plants for Hawai´i's landscape industry use.

Materials and Methods

The project was designed with four phases: (1) identification of the invasive plants most frequently used by landscape industry in Hawai´i; (2) selection of possible non-invasive alternative species to the invasive plants in phase 1; (3) field trials of alternative species; (4) dialogue with landscape industry members and diffusion of information gained from this project.

A list containing 68 invasive species frequently cultivated in Hawai´i was generated from a list available in the Hawai´i Weed Risk Assessment website (HWRA, 2004). The HWRA is a system that classifies plant species regarding their risk to become invasive in Hawai´i. The plants can be classified as presenting low risk, high risk, or to be evaluated, based on a score given according to botanical and ecological characteristics of the species. Historic of occurrences in other parts of the globe is also considered.

An email survey with professionals from the landscape industry in Hawai´i was conducted to identify the most frequently used trees and shrubs from the list of 68 invasive species mentioned above. Each professional, mainly from landscape architecture firms, selected five trees and five shrubs frequently used in their designs.

Literature reviews and local botanical collections were considered to select the alternative species. A profile containing information including morphological and ecological characteristics and landscape use was generated for each invasive species. At least two exotic and one native non-invasive species were selected for each invasive species, trying to match as many characteristics as possible, especially landscape uses (figure 1). A plant quality matrix was developed with information on both invasive and alternative species.

Since Hawaii has a diverse set of microclimates, three locations were utilized for the alternative plant trials: Waimanalo Research Station, on the Windward side of the Island of Oahu; Poamoho Research Station, in Northwest Oahu; and Waiakea Research Station, on the Windward side of the Big Island of Hawaii. Field trials were established in July 2009. Each research station will be described in the section "Research Stations" of this report.

The experiment was designed to compare the growth of the different species at the three research stations with or without fertilizer. A split plot model was adopted, with fertilizer being the main plot (lines) and species the submain (rows). Trees were spaced 3.3 m apart and shrubs were spaced 2 m apart. At each site, there were 5 replicates of each species in each fertilizer treatment. The final number of plants was 510 plants, with 170 in each station. The irrigation varied according to environmental conditions of each station and resources available (see Table 4 for details).

The fertilizer treatment consisted of slow release fertilizer (Nutricote Total Type 180 13N-5.7P-10.8K, Arysta Lifescience, Cary/NC) applied manually every 6 months in the perimeter of 1 m around the plants base. Shrubs received 50g each application, and trees received 100g. Big shrubs, more than 1.3m high and 2m wide, received the same amount as trees. In this case, all shrubs of the same species received the same higher doses of fertilizer.

Plants were evaluated monthly from July 2009 to July 2011 using growth and visual assessments. Growth was evaluated with two measures of the plant width (each measure perpendicular to each other) and height. The plant shape was not modified during measurements (i.e., branches were not lifted). A growth index (GI) was calculated to compare plant growth rate, based on the average of two perpendicular measures of the plant canopy diameter multiplied by the height of the plants.

$$GI = [\ (W1 \times W2) / 2\ ] \times H$$

Visual assessments were made with grades for presence of flowers, quality of foliage, and overall landscape quality. The grades varied from 1 to 5, 1 being low quality and 5 excellent quality. Unusual plants, that showed extraordinary qualities such as unusually exuberant flowers, or ornamental foliage, received grade 6 to the respective quality.

The grades for flowers considered the number of flowers and ornamental appeal. Plants with no flowers at all received grade 1; plants with flower buds or very few flowers (less than 10% of shoots with flowers) received grade 2; plants with flowers irregularly distributed in the plant, but noticeable because of color or size, received grade 3; plants with flowers equally distributed and attractive, but not striking, received grade 4; and, finally, plants with very attractive and uniform flowers covering most of the plant received grade 5.

The grading for foliage considered its quality and uniformity. Plants with all leaves presenting any sort of damage, such as dry leaves, pests, disease or bad nutrition symptoms, received grade 1; plants with most of the leaves presenting damage but with few healthy new shoots received 2; plants with half of the foliage presenting damage and the other half healthy, received 3; plants with most of the foliage healthy, but still presenting some damage in the foliage, received grade 4; and plants with no damage on leaves received 5. Exceptional plants with no damage in the foliage and with ornamental qualities such as distinctive color or texture, received a grade of 6. Notes were recorded when exceptional qualities were observed.

The overall landscape quality (grade) was similarly graded 1 to 5 considering the suitability of the plants for expected landscape use (screen, shade, groundcover, color, texture, etc.).

The evulations were compared using statistical methods (analysis of variance using general linear methods and Tukey's test at 5% of significance).

Selection of Invasive Species

The selection of invasive species was done through a review of the current invasive species list, generated from the WRA Daehler et al. (2004), and a survey with professionals from the landscape industry to select 5 each of the most highly rated invasive tree and shrub species that are used extensively in the landscape industry.

Licensed landscape architects received an email with a list of 41 plants (Appendix A), between trees and shrubs, and were asked to select 5 trees and 5 shrubs that they would like alternatives for (tables 1 and 2).

Table 1. Result of landscape architects' votes for trees that need alternative plants.

Code	Scientific name	Common name	Votes	%
36*	Pimenta dioica	Allspice tree	9	15.79
37*	Psidium cattleianum	Strawberry guava	9	15.79
39*	Thevetia peruviana	Bestill tree	8	14.04
16	Chrysophyllum oliviforme	Satin leaf	6	10.53
19*	Citharexylum spinosum	Fiddlewood	6	10.53
35	Melaleuca quinquenervia	Paper bark tree	5	8.77
11	Bauhinia bonandra	Pink orchid tree	3	5.26
38*	Senna surattensis	Kolomona	3	5.26
22	Corymbia citriodora	Lemon-scented gum	2	3.51
3	Acacia farnesiana	Sweet acacia	1	1.75
15	Casuarina cunninghamiana	Cunninghamia tree	1	1.75
28	Falcataria moluccana	Albizia ???	1	1.75
31	Grevillea robusta	Silk oak	1	1.75
40	Washingtonia filifera	California Fan palm	1	1.75
41	Washingtonia robusta	Mexican Fan palm	1	1.75
Total			57	100.00

* Plants selected for this project

Based on the votes and a screening of the most voted plants, 10 plants were selected to be the invasive plants which this project would look for alternatives. The five trees are: *Pimenta dioica*, *Psidium cattleianum, Thevetia peruviana, Citharexylum spinosum, and Senna surattensis*. The five shrubs are: *Ligustrum sinense, Clerodundrum buchananii, Clerodendrum quadriloculare, Lantana camara, and Tibouchina urvelleana*. The plant species *Tibouchina urvilleana* were not included in the list and were added considering the high invasive behavior of this species, as can be observed on the windward side of the Big Island of Hawaii.

Table 2. Result of landscape architects' votes for shrubs that need alternative plants.

Code	Scientific name	Common name	Votes	%
34*	Ligustrum sinense	Chinese privet	10	25.64
20*	Clerodundrum buchananii	Red clerodendrum	8	20.51
21*	Clerodendrum quadriloculare	Bronze leaved clerodendrum	7	17.95
23	Cryptostegia madagascariensis	Madagascar rubber vine	5	12.82
32*	Lantana camara	Lantana wildtype	4	10.26
13	Buddleja davidii	Orange-eye butterfly-bush	2	5.13
25	Elaeagnus umbellata	Autumn olive	2	5.13
33	Leptospermum scoparium	Broom tea tree	1	2.56
Total			39	100.00

* Plants selected for this project

Selection of Alternative Species

The first step for selection of alternative species was the creation of a matrix with the characteristics of each invasive species. This matrix is necessary to identify the key characteristics and landscape uses of each invasive species. An example of this matrix, built for *P. cattleianum*, is shown in table 3. The complete matrix with all species can be found in Appendix B.

Table 3. Example of matrix with characteristics of each invasive species

Botanical name	Psidium cattleianum
Common name	Strawberry guava
WRA	18 (high)

Family		Myrtaceae
Origin		Brazil
Growth		Aggressive
Drought		Tolerant
Salt		Not tolerant
Height		20'
Width		15'
Foliage	Habit	Dense Rounded
	Per/Dec	Evergreen
	Color	Dark green
Flower	Showy	Irrelevant
	Color	Write
	Size	Small
Fruit	Edible	Yes
	Color	Purple/Red or Yellow
	Size	1"
Trunk structure		Thin
Bark		Light brown/Purple/Green
Propagation		Seed
Ladscape use		Fruit tree/ Container/ Accent

After the selection and description of invasive species, non invasive species were selected. After an initial match has been confirmed, at least 3 alternative trees and shrubs where selected as potential alternatives for each of the 5 each invasive tree and shrubs previously selected by Landscape Architecs by survey (figure 1). Each candidate as alternative species were evaluated through the HWRA for analysis of their potential invasiveness (Daehler et al., 2004).

Once the candidates for alternative trees and shrubs were selected, a matrix for plant characteristics assessment was generated following the same standards as for the matrix describing the invasive species. Examples of characteristics included in the matrix were: caliper growth, shoot growth, drought tolerance, and presence of disease and pest problems. Appendixes C to M contain matrixes with invasive and respective alternative species (at least 3 alternatives to each invasive).

More than 16 nurseries from Oahu and Big Island, specialized in landscape plants, were consulted for their availability of selected alternative plants. Only 16 species were located, including native and exotic species, and they have being evaluated since the Summer of 2009.

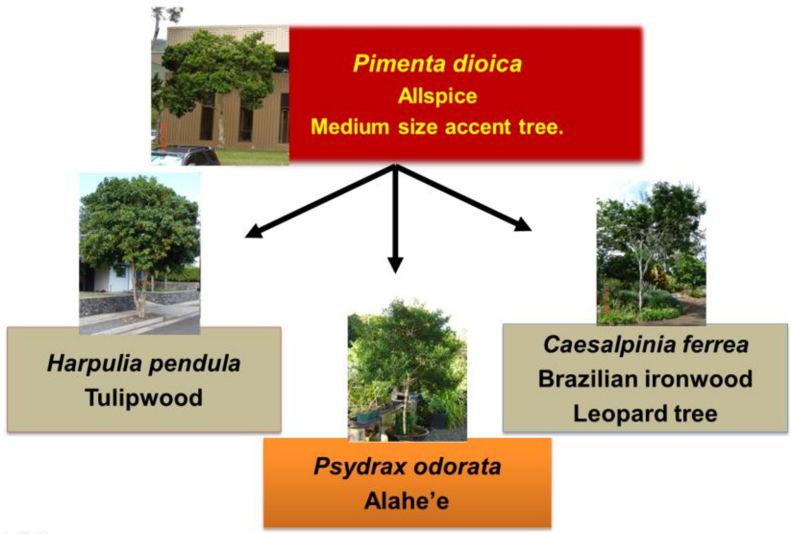

Figure 1. Diagram illustrating the selection of alternative species for each invasive species.

Field plant evaluation trials

An experimental block design was utilized. This consisted of 5 trees and 5 shrubs selected from the invasive species list. For each of the 5 selected trees and shrubs, 3 alternative species were selected for each of the 5 plants, for a total of 30 species. However, the trial consists of 18 species because several alternative species were not available from local nurseries.

The 18 alternative plant species were cultivated with and without fertilizer, with five replications, resulting in 170 plants in each research station for a total of 510 plants evaluated across the State.

The irrigation varied according to environmental conditions of each station and resources available.

Evaluation criteria include growth, health, and visual quality assessments. Qualitative and quantitative data was collected during three consecutive years, from initial planting in July 2009 until September 2012.

More details of the experiments in each research station can be found below.

Research Stations

Since Hawaii has a diverse set of micro climates, three locations were utilized for the variety evaluation trials: Waimanalo Research Station, on the Windward side of Oahu; Poamoho Research Station, in the Northwest Oahu; and Waiakea Research Station, on the Windward side of the Big Island.

The Research Stations present different soil and environmental characteristics, which will be described in this report. The table 4 presents some general data from each station, and maps with the locations of each station can are shown in figures 2 and 3.

Table 4. Soil, precipitation and altitude for the different research stations.

	Waimanalo	Poamoho	Waiakea
Soil	Mollisol, fertile	Oxisol, low fertility	Histosol, low fertility
Soil pH	Neutral	Acid / low pH	Slightly acid
Precipitation (in)	43	31	192
Irrigation	3x week	1x week	No irrigation
Elevation	Coastal, 70ft	Mid elevation, 600ft	Mid elevation, 700ft

Figure 2. Map of Oahu with the Waimanalo and Poamoho Research Stations indicated by the red stars.

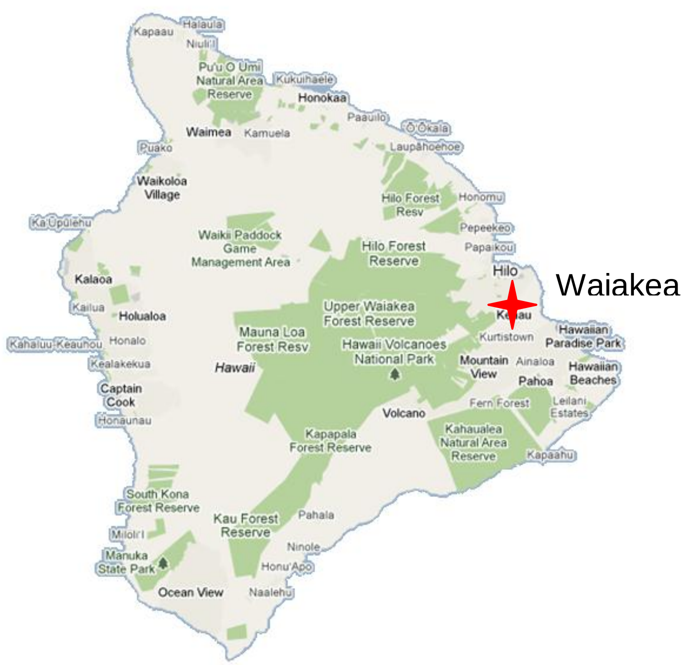

Figure 3. Map of Hawai´i Island with the Waiakea Research Station indicated by the red star.

Waimanalo Research station

1. The environment

The Waimanalo Research Station is located in the Windward side of Oahu. The average high temperature is 81.2 °F, the average low temperature is 69.6 °F, and the average annual rainfall is 43.05 inches, mainly concentrated in the winter (table 5). The elevation is near sea level, 65 to 85 feet (data from CTAHR website http://www.ctahr.hawaii.edu/site/locationdetails.aspx?id=ER-OWAIM).

The soil is represented by the Mollisol order, specifically a Waialua gravelly clay variant (WngB) (figure 3). It is a fertile soil with neutral to slightly alkaline pH. Due to the high clay content, this soil tends to be stick when wet; however, when dry, the soil is hard, difficult to manage, and cracks (Deenik and McClellan , 2007). The full description of this soil, as in the "Soils of the Hawaii Agricultural Experiment Station, University of Hawaii: Soil Survey, Laboratory Data, and Soil Descriptions" (Ikawa et al 1985), is a follows:

"The soil (WngB) is similar to the Waialua clay variant, 2 to 6 percent slopes, except there is common weathered gravel on the surface layer and throughout the profile. The gravel has little or no effect on management for most crops" (page 33).

"The soil (Waialua clay variant, 2 to 6 percent slopes, WnB) occurs on smooth gentle slopes.

The surface layer is dark brown clay about 15 inches thick. The subsoil is dark reddish-brown silty clay that has subangular blocky structure. There are many soft weathered pebbles in the subsoil.

Permeability is moderate. Runoff is slow and the erosion hazard is slight. The available water-holding capacity is about 1.8 inches per foot in the surface layer and 1.6 inches per foot in the subsoil. In places, roots penetrate to a depth of 5 feet or more" (page 31).

"Depth of the bedrock is more than 5 feet. The amount of soft weathered pebbles in the profile increases with depth. The soil is less friable and more sticky at the lower elevations of the station. This soil was formely mapped as the Waimanalo series in the *Soil survey of the Territory of Hawaii*" (page 33).

Figure 4. Map of Waimanalo Research Station. The experimental plot is indicated by the red rectangle.

Table 5. Averages of temperatures at the Waimanalo Research Station, recorded from 9/1/1969 to 12/31/2009 by the Western Regional Climate Center (Waimanalo EXP FM 795.1, HAWAII 519523)

Average	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Max	78.0	78.1	78.4	79.2	81.0	82.8	83.8	84.7	85.0	83.7	81.0	78.9	81.2
Min	64.9	64.7	66.4	68.3	69.5	71.9	73.0	73.6	73.7	72.0	70.0	66.9	69.6
Precip	6.63	4.57	3.99	3.30	2.86	1.33	1.61	1.57	1.90	3.54	6.08	5.67	43.05

Max= Maximum temperature, Min= Minimal temperature, Prec= Total precipitation for each month.

2. Experimental design

The experiment was designed to test different plant species and compare their growth using fertilizer or not. A split plot model was adopted, with fertilizer being the main plot (lines) and species the submain (rows) (figure 1). Trees were spaced 10 feet apart and shrubs were spaced 6 feet apart.

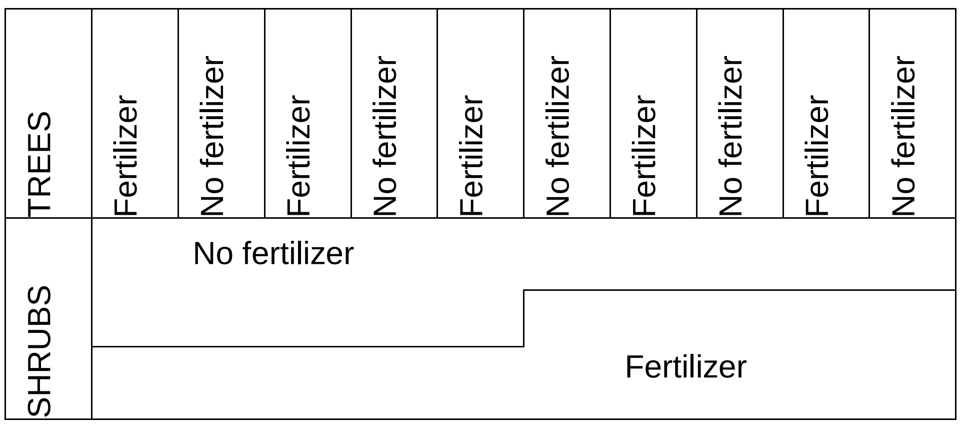

Figure 5. Experimental design in Waimanalo

3. Field preparation, irrigation and planting

In June, 2009, the field was prepared using tiller and subsoiler in the lines of planting. The weeds, mainly grasses, *Bidens pilosa* and *Commelina erecta*, were mowed and sprayed with RoundUp before planting.

The irrigation is presented in figures 2, 3 and 4. In order to reduce the risks of pipe damage during plot's maintenance, the submain was installed under the ground level.

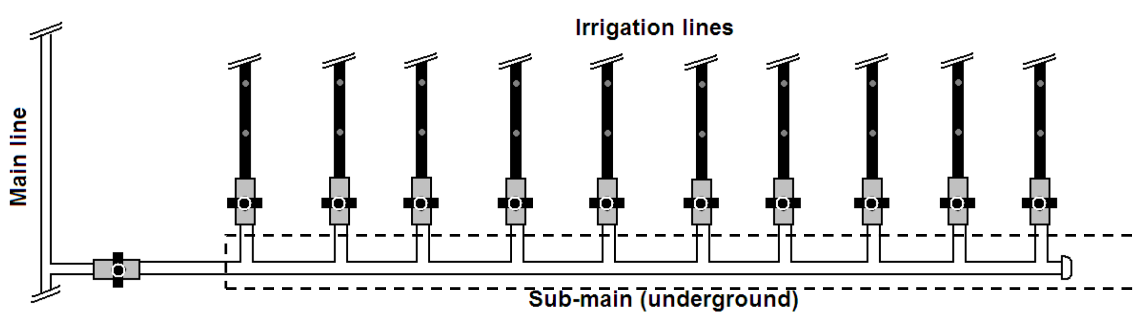

Figure 6. Irrigation layout for Waimanalo Research Station.

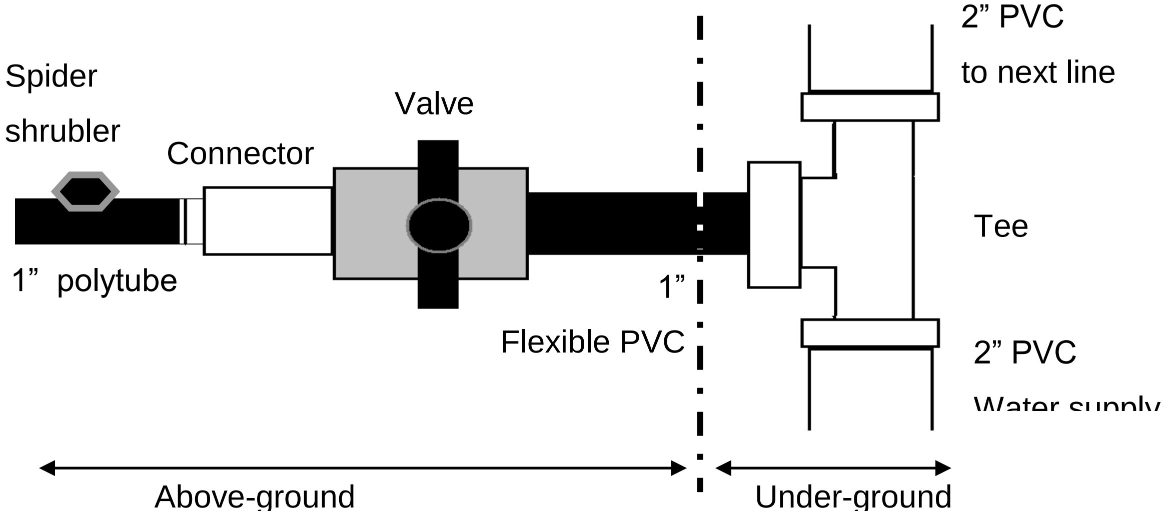

Figure 7. Lines installation. The dashed line divides the above ground (left) from the under ground (right) parts.

Figure 8. Irrigation system at Waimanalo after installed.

The trees and shrubs were planted on July 2nd, 2009. As the fertilizer was applied in the first 7 rows of shrubs, the design was adapted to keep the same number of treatments and replications. However, the trees section was not affected and was maintained accordingly the original design, with alternated fertilized and not fertilized rows.

The holes were dug by hand with a diameter at least twice the root ball diameter. The roots were spread before planting (figures 5 and 6). A mix of 5 parts of controlled release fertilizer (180 days) to 1 part of fast release (40 days), both 13-13-13 plus micronutrients, was used in plants included in the fertilized treatment. The fertilizer was handy applied at the bottom of the hole, in rates of 70 g per plant, and mixed with native soil before planting (figures 7 and 8).

Figure 9. Hole dug at least twice of the root ball diameter.

Figure 10. Roots were spread to enhance roots distribution and contact with native soil.

Figure 11. Fertilizer applied in the bottom and then mixed with native soil before planting.

Figure 12. Tree planted with water well to enhance water around the root ball.

After planting, ‘spider’ shrublers were added to each plant. The water flow was adjusted manually until the “umbrella” was regulated to a diameter of approximately 6 inches (figure 9).

Figure 13. Irrigation using spider shrublers.

4. Post-planting observations

Most of the plants didn't show any symptoms of stress after planting, with the exception of kului (*Nototrichium humile*) and giant crape myrtle (*Lagerstroemia speciosa*), probably associated with the change of moisture and light conditions, as these plants were being cultivated in a cooler environment (Waimanalo) and protected by trees in the surroundings, with less sun exposition, and irrigated three times a day.

Kului quickly recovered from wilt symptoms after irrigated. Some giant crape myrtle lost its leaves (figure 10), but there was several buds and the stems tissue were alive, indicated by the green tissue when the stems were peeled. In the beginning of the rainy season (winter) the foliage started to grow again.

Figure 14. *Lagerstroemia speciosa* without leaves after planting. New shoots came after few weeks.

Weeding

The weeds started to grow quickly, both grasses and broad leaves. As the weeds were growing more closely to the plants because of the irrigation, some plants were completely covered by the weeds (figure 11). They were removed in August with manual weeding followed by application of Ronstar (preemergent granular herbicide) to suppress the germination of more weeds (figure 12).

Figure 15. Detail of *Lantana camara* before (left) and after weeding (right). The plant was covered of weeds before weeding.

Figure 16. Overal view of field before (left) and after weeding (right).

In the first week of September weed mats were installed for each plant, as shown in figures 13 and 14, with spaces for the irrigation system.

Figure 17. Overall view of field after installation of weed mats.

Figure 18. Detail of plant with shrubler located underneath the weed math.

Figure 19. Overall view of the field in October 26, 2009.

Figure 20. Overall view of the field in May 12, 2010.

Figure 21. Overall field view in May 26, 2010, after spraying herbicide to control weeds.

Figure 22. Overall field view in June 7, 2010, three weeks after spraying herbicide to control weeds.

Figure 23. Overall field view in July 17, 2010.

Figure 24. Overall field view in August 19, 2010.

Poamoho Research Station

1. The environment

The Poamoho Research Station is up-hill from Wahiawa, Island of Oahu. Latitude is 21°05’15” N and longitude is 158°05’15”W. Altitude is approximately 600 feet above sea level.

The soil is classified as Oxisol, Wahiawa series, Wahiawa silty clay (WaB), 3 to 8 percent slopes (figure 7, Ikawa et al, 1985).

The description of this soil, as the “Soils of the Hawaii Agricultural Experiment Station, University of Hawaii: Soil Survey, Laboratory Data, and Soil Descriptions”, is a follows:

“In a representative profile, the surface layer is very dusky-red and dusky-red silty clay about 12 inches thick. The subsoil is dark reddish-brown silty clay with subangular blocky structure, 3 to 4 feet thick. The substratum is weathered basic igneous rock. The surface layer is medium acid, and the subsoil is medium acid to neutral.

Permeability is moderately rapid. Runoff is slow and erosion hazard is slight. Available water holding capacity is about 1.3 inches per foot in the surface layer and 1.6 inches per foot in the subsoil. Roots can penetrate to 5 feet or more.” (page 21)

In Poamoho, the average annual rainfall is 31.01 inches, the average maximum temperature is 82.1 °F, and the average minimal temperature is 65.9 °F (table 6, Western Regional Climate Center, consulted September 30, 2010).

Figure 25. Map of Poamoho Research Station. The experimental plot is indicated by the red rectangle.

Table 6. Averages of temperatures at the Waimanalo Research Station, recorded from 11/01/2005 to 04/30/2010 by the Western Regional Climate Center (Poamohi EXP FM 855.2, HAWAII 518055)

Average	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Max	77.6	77.0	78.4	79.0	82.5	85.9	86.4	87.0	86.7	84.5	81.5	78.7	82.1
Min	63.3	61.7	63.7	63.4	65.3	67.9	69.1	69.3	68.7	68.5	66.9	63.6	65.9
Precip	3.88	2.16	5.27	2.25	1.19	0.42	0.82	1.58	0.79	2.05	4.15	6.45	31.01

Max= Maximum temperature, Min= Minimal temperature, Prec= Total precipitation for each month.

2. Experimental design

The experimental design in Poamoho was the same for shrubs and trees (figure 4), in a random complete block design (figure 4).

TREES	Fertilizer	No Fertilizer	Fertilizer	No Fertilizer	Fertilizer	No Fertilizer	Fertilizer	No Fertilizer	Fertilizer	No Fertilizer
SHRUBS	Fertilizer	No Fertilizer	Fertilizer	No Fertilizer	Fertilizer	No Fertilizer	Fertilizer	No Fertilizer	Fertilizer	No Fertilizer

Figure 26. Experimental design in Poamoho

3. Field preparation, irrigation and planting

The field at Poamoho was prepared by the farm's crew in July, 2010. Before planting, the weeds, mainly guinea grass (*Panicum maximum*), were mowed and the field was prepared using tiller and subsoiler (figure 2). The irrigation was installed similarly to Waimanalo, but all above ground (figures 3, 4 and 5), since the sub-main is not placed on the way of any vehicles.

The planting of the field was done in July 23th and 24th, with assistance of the farm's manager Susan Migita and her crew. The same procedures of Waimanalo were used for the field in Poamoho (see Waimanalo report for planting methods).

Figure 27. Field ready for planting.

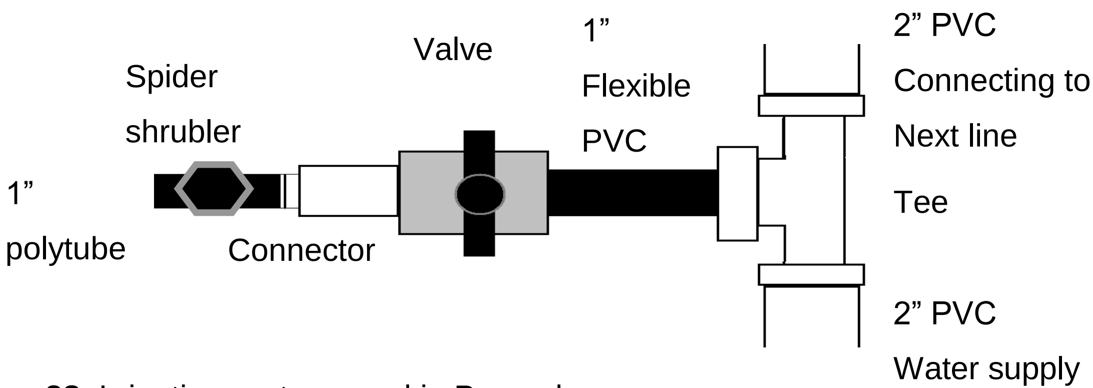

Figure 28. Irrigation system used in Poamoho.

Figure 29. Overall view of field after the irrigation was installed.

The planting, done in August 23 and 24, 2009, following the same procedures as for Waimanalo (see Waimanalo's procedures in this report for a description of the planting methods).

4. Post-planting observations

Poamoho presents a different environment compared to Waimanalo and Waiakea. The main differences are temperature and water availability. Poamoho has an average of 35 inches of annual rainfall (plus irrigation once a week), while Waimanalo have an average of 55 inches (plus irrigation three times a week), and Waiakea receives 170 inches (with no irrigation). A picture with the plot at Poamoho after planting is shown in figure 6.

Figure 30. Plot at Poamoho research station in September 2009, two months after planting.

Figure 31. Plot at Poamoho research station in March 2010, 8 months after planting.

Figure 32. Plot at Poamoho research station in May 2010, 10 months after planting.

Figure 33. View of the plot at Poamoho Research Station in August, 2010, a year and a month after planting. Severe drought.

Waiakea

1. The environment

The experiment is located in an area which soil is composed by Papai series, extremely stony muck. The description of this soil, as it is found in "Soils of the Hawaii Agricultural Experiment Station, University of Hawaii: Soil Survey, Laboratory Data, and Soil Descriptions", is a follows:

"The Papai series consists of well-drained muck soils developed in organic matter and volcanic ash underlain by a´a lava. These soils occur on nearly level to strongly sloping uplands. Mean annual rainfall is 90 to more than 150 inches. Mean annual soil temperature is about 72 °F. Papai soils are geographically associated with the Keaukaha, Keei, Kiloa, Malama, and Opihikao series."

…"In a representative profile, the surface layer (of a Papai extremely stony muck soil) is a very dark brown extremely stony muck about 8 inches thick, underlain by a´a lava.

Permeability is very rapid, runoff is slow, and erosion hazard is slight. Roots may penetrate deep into the fragmental a´a lava." (page 75)

The experimental area in the University of Hawai´i Waiakea Research Station, located about 6 miles from Hilo in the windward side of the Big Island of Hawai´i, presents a soil very shallow and sticky, formed mainly by organic matter and lava rocky, with layers of lava rock since 2 feet under ground level up to surface (figures 1,2,3 and 4). This condition contrasts with other experimental areas in Waimanalo and Poamoaho, where the soils can be deeper and poor in organic matter, respectively. We also found one lava tube while digging a hole (figure 5). The precipitation is the highest of all the three stations (table 7).

As the area had been mowed several times the soil was covered with mulch up to 6 inches (figure 3). This mulch is important for inhibition of weed's growth and retention of moisture, also protecting the soil from erosion, but can makes difficult the management. Also, boars are frequent in the area, digging the soil looking for worms and are capable to injury the plants if they dig close to the root ball, or even feed themselves by plant tissue.

The space between lines was reduced from 10 to 9 feet, as the weeds will be controlled mainly by herbicide (Roundup) and the farm manager agreed that it would be enough space to drive a tractor between the lines.

Each plant site was marked with flags or stakes and after that we started digging, using a retro excavator, operated by farm crew (figures 4 and 5). The operation took two days. All holes for shrubs were shallow dug, about 6 inches (not considering the mulch) and the tree-holes were dug about 1.5 ft, to afford 7 gallon pots.

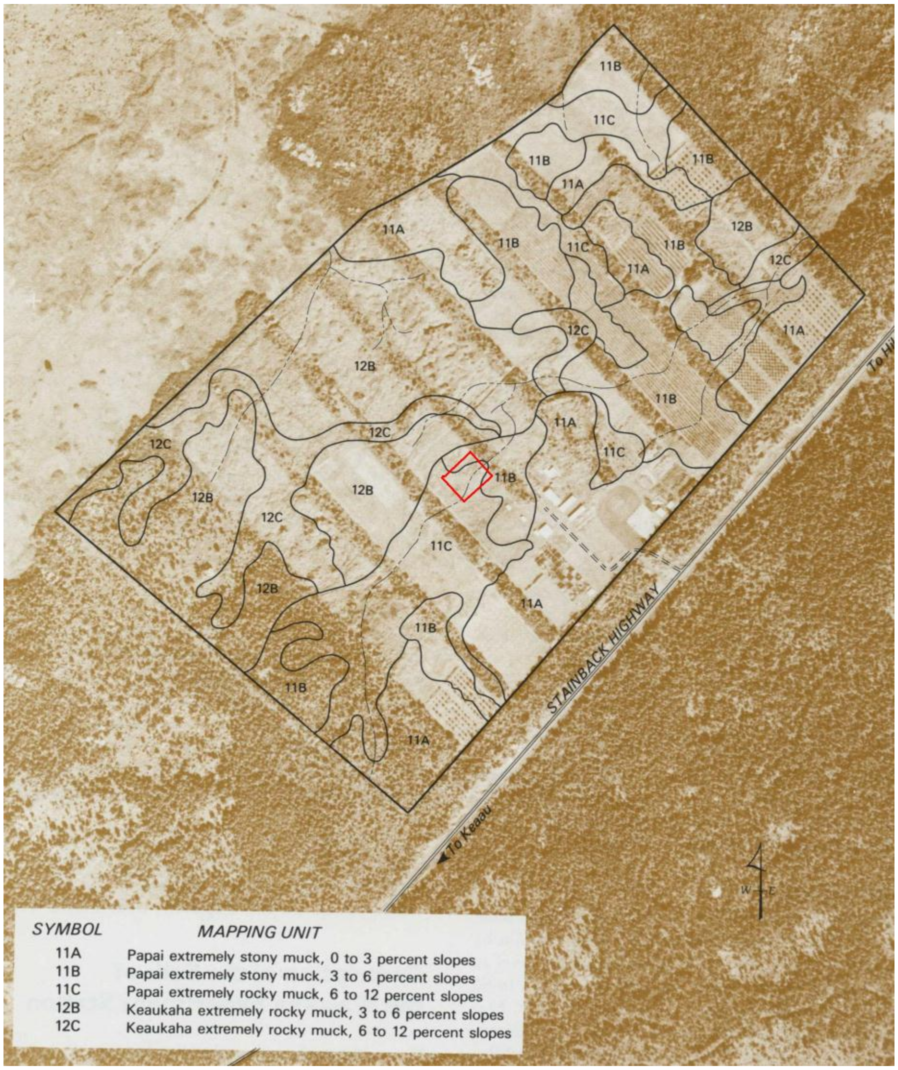

Figure 34. Map of Waiakea Research Station. The experimental plot is indicated by the red rectangle.

Figure 35. Aerial view of University of Hawai´i Waiakea Research Station. The write square with an “A” indicates the plot area.

Table 7. Averages of precipitation in Waiakea, recorded from 1/1/1953 to 12/31/2009 by the Western Regional Climate Center (Waiakea SCD 88.2, Hawaii 519025)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Average (in.)	13.01	15.46	20.37	20.41	15.03	11.01	16.26	16.83	12.56	14.31	19.73	17.59	192.57

Western Regional Climate Center, http://www.wrcc.dri.edu/cgi-bin/cliMAIN.pl?hi9025

2. Experimental design

The experimental design in Waiakea was the same for shrubs and trees (figure 4), in a random complete block design and the planting was done using the same procedures as for Waimanalo.

TREES	Fertilizer	No Fertilizer	Fertilizer	No Fertilizer	Fertilizer	No Fertilizer	Fertilizer	No Fertilizer	Fertilizer	No Fertilizer
SHRUBS	Fertilizer	No Fertilizer	Fertilizer	No Fertilizer	Fertilizer	No Fertilizer	Fertilizer	No Fertilizer	Fertilizer	No Fertilizer

Figure 32. Experimental design in Waimanalo

3. Field preparation, irrigation and planting

Figure 36. Thick layer of mulch, high organic matter content and presence of lava rocks are characteristic from the experimental area.

Figure 37. Detail of lava rock in the ground surface (indicated by the red arrow).

Figure 38. Lava tube found while digging a hole, about 1.5 feet under ground level. The picture was over-exposed to show the tube.

Figure 39. Plot marked with flags and stakes and being dug.

Figure 40. Equipment used for digging, operated by farm crew.

4. Plants arrival

The plants were shipped from Oahu to Hilo by Young Brothers, with assistance of Koba's Nursery. Once arrived in the Research Station the plants where separated by species for planting in the following week (figure 6). They were planted on the first week of September.

Figure 41. Plants separated by species for planting allocation.

Figure 42. As in the other Research Stations, the roots were spread to enhance roots distribution and contact with native soil.

Figure 43. Waiakea Research Station's crew assisting with the planting.

Results

Plant Responses by Research Stations and Fertilizer Treatments

The location where plants were evaluated affected plant growth and visual ratings at 95% probability using Tukey test, as show in tables 8 through 10. Fertilizer influenced plant growth as well. Plant mortality is presented in figures 44 to 46.

Table 8. Values marked with * indicate significant difference detected for location using Tukey test at 95% probability. Native plants are marked in italic.

Plant	HI	Height	Width1	Width2	GI	Flower	Foliage	Grade
Dodonea	***0.03****	*0.05*	*0.06*	*0.41*	*0.11*	*0.16*	*0.12*	*0.06*
H. furcellatus	.	.	.	.	.	.	.	.
H. kokio	***0.00****	***0.00****	***0.00****	***0.00****	***0.00****	*0.11*	***0.00****	***0.00****
H. waimeae	***0.00****	***0.00****	*0.61*	*0.54*	*0.27*	*0.06*	*0.94*	*0.82*
Myoporum	*0.07*	*0.81*	*0.06*	***0.03****	*0.39*	***0.02****	*0.81*	*0.34*
Nototrichium	*0.99*	***0.00****	***0.00****	***0.00****	***0.00****	*0.29*	***0.01****	***0.01****
Psydrax	*0.39*	*0.08*	*0.06*	***0.04****	***0.03****	***0.03****	*0.65*	***0.04****
Reynoldsia	*0.67*	*0.35*	*0.83*	*0.81*	*0.79*	.	*0.63*	*0.98*
Sapindus	***0.00****	***0.01****	*0.81*	*0.27*	*0.91*	.	***0.01****	*0.05*
Wikstroemia	*0.49*	*0.91*	*0.33*	*0.36*	*0.52*	***0.01****	*0.40*	*0.41*
Harpullia	0.21	0.50	0.95	0.48	0.75	0.53	**0.01***	**0.01***
Hemigraphis	**0.01***	0.43	**0.01***	**0.01***	0.11	**0.01***	0.09	**0.05***
Ixora	**0.00***	**0.01***	**0.00***	**0.00***	**0.00***	**0.00***	**0.00***	**0.00***
Lagerstroemia	0.66	**0.00***	**0.02***	**0.01***	**0.00***	0.09	0.35	0.37
Lantana	0.22	**0.01***	**0.00***	**0.01***	**0.00***	**0.00***	0.28	**0.02***
Myrciaria	**0.01***	**0.01***	**0.01***	**0.01***	**0.01***	.	**0.01***	**0.01***
Stemmadenia	**0.00***	**0.00***	**0.00***	**0.00***	**0.00***	**0.01***	**0.00***	**0.00***

Table 9. Values marked with * indicate significant difference detected for fertilizing using Tukey test at 95% probability. Native plants are marked in italic.

Plant	HI	Height	Width1	Width2	GI	Flower	Foliage	Grade
Dodonea	*0.57*	*0.79*	*0.67*	*0.46*	*0.63*	*0.43*	*0.52*	*0.71*
H. furcellatus	*0.15*	*0.52*	*0.42*	*0.63*	*0.70*	*1.00*	*0.11*	*0.31*
H. kokio	*0.23*	*0.74*	*0.70*	*0.77*	*0.91*	*0.28*	***0.02****	***0.03****
H. waimeae	*0.09*	*0.55*	*0.07*	***0.01****	***0.04****	*0.21*	*0.47*	*0.76*
Myoporum	*0.89*	*0.61*	*0.26*	*0.77*	*0.45*	*0.53*	*0.70*	*0.34*
Nototrichium	***0.03****	***0.02****	***0.01****	***0.01****	***0.00****	*0.90*	*0.62*	*0.09*
Psydrax	*0.89*	*0.43*	*0.17*	*0.24*	*0.21*	*0.70*	*0.21*	*0.84*
Reynoldsia	*0.62*	*0.42*	*0.82*	*0.94*	*0.82*	.	*0.22*	*0.33*
Sapindus	***0.03****	*0.69*	*0.74*	***0.04****	*0.38*	.	*0.37*	*0.84*
Wikstroemia	*0.18*	*0.17*	*0.98*	*0.64*	*0.38*	*0.36*	*0.05*	*0.07*
Harpullia	0.81	0.83	0.85	0.53	0.99	0.69	0.12	0.06
Hemigraphis	**0.04***	0.16	0.18	0.08	0.83	**0.03***	0.57	0.56
Ixora	0.59	**0.01***	**0.04***	0.17	**0.03***	0.88	0.62	0.69
Lagerstroemia	0.20	0.13	0.05	0.14	0.07	0.87	0.08	**0.04***
Lantana	0.16	0.14	0.67	0.45	0.37	0.65	0.33	0.76
Myrciaria	0.53	**0.04***	**0.02***	0.30	0.05	.	**0.02***	0.36
Stemmadenia	0.82	0.01*	0.11	**0.01***	**0.01***	0.44	0.39	0.70

Table 10. Values marked with * indicate significant difference detected for interaction between fertilizing and location using Tukey test at 95% probability. Native plants are marked in italic.

Plant	HI	Height	Width1	Width2	GI	Flower	Foliage	Grade
Dodonea	*0.10*	*0.67*	*0.64*	*0.60*	*0.94*	*0.81*	*0.75*	*0.98*
H. furcellatus	.	.	.	.	.	.	.	.
H. kokio	***0.03****	*0.05*	*0.42*	*0.59*	*0.37*	*0.15*	***0.02****	*0.11*
H. waimeae	*0.07*	*0.40*	***0.04****	***0.02****	***0.03****	*0.68*	*0.43*	*0.89*
Myoporum	*0.45*	*0.72*	*0.73*	*0.79*	*0.96*	*0.46*	*0.24*	*0.36*
Nototrichium	*0.21*	*0.09*	***0.03****	*0.06*	***0.03****	*0.90*	*0.05*	*0.19*
Psydrax	*0.48*	*0.31*	*0.54*	*0.92*	*0.52*	*0.38*	*0.27*	***0.03****
Reynoldsia	*0.67*	*0.83*	*0.83*	*0.73*	*0.77*	.	*0.80*	*0.39*
Sapindus	***0.04****	*0.08*	***0.02****	***0.01****	***0.01****	.	*0.76*	*0.07*
Harpullia	0.29	0.94	0.58	**0.04***	0.42	0.12	**0.05***	0.27
Wikstroemia	*0.92*	*0.28*	*0.31*	*0.14*	*0.15*	*0.93*	*0.40*	*0.19*
Hemigraphis	0.41	0.90	0.08	0.34	0.76	**0.03***	0.77	0.84
Ixora	0.06	**0.01***	0.06	0.45	**0.04***	0.64	0.15	0.54
Lagerstroemia	0.83	0.48	0.72	0.60	0.54	0.11	0.55	0.82
Lantana	0.17	0.14	0.63	0.91	0.59	0.89	0.82	0.89
Myrciaria	0.81	0.18	0.35	0.66	0.34	.	0.35	0.13
Stemmadenia	0.35	0.37	0.73	0.82	0.58	0.27	0.95	0.57

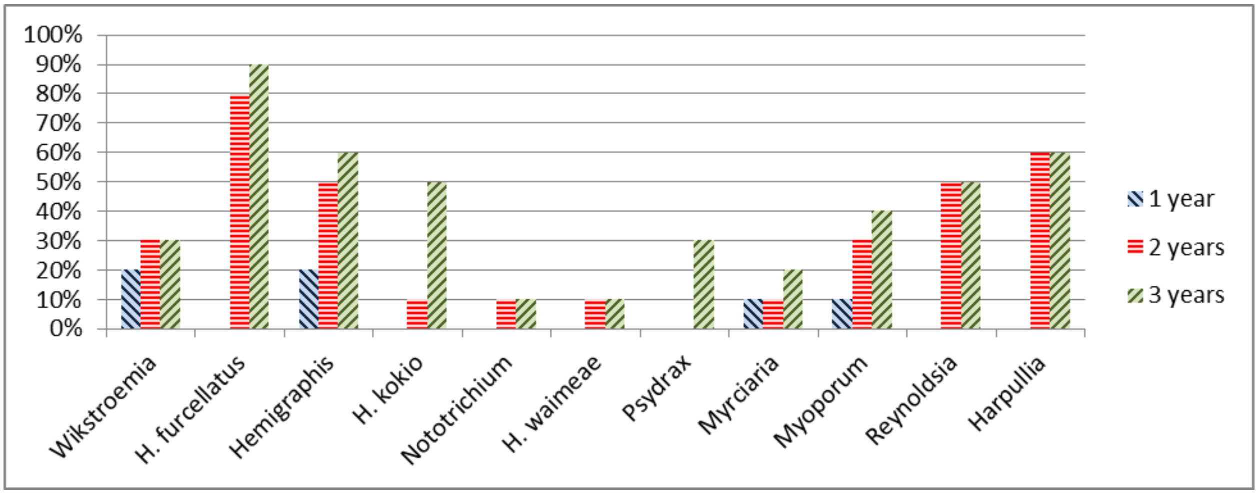

Figure 44. Mortality rates in Waimanalo. Species that did not have any mortality recorded were not included in this graph.

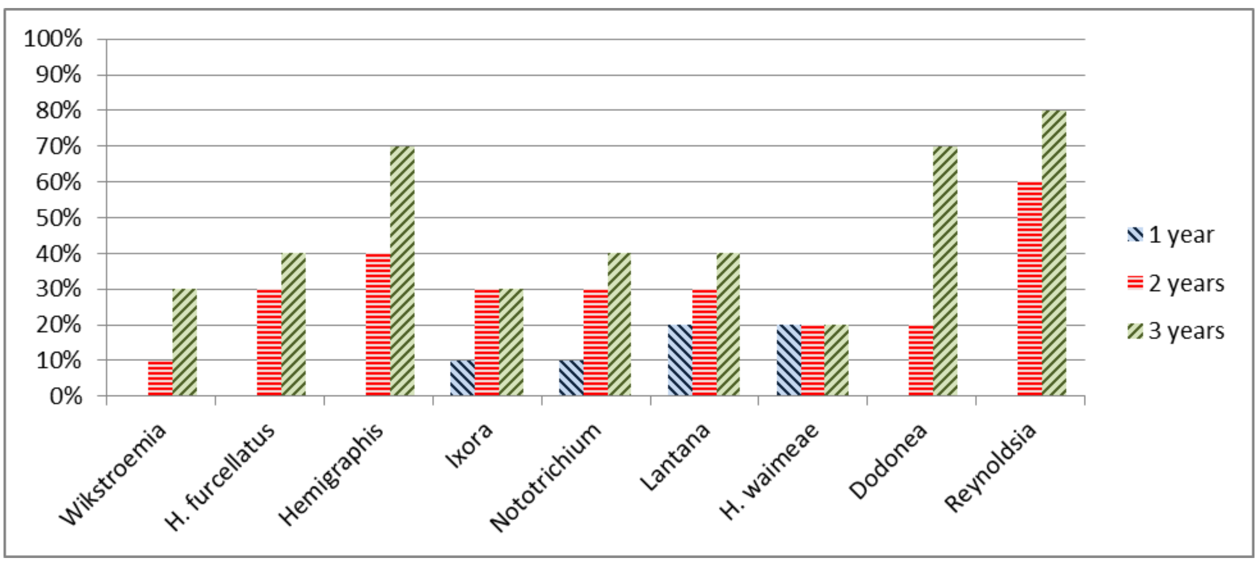

Figure 45. Mortality rates in Waiakea. Species that did not have any mortality recorded were not included in this graph.

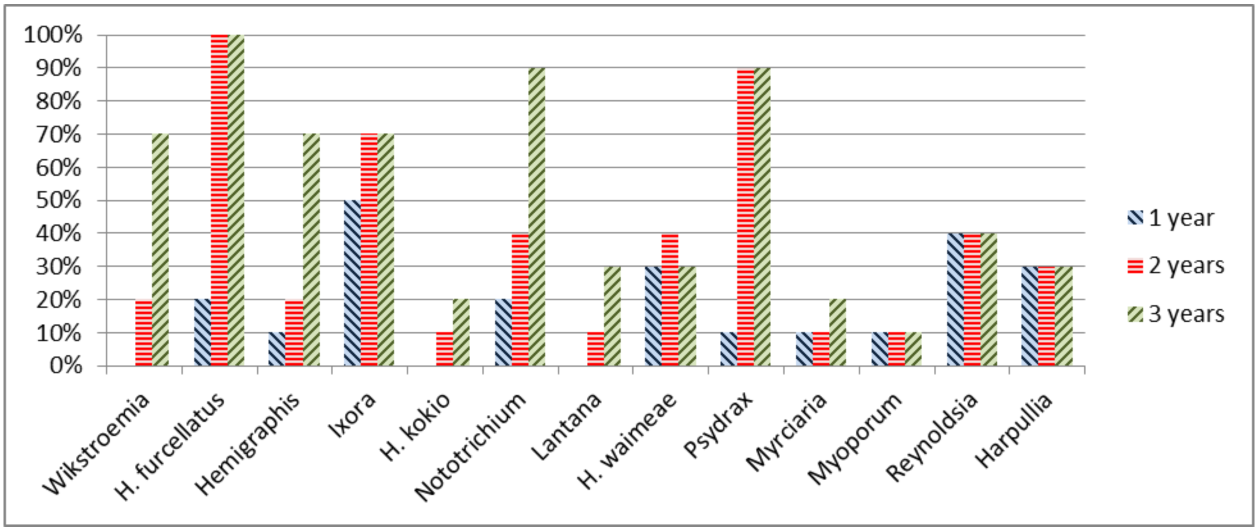

Figure 46. Mortality rates in Poamoho. Species that did not have any mortality recorded were not included in this graph.

Plant evaluation

After the selection of alternative species, only 17 of 43 species were located, including native and exotic species.

Growth and visual performances were different between the three locations, with plant mortality rates of 1.9, 17.8, and 10.4 percent at Waimanalo, Poamoho, and Waiakea, respectively. *Hibiscus* spp*.* and *Psydrax odorata* growing in Waimanalo and Waiakea tended to have higher growth rates and visual ratings, probably due to higher water availability and more favorable soil conditions compared to Poamoho. However, some species had satisfactory performance independent of the research station, such as the exotics *Lantana camara* 'SunGold' and *Stemmadenia littoralis* and the native *Myoporum sandwicense.* Despite the high invasive rating of *L. camara*, there were no stray plants observed of 'Sungold' at the field sites, since it is a seedless cultivar.

Hibiscus furcellatus had vigorous growth. It grew very well in Waiakea, with plants reaching 3.3 m tall. However, it lost the leaves and died after 18 months in Poamoho and Waimanalo, in part because of severe damage from of rose-beetle. Its hairy and skin-irritant stems and capsules were not desirable for a landscape plant, unless used as a barrier plant. There were abundant *H. furcellatus* seedlings in

Waiakea and Waimanalo, paralleling characteristics of exotic invasive species. This could limit its use as a landscape plant because of population control costs (weeding). However, this could be a desirable characteristic if *H. furcellatus* is used in restoration projects within its native range.

Hibiscus waimeae presented very inconsistent growth. Some plants grew very well with abundant flowers, while others had much insect damage to the foliage, few flowers and irregular growth, even in the same location. The same was observed for *Wikstroemia uva-ursi*, which presented very variable growth rate and form even within the same research station, but this would be expected of seed-produced plants. While some plants have grown poorly, others presented very healthy and dense foliage, which is desirable for a ground cover or small shrub as *Lantana camara*, its respective invasive species. *Hemigraphis* sp. did well in Waimanalo and Poamoho, but not in Waiakea, probably because of excessive water.

Myrciaria cauliflora growth was poor in Waimanalo and Poamoho, probably because of the hot and dry climate, added to strong winds. In Waiakea which has a climate more similar to its native environment (Atlantic rain forest), *M. cauliflora* grew slowly but with healthy and abundant foliage.

Nototrichium sandwicensis did not grow well in Waiakea also because of excessive water. *Reynoldsia sandwicensis* has grown well in Waimanalo, however most of the plants were still dormant even after 3 years of cultivation in Waiakea and many plants died in Poamoho.

Plants from the same seed bank have also shown different growth habit. For example, *Dodonea viscosa* habit in Poamoho and Waimanalo is very rounded and dense, up to 2 m tall and 3 m diameter, while in Waiakea the plants have more compact growth and sparse branches, measuring about 1.15 m height and 2.3 m diameter. This information is important to landscape architects specifying plants based on form and size of the plants. Ignoring this information could lead to improper plant specification and frustration of designers, contractors and clients.

This project has shown that substitutes for invasive plants can be chosen by the landscape industry. Also, it has shown that the weed risk assessment alone is not the best way to decide whether to avoid or not certain species since many species considered invasive have non-invasive cultivars, such as the seedless *Lantana camara* ‘SunGold’ tested in this project.

Use of both exotic and native species requires good knowledge of the plants ecology, since their performances were clearly affected depending on the research station where it was cultivated. Therefore, landscape professionals should be aware of the native ranges of each species in order to design successful projects.

Wisktroemia uva-ursi – Akia

Alternative to Lantana - *Lantana camara*

Akia is the common name for the Hawaiian endemic species *Wikstroemia uva-ursi*. It has been used for landscaping as a ground cover as well as small bushes. It is usually cultivated up to 3 feet tall, forming green-bluish groups along walkways and in compositions. The red berries are very ornamental and are formed throughout summer to fall, although they are known as toxic to cold blood animals and should not be ingested. The flowers, formed during spring, are pale yellow with secondary ornamental value.

The plants have a somewhat crowling growth form and are very attractive when cultivated with rocks or other elements, especially along or on top of rock walls and benches. Akia plants cultivated in containers can be shaped as “bonsais” and used as accent plants.

Plants tested in this experiment presented slow growth in the beginning of the experiment. However, after established, the plants developed very healthy leaves and abundant flowers (figure 47 and 49). There was no significant difference for height and width of plants, nor for foliage and overall grade, however, plants in Waimanalo tended to be larger and healthier (figure 48). Only flowering was significantly higher in Waimanalo, followed by Waiakea and Poamoho.

Based on the results of this research, field observations, and current literature, Akia should be cultivated in soils or media with good drainage and regularly moist. The mortality rates in Waiakea and Waimanalo, 30%, were the same after three years of evaluation (figures 44 and 45). On the other hand, plants cultivated in Poamoho had a higher mortality rate (70%), mainly due to lack of water (figure 46).

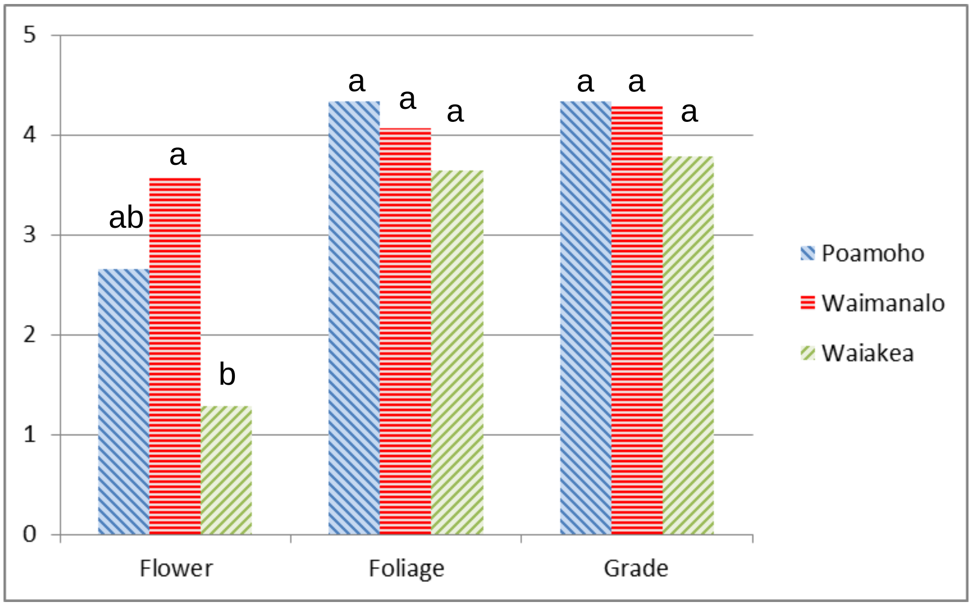

Figure 47. Comparison of visual evaluations of *W. uva-ursi* in different locations.

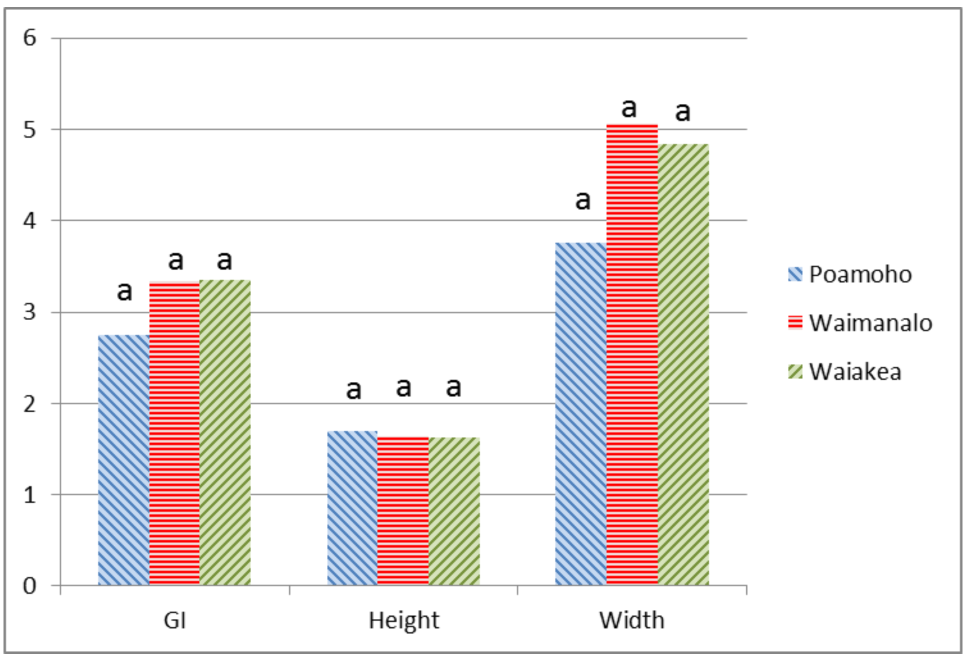

Figure 48. Comparison of growth evaluations of *W. uva-ursi* in different locations.



Figure 49. *W. uva-ursi* specimens after one year of evaluation in Waimanalo (left), Poamoho (center), and Waiakea (right).

Nototrichium sandwicense – Kului

Alternative to Ligustrum

Kului is a dense shrub, endemic to Hawai´i, very suitable to be used as a hedge or as an accent plant (figure 53). The flowers, shaped as silver spikes, can cover the plant during spring conferring a very ornamental effect to the plant. It usually grows up to 4 feet tall in 6 months and requires regular irrigation, especially during the first weeks after transplant, however, leaves should be kept dry otherwise they will rot.

Plants evaluated in this trial grew better in Waimanalo due to environmental conditions (regular watering and high sun incidence, keeping the leaves dry) with 10% mortality rate and significantly higher grades for flowering, foliage and overall grade comparing to Waiakea and Poamoho (figures 44,45,46 and 50). Plants in Waiakea showed symptons of excessive moisture, with rotted stems and leaves, and mortality rate of 40%, however, foliage and grade was significantly better than Poamoho. On the other side, plants in Poamoho had high mortality rates of 80% after three years, mainly due to dry conditions, and the leaves were too small and dry looking, probably an physiological adaptation to compensate the low water availability.

Growth rate was affected by both location and fertilizing treatment. Plants grown in Waimanalo presented higher growth rates (figure 51), and fertilizer increased growth by 30% when compared to plants that were not treated with fertilized during planting and over the three years of evaluation (figure 52).

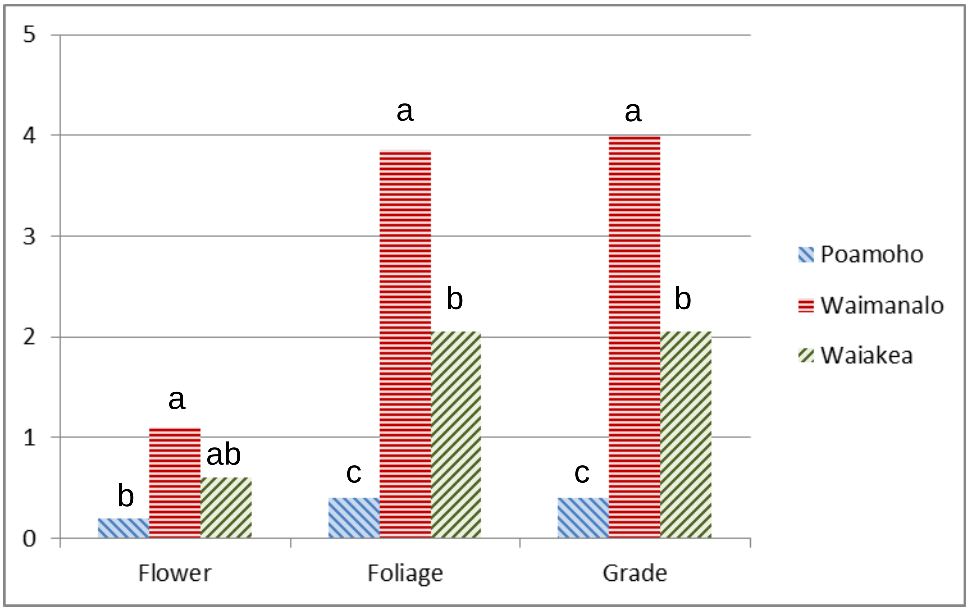

Figure 50. Comparison of visual evaluations of *N. sandwicense* in different locations.

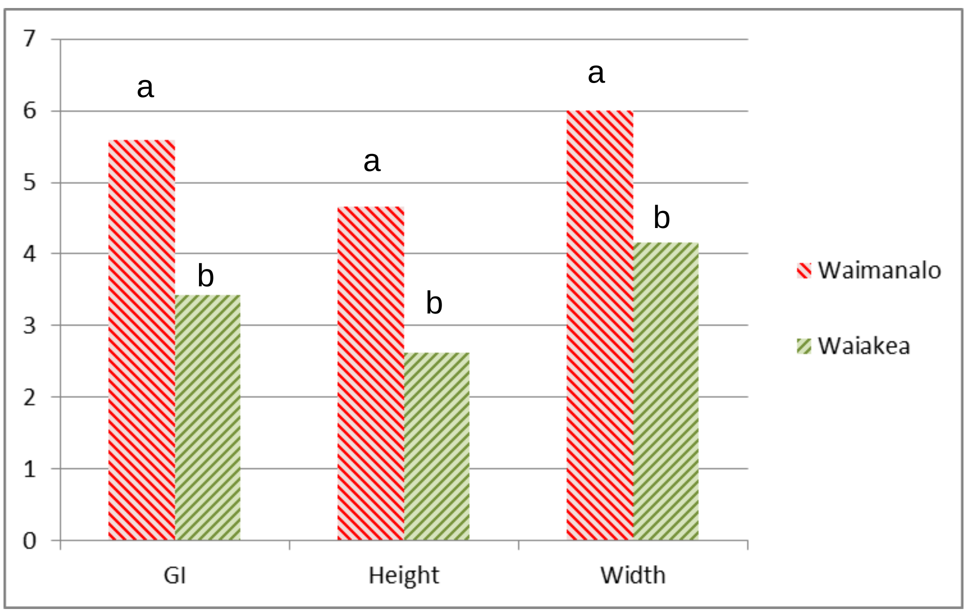

Figure 51. Comparison of plant growth evaluations of *N. sandwicense* in different locations.

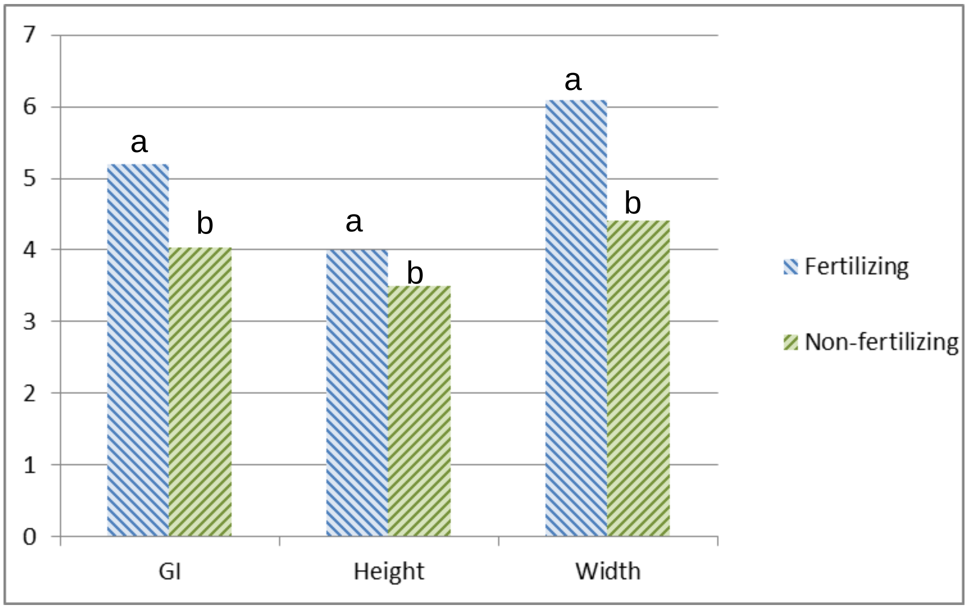

Figure 52. Comparison of plant growth evaluations of *N. sandwicense* under different fertilizing treatments.

Figure 53. *N. sandwicense* specimens after one year of evaluation in Waimanalo (left), Poamoho (center), and Waiakea (right).

Hibiscus furcellatus – 'Akiohala

Alternatice to Glory bush - *Tibouchina urvelliana*

Akiohala is a vigorous indigenous shrub reaching 6 ft tall in 6 months, with a vase like branch structure. However, it presented 90% mortality rate in Waimanalo and 100% mortality rate in Poamoho after three years, probably due to the dry environments or dry seasons, since in Waiakea the mortality rate was 40% and the surviving plants were very vigorous (figures 44, 45, 46 and 54), reaching 12 ft height. The foliage is light green and very susceptible to rose beetle, witch can damage over 90% of the foliage. The flowers are purple, 4 inches across, and are formed year round. The seed pods are 2 inches wide and remain in the plant for a long time, affecting the visual quality of the plant. The stems and seed pods are picky, with pubescence that can irritate the skin if touched, therefore affecting the management of this plant in the landscape and in the nursery and making it not suitable to areas of high traffic.

Akiohala seems to be a good barrier plant due to its density of branches, vigor, and irritant pubescence. Plants in the field self propagated, with seedlings germinating up to 10ft from mother plants. This is very important to take in consideration; it might be a desirable feature when *H. furcellatus* is used for reforestation, however, it would increase the maintenance need in small areas.

It was not possible to run statistical tests between location since there were not enough representatives in Waimanalo and Poamoho due to the high mortality rate.



Figure 54. *H. furcellatus* specimens after one year of evaluation in Waimanalo (left), Poamoho (center), and Waiakea (right).

Hibiscus kokio – Koki‘o

Alternative to Hibiscus quadriloculare

Hibiscus kokio is an endemic shrub that can be used as accent plant or hedge. It has upright growth and dense foliage, with reddish purple stems that contrast with the light green foliage. The flowers, red, are up to 3 inch of diameter and are produced mainly during spring and summer.

Plants in Waiakea had significantly higher foliage grades and growth rates comparing to Poamoho and Waimanalo (figure 55, 56, 58 and 59). Plants produced more flowers in Waimanalo comparing to Poamoho and Waiakea (figure 55). Fertilizing treatments affected only foliage and overall grades (figure 57). However, flowering might have been inhibited by high incidence of mite damage. These results shown that *H. kokio i*s more suitable to areas with regular moisture, requiring regular irrigation during dry periods for full blooming.

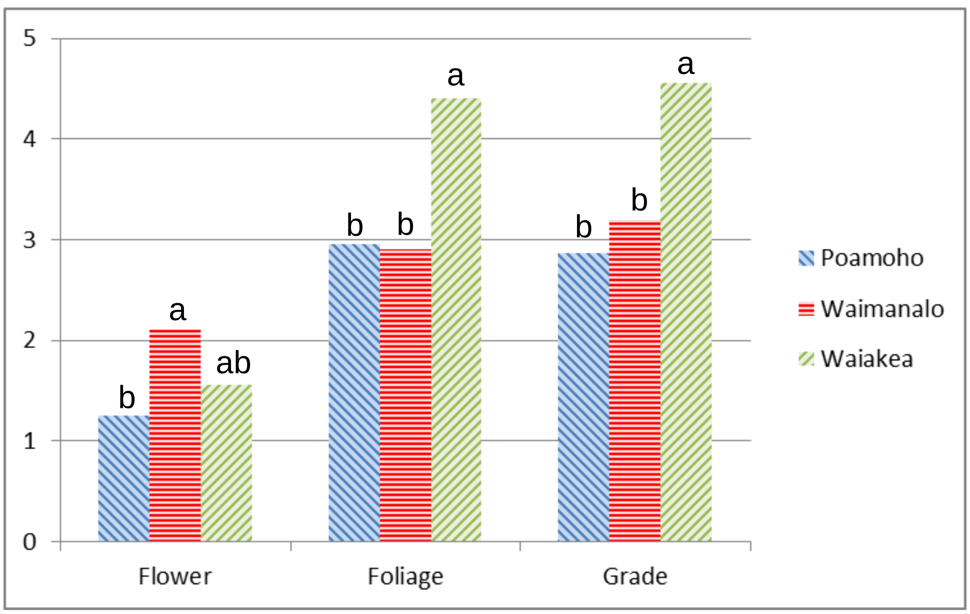

Figure 55. Comparison of visual evaluations of *H. kokio* in different locations.

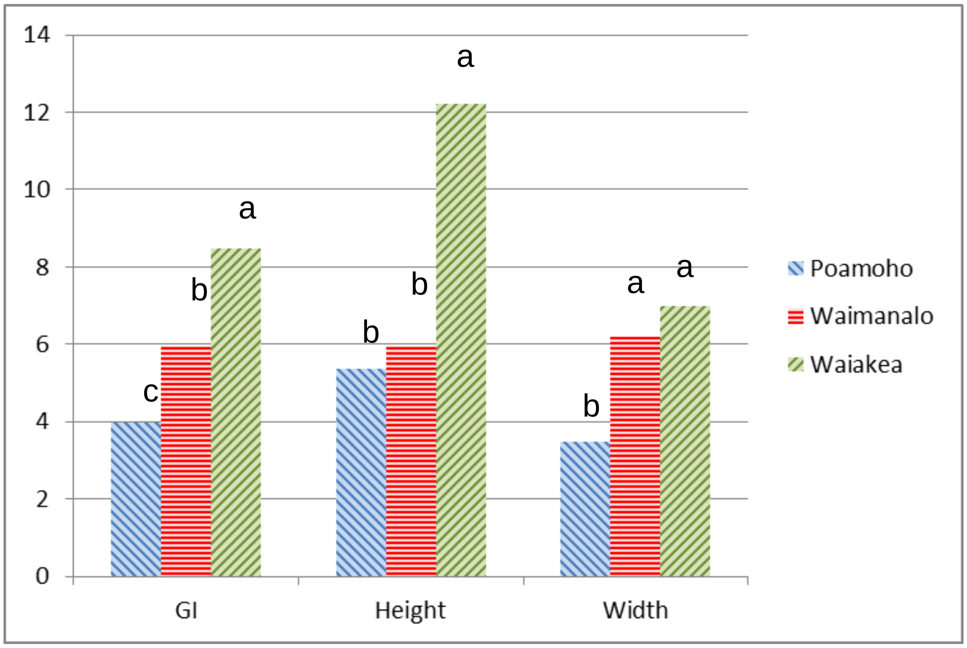

Figure 56. Comparison of plant growth evaluations of *H. kokio* in different locations.

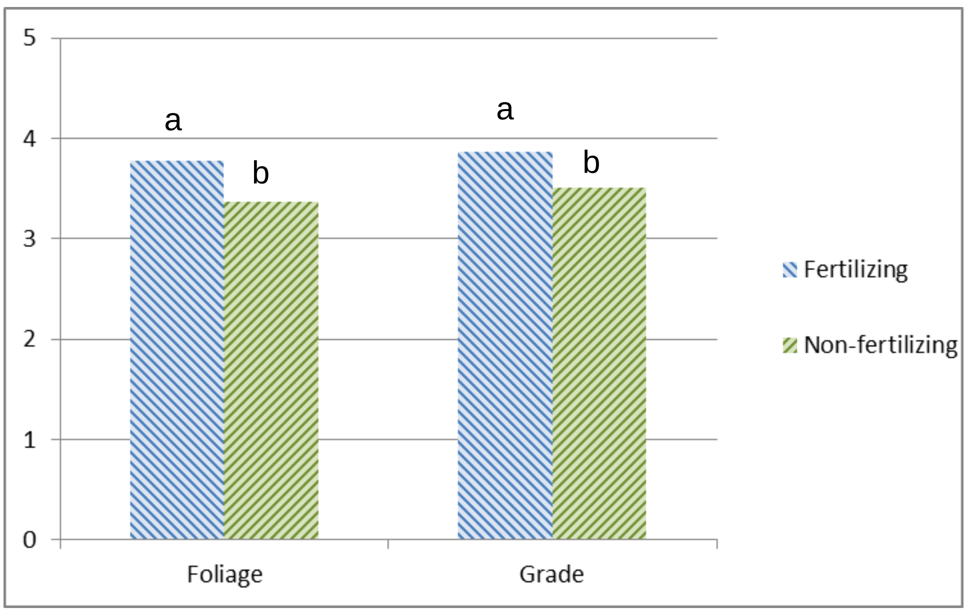

Figure 57. Comparison of visual evaluations of *H. kokio* with different fertilizing treatments.

Figure 58. *H. kokio* specimens after one year of evaluation in Waimanalo (left), Poamoho (center), and Waiakea (right).

Figure 59. *H. kokio* specimens after three years of evaluation in Waimanalo (left), Poamoho (center), and Waiakea (right).

Hibiscus waimeae – Koki‘o ke‘oke‘o

Alternative to Clerodendrum buchamani

Koki´oke´okeo is the common Hawaiian name for the endemic species *Hibiscus waimeae*. The species has fragrant flowers with large white petals contrasting with the purple stamens and dark green foliage. The plants had very slow growth in the first months after transplant, with 10 to 30% mortality rates in the first year (figures 44 to 46). However, after the second yea r, new shoots started to grow and the plants are flowering abundantly in in all research stations. Plants in Waiakea presented higher growth rates comparing to Waimanalo and Poamoho (figure 61 and 63). Fertilizer treatments affected growth rates as well (figure 62).

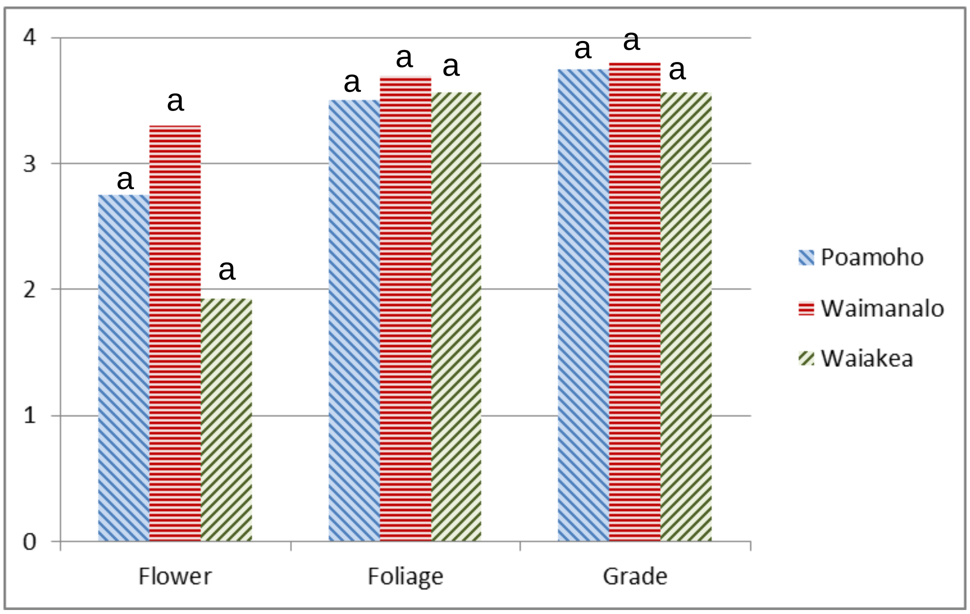

Figure 60. Comparison of visual evaluations of *H. waimeae* in different locations.

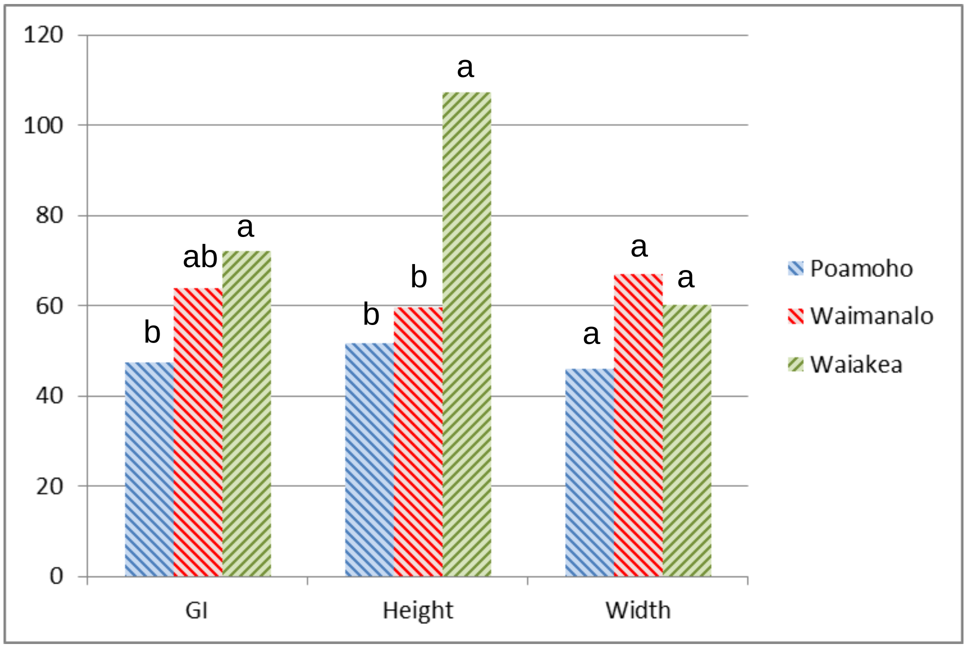

Figure 61. Comparison of growth evaluations of *H. waimeae* in different locations.

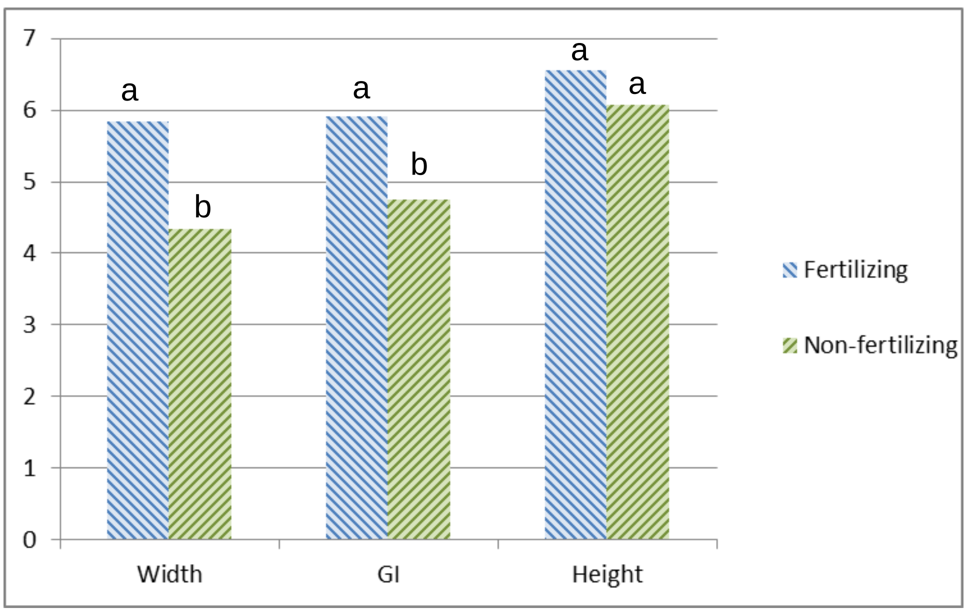

Figure 62. Comparison of growth evaluations of *H. waimeae* with different fertilizing treatments.

Figure 63. *H. waimeae* specimens after one year of evaluation in Waimanalo (left), Poamoho (center), and Waiakea (right).

Lantana camara – Lantana Sungold

Alternative to *Lantana camara*

Lantana is a well know invasive plant and is also widely used in Hawaiian landscape industry. Fortunately, several seedless hybrids have been released by seed companies, some of them already available in the local nursery trade. The cultivar SunGold was evaluated in this project. SunGold is a cultivar with bright golden yellow flowers, crowling habit, and performed very well in all of the three Research Stations, with the best results in Waimanalo. Figures 64, 65 and 66 presents the performance of Lantana in each research station. Fertilizing treatments did not affect plant growth or visual evaluation.

Lantana SunGold grows very fast as a ground cover, easily reaching up to 8 feet diameter in the first year and 12 feet diameter in second year (figure 66). Annual trimming would promote new growth with abundant flowers and improve visual quality by removing dry stems and flowers. It could be grown in containers and used as a small bush when permanently trimmed, or as an accent plant.

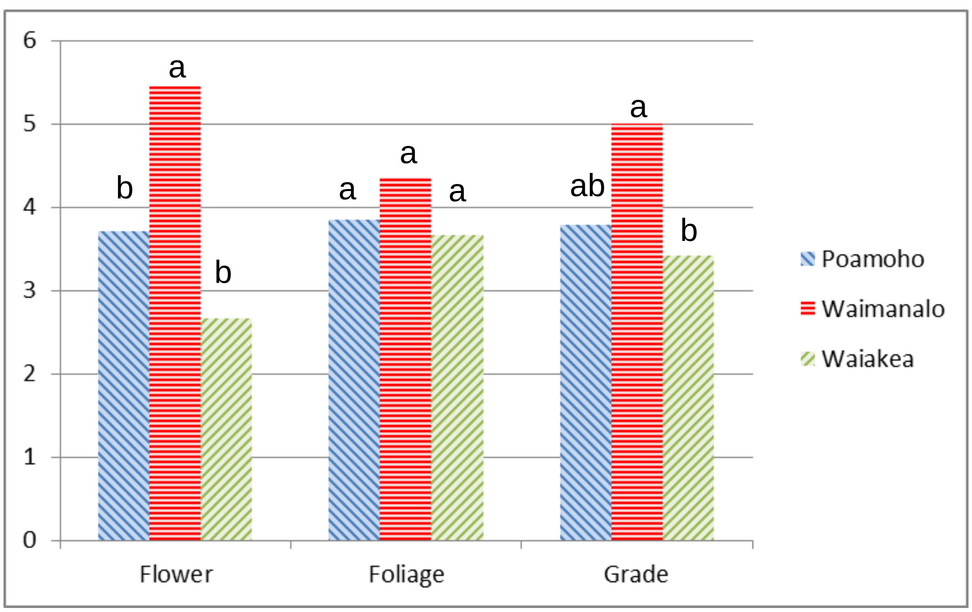

Figure 64. Comparison of visual evaluations of *Lantana sp.* ‘SunGold’ in different locations.

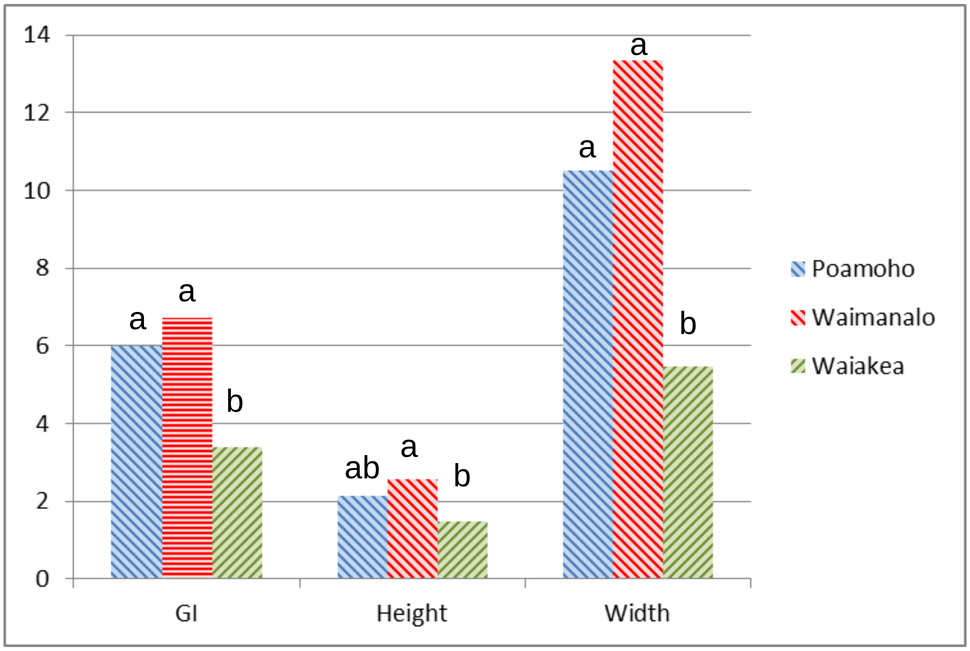

Figure 65. Comparison of growth evaluations of *Lantana sp.* ‘SunGold’in different locations.

Figure 66. *Lantana* ‘SunGold’ specimens after one year of evaluation in Waimanalo (left), Poamoho (center), and Waiakea (right).

Hemigraphis sp. – Metal leaf plant

Alternative to Lantana – *Lantana camara*

Metal-leaf is a low groundcover with dense and dark foliage. The leaves are metallic in the center, with purple borders. The flowers are white, 1 inch across, creating a attractive contrast with the foliage.

Metal-leaf requires regular irrigation for good results. The leaves easily achieve the permanent wilting point and will drop if exposed to dry conditions with strong sun. Leaves also drop with permanent contact with water, therefore, drip irrigationis prefereable over overhead irrigation.

Only flowering was significantly different between stations, with Waiakea having more flower than Waimanalo and Poamoho (figure 67 and 68). Mortality rates where low in the first two years, an average of 40% mortality rate among all research stations, however, it increased to 70% after the third year (figures 44 to 46). Somer plants did not die, but where so affected by drought and strong sun that would need to be replaced. Plants did not respond significantly to fertilizing, except for flowering, with higher flowering rates in plants that received fertilizer.

Hemigraphis spp. should be used in shaded areas, spaced 4 ft apart and regularly trimmed to remove dry leaves and promote new foliage. Representative photos are shown in figure 69.

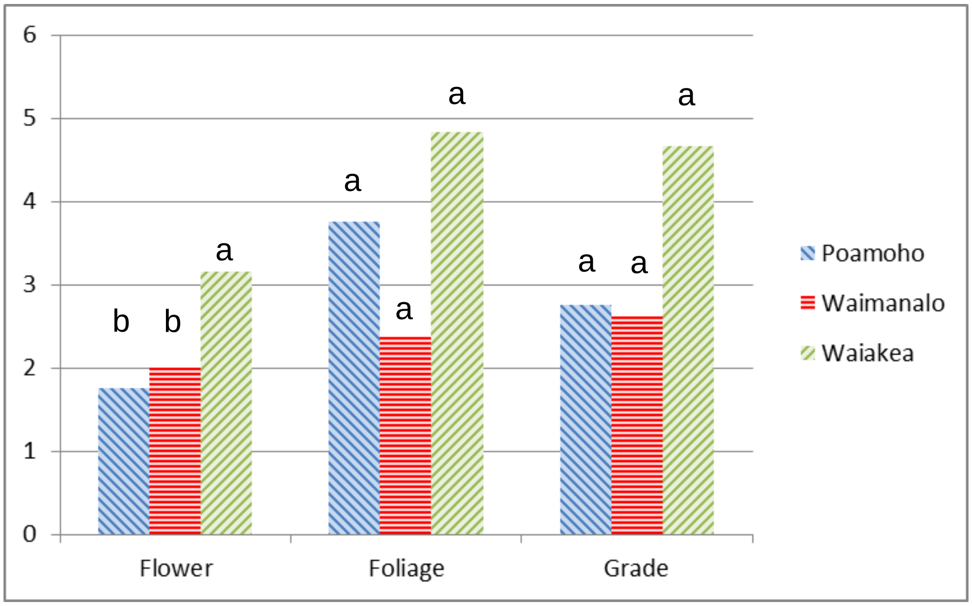

Figure 67. Comparison of visual evaluations of *Hemigraphis* sp. in different locations.

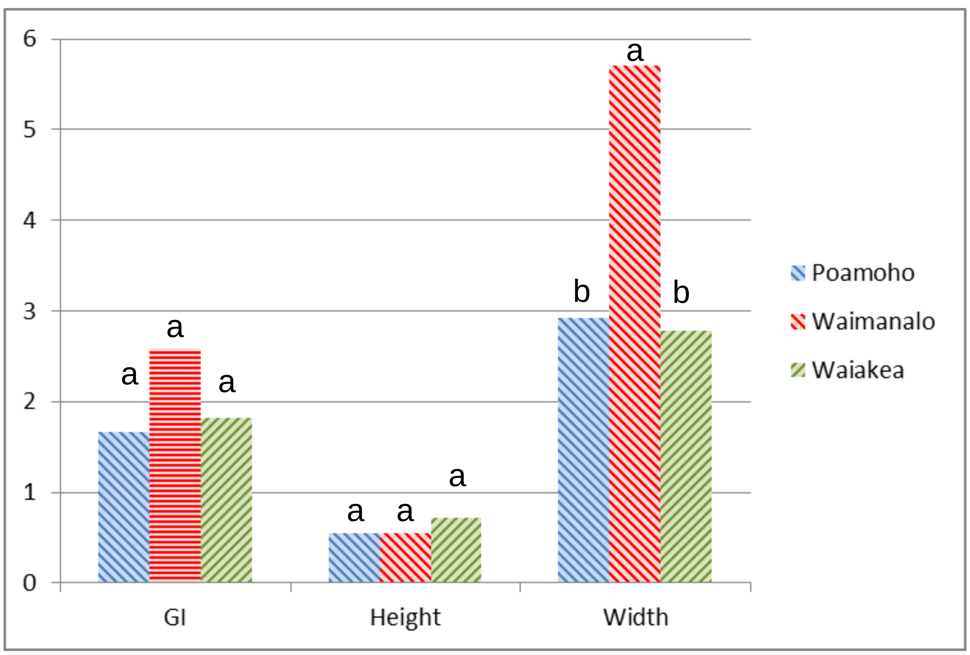

Figure 68. Comparison of growth evaluations of *Hemigraphis* sp. in different locations.

Figure 69. *Hemigraphis sp.* specimens after one year of evaluation in Waimanalo (left), Poamoho (center), and Waiakea (right).

Ixora grandiflora – Ixora 'Superking'

Alternative to Clerodendrum quadriloculare

Ixora 'Super King' is a cultivar of *Ixora grandiflora*. It has been used as an accent plant, mostly in residential gardens, and is available in some local nurseries. It could be more used as hedges, individual plants or in groups. It has upright growth with long stems, somewhat transparent in the first year; however, it branches out and becomes a full shrub after the second year. The exuberant red flower clusters are very ornamental and contrasting with the dark foliage.

Plants growing in Waimanalo presented higher growth rate and visual grades than plants cultivated in Waiakea and Poamoho, and no mortality rate (figures 44 to 46). The mortality rate in Poamoho was 50% in the first year and 70% in the second year, and plants that surved had very low visual grades. At Waiakea, the mortality rate was 30 percent in the second and third years, and visual rates were not satisfactory as well. Plants from Waiakea presented slow growth and evident chlorosis, probably because of the very moist soil. Fertilizing improved growth rate. Visual and growth evaluations are presented in figures 70 to 72 and representative photos in figures 73 and 74.

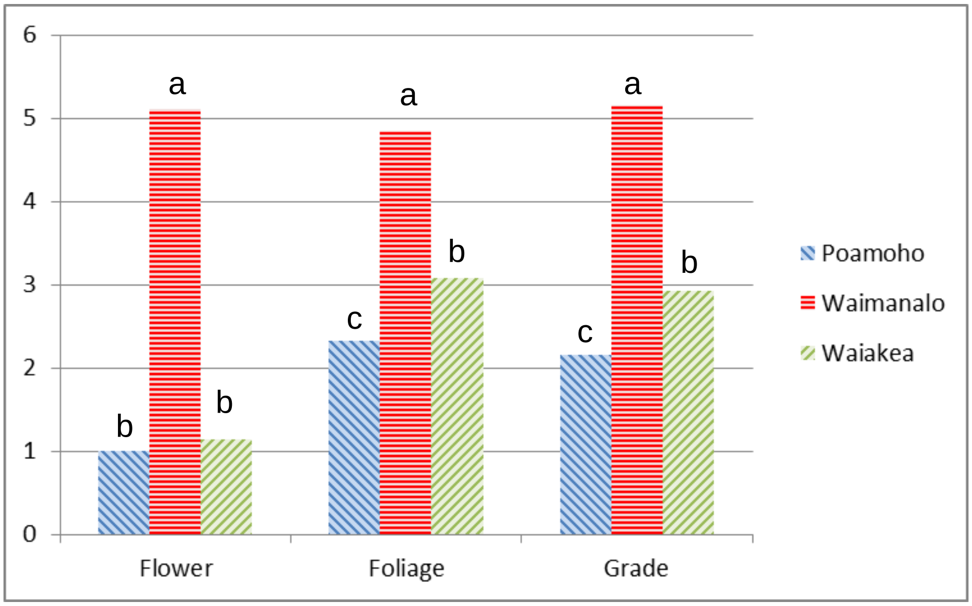

Figure 70. Comparison of visual evaluations of *Ixora sp.* 'Superking' in different locations.

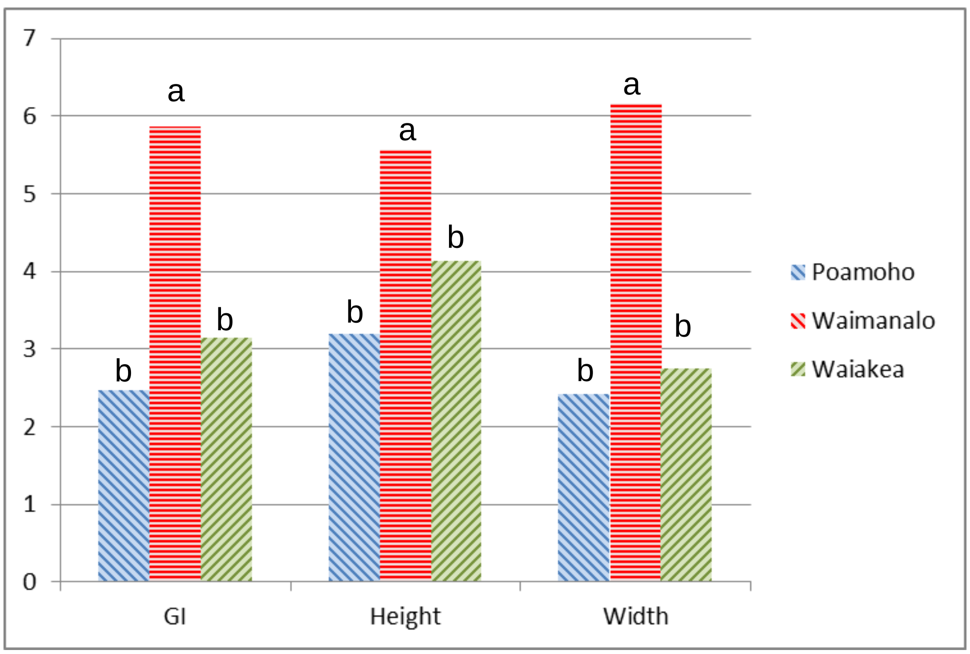

Figure 71. Comparison of growth evaluations of *Ixora sp.* 'Superking' in different locations.

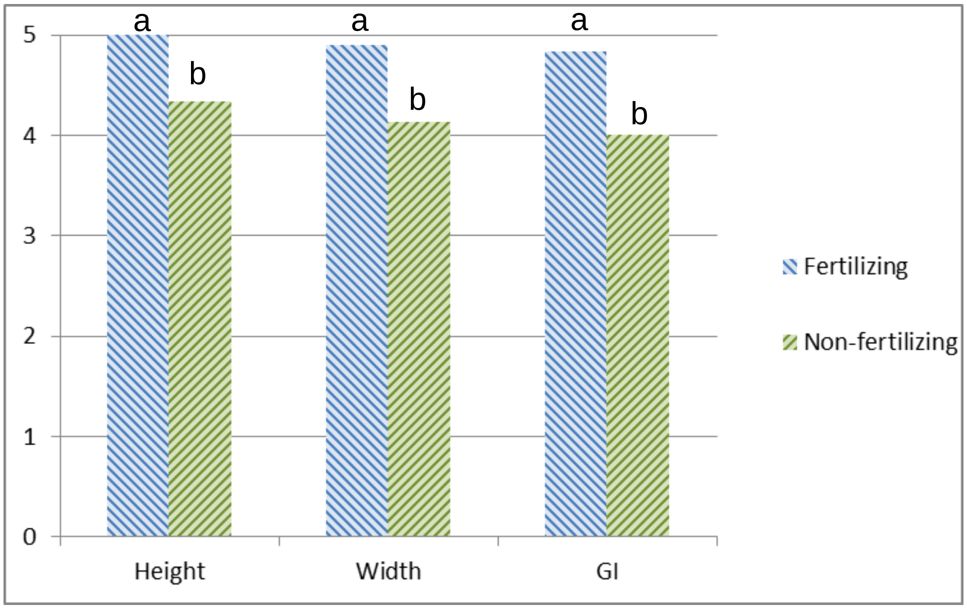

Figure 72 Comparison of growth evaluations of *Ixora sp.* ‘Superking’ in different locations.

Figure 73. *Ixora grandiflora* specimens after one year of evaluation in Waimanalo (left), Poamoho (center), and Waiakea (right).

Figure 74. *Ixora grandiflora* specimens after three years of evaluation in Waimanalo (left), Poamoho (center), and Waiakea (right).

Dodonea viscosa – A‘ali‘i

Alternative to Cassia suratensis.

Dodonea viscosa is an species indigenous to Hawaii, with the common name a‘ali‘i*.* It has a worldwide distribution in the tropics and subtropics and is adapted to generally harsh conditions. In Hawaii, it grows on volcanic and mountain slopes and in low elevations as well. There is a ‘ōlelo no‘eau that makes reference to a‘ali‘i: He a‘ali‘i kū makani au, ‘a‘ohe makani nāna e kula‘i (I am an a‘ali‘i that stands the winds, there is no wind that will blown me out).

A´ali´i can be used as a screen, informal hedge, or small specimen tree. It thrives under a wide array of conditions, tolerant to dry to wet conditions, partial to full sunlight, soils of many types and tolerates strong winds (Staples and Herbst, 2005). However, it requires good soil drainage, since it was probably the main reason for the high mortality rate observed in Waiakea (70%), where no plants died in Waimanalo and Poamoho.

A‘ali‘i grew up 5 feet in three years in this evaluation, and the shape of the canopy was very variable (figure 76). Width was significantly different beteen research stations, with variations within research stations as well. Results from the research stations show that *D. viscosa* is very versatile, adapting well to all three environments were it has been tested (figure 75).

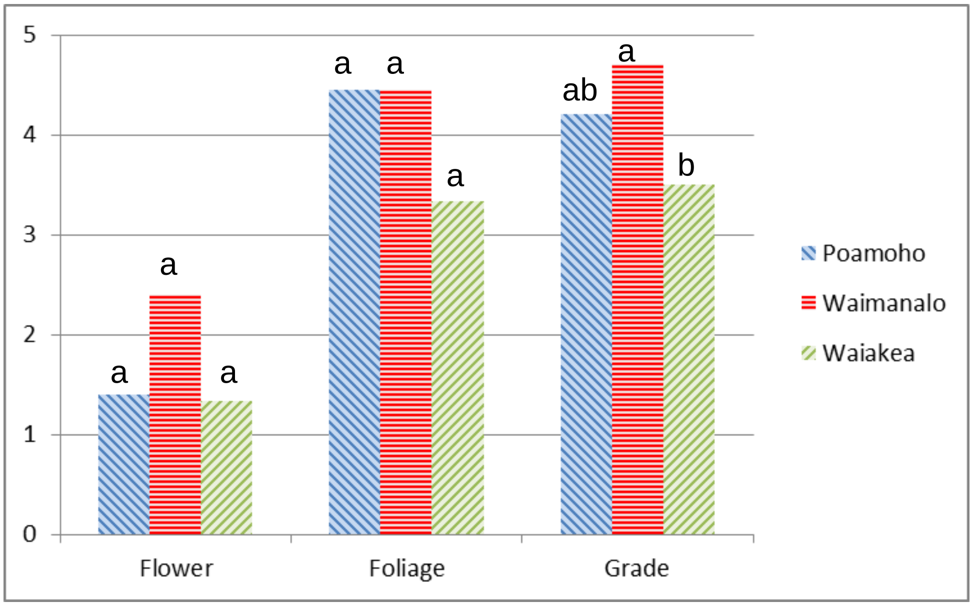

Figure 75. Comparison of visual evaluations of *Dodonea viscosa* in different locations.

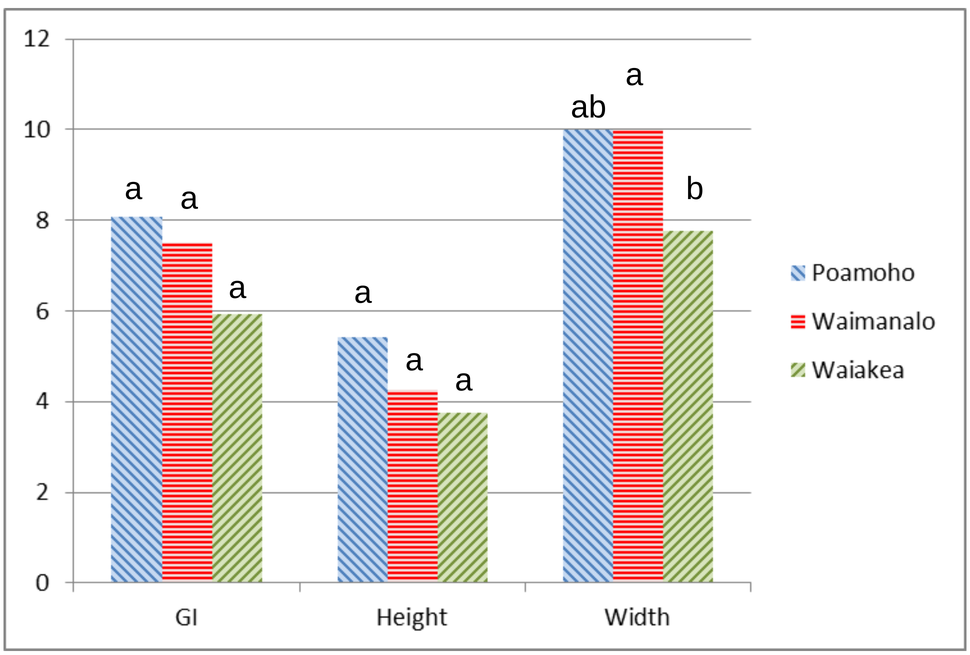

Figure 76. Comparison of growth evaluations of *Dodonea viscosa* in different locations.

Figure 76 *Dodonea viscosa* specimens after one year of evaluation in Waimanalo (left), Poamoho (center), and Waiakea (right).

Lagerstroemia speciosa – giant Capre myrtle

Alternative to *Citharexylum spinosum*

Lagerstroemia speciosa is a tree with rounded canopy and very ornamental purple and pink flowers. The tested tree grew well in all three research stations, with variations in growth form (figures 80 and 81). Trees in Waimanalo had the best results, with canopies offering a clearance of 6 feet and growing up to 13 ft tall average, while in Waiakea the trees did not have the same clearance, with longer and arching branches. At Poamoho, the canopies were more compact and very attractive. Figures 77 and 78 show the comparisons between locations and figure 79 show the effect of fertilizing, which did not affect plant growth of *Lagerstroemia speciosa* in this evaluation.

There was no mortality at all in all tree research stations (figures 44 to 46). Designers should be aware to the fact that *L. speciosa* drops it leaves throout summer, cousing littering, but it might be a desirable quality to provide more light during the winter. Another important aspect of the foliage is the color of new shoots, which are redish to purplish and very ornamental.

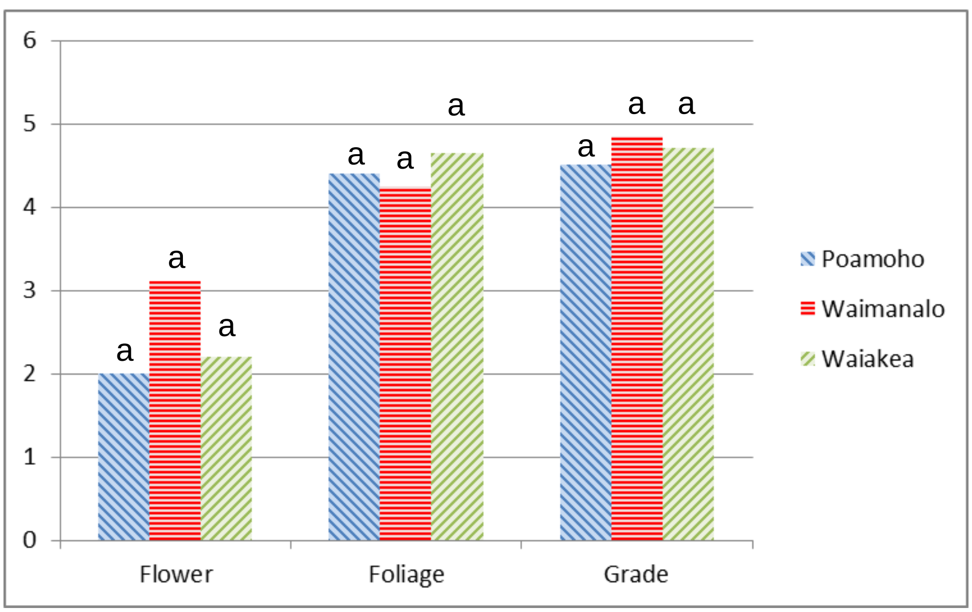

Figure 77. Comparison of visual evaluations of *Lagerstroemia speciosa* in different locations.

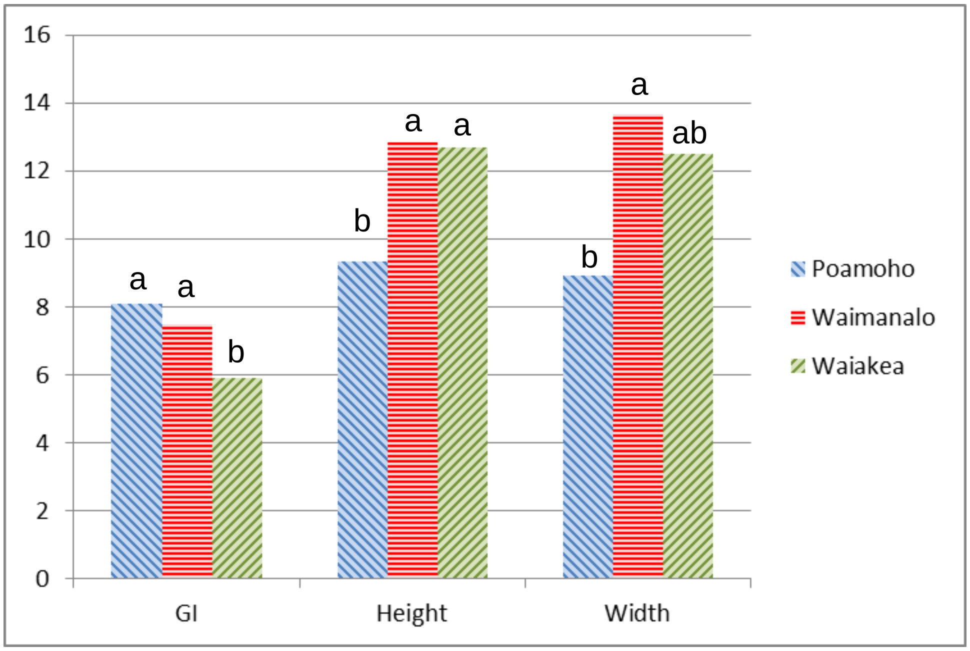

Figure 78. Comparison of growth evaluations of *Lagerstroemia speciosa* in different locations.

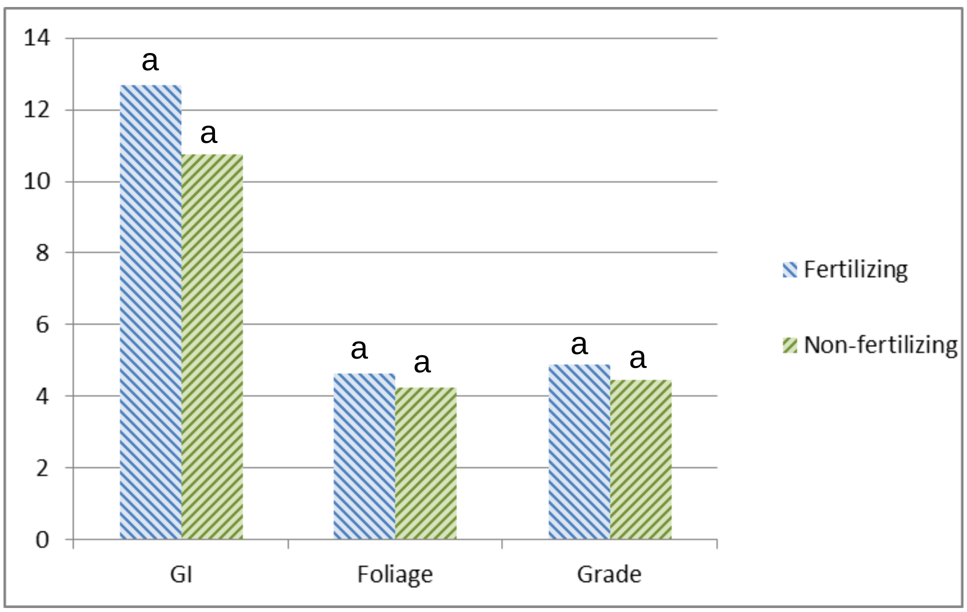

Figure 79. Comparison of visual evaluations of *Lagerstroemia speciosa* with different fertilizing treatments.

Figure 80. *Lagerstroemia speciosa* specimens after one year of evaluation in Waimanalo (left), Poamoho (center, during pruning), and Waiakea (right).

Figure 81. *Lagerstroemia speciosa* specimens after three years of evaluation in Waimanalo (left), Poamoho (center, during pruning), and Waiakea (right).

Myrciaria cauliflora – Jabuticaba

Alternative to Psidium cattleianum

Jabuticaba is a slow growing tree from the tropical Atlantic forest in Brazil, where it is considered a very valuable accent tree. It usually grows in areas with high water availability and low wind. It also produces black berries that cover the trunk and branches, which are very ornamental and are consumpted in nature and used for jelly and wine.

In this trial, jabuticaba developed very healthy foliage in Waiakea, where the high precipitation is similar to its place of origin, but did not perform well in Poamoho and Waimanalo because of the dry conditions and strong winds (figure 52). As mentioned before, growth was slow, with plants in Waiakea reaching 5 ft after three years, coming from plants that were 2 to 2 and half feet height at time of planting. They grew very little in Waimanalo and Poamoho. The data of growth and visual analysis is presented in figures 82 to 84, and figure 85 has representatives of each research station.

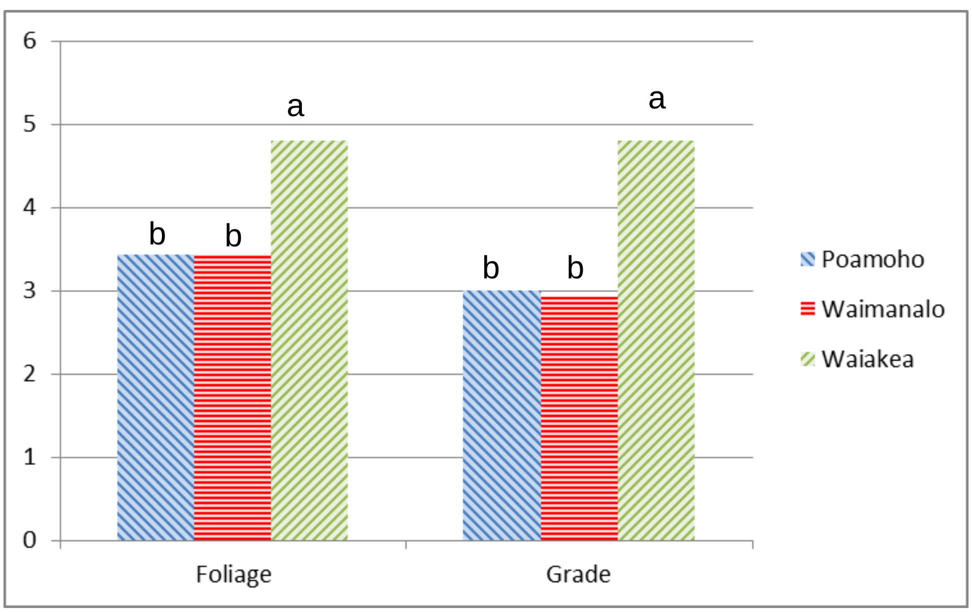

Figure 82. Comparison of visual evaluations of *Myrciaria cauliflora* in different locations.

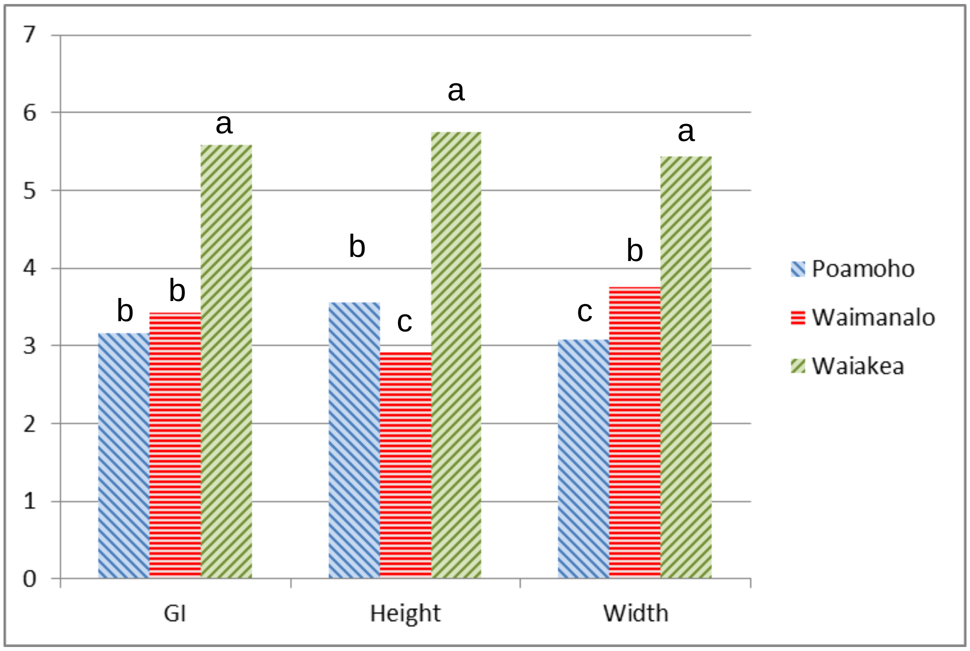

Figure 83. Comparison of growth evaluations of *Myrciaria cauliflora* in different locations.

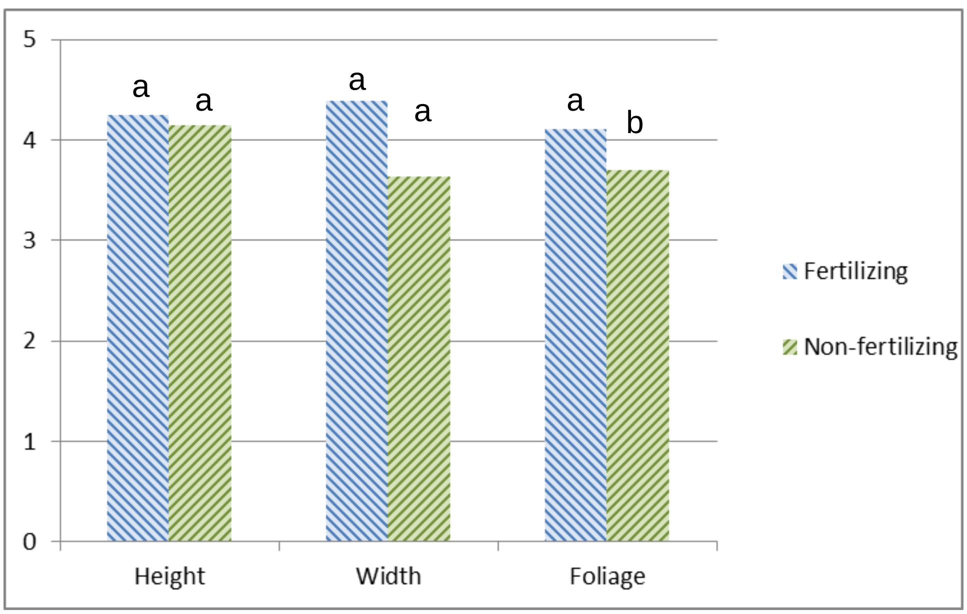

Figure 84. Comparison of growth evaluations of *Myrciaria cauliflora* under different fertilizer treatments.

Figure 85. *Myrciaria cauliflora* specimens after one year of evaluation in Waimanalo (left), Poamoho (center), and Waiakea (right).

Sapindus oahuensis/saponaria – Lonomea / Manele

Alternative to Citharexylum spinosum

Sapindus oahuensis and *Sapindus saponaria* are two species native from Hawai´i, the first being endemic to Oahu and the other indigenous from Hawai´i Island. They are medium size trees, with rounded canopy, suitable for larger areas and shading; however, its soapy fruits should be considered especially when used along paved areas. They grew satisfactorily in all research stations, with the best results in Waimanalo, followed by Waiakea and Poamoho (figures 86 to 87). Fertilizer promoted canopy width (figure 88). Figures 89 and 90 shows representative plants from each station.

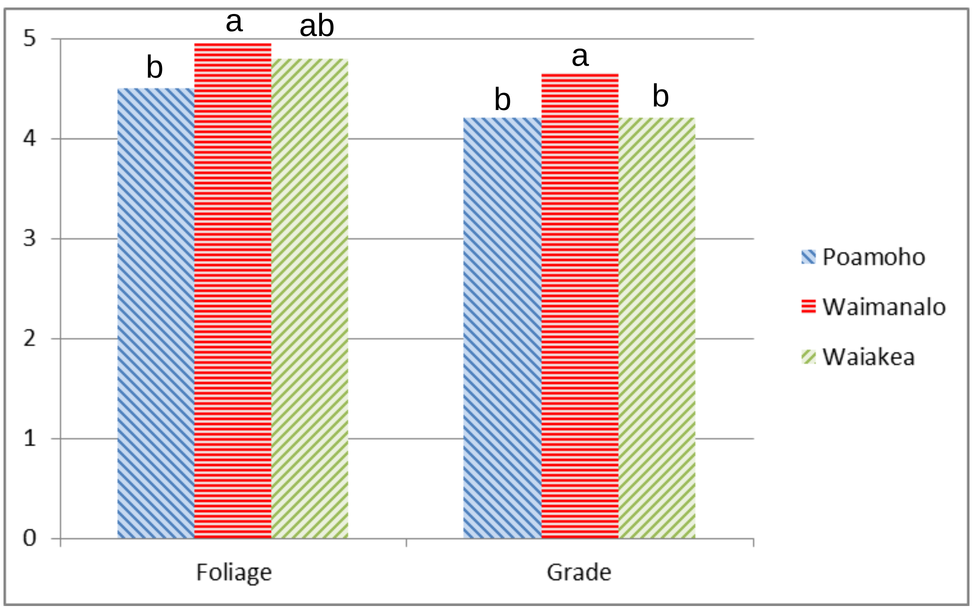

Figure 86. Comparison of visual evaluations of *Sapindus spp.* in different locations.

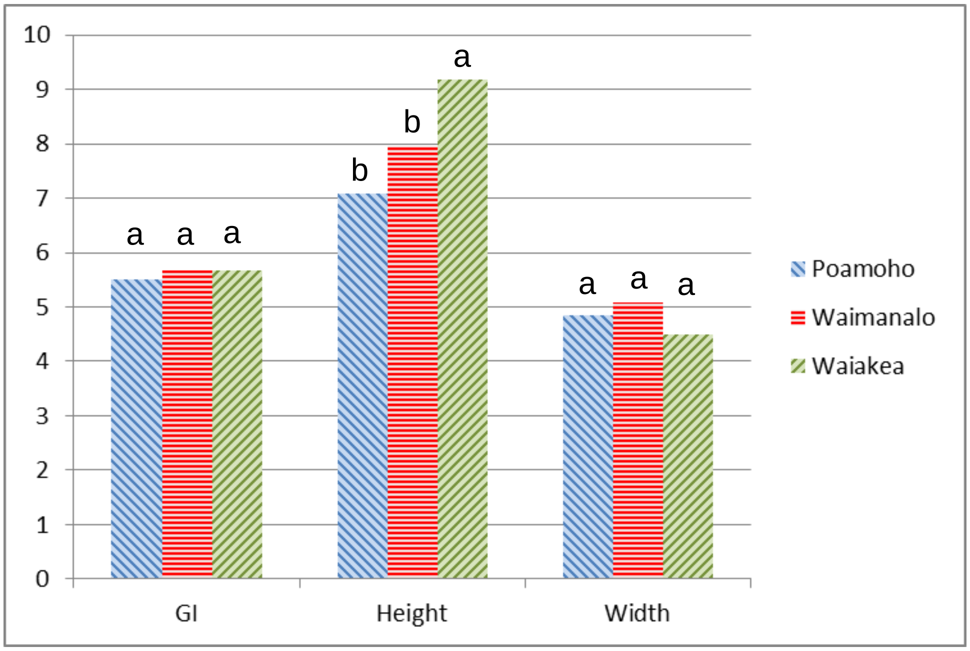

Figure 87. Comparison of growth evaluations of *Sapindus spp.* in different locations.

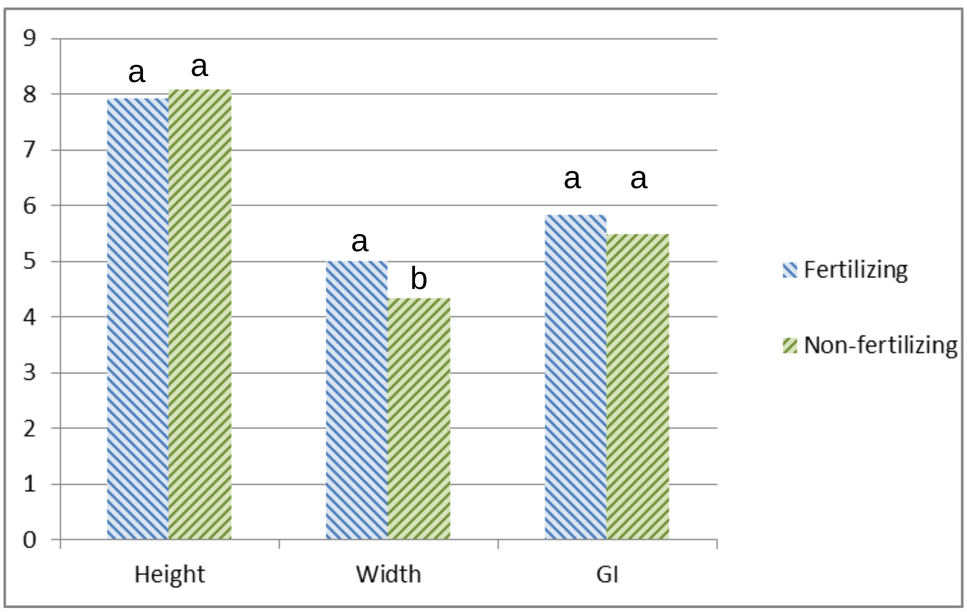

Figure 88. Comparison of growth evaluations of *Sapindus spp.* under different fertilizer treatments.

Figure 89. *Sapindus oahuensis* specimens after one year of evaluation in Waimanalo (left) and Poamoho (center), and *Sapindus saponaria* cultivated at Waiakea (right).

Figure 90. *Sapindus oahuensis* specimens after three years of evaluation in Waimanalo (left) and Poamoho (center), and *Sapindus saponaria* cultivated at Waiakea (right).

Psydrax odorata – Alahe´e

Alternative to *Pimenta dioica*

Psydrax odorata, which Hawaiian name is Alahe´e, is a shrub or small tree, ranging from coastal areas to moist forests. It has dark and glossy green leaves, white and gray bark, and fragrant white flowers. Usually the plants present upright growth, somewhat pyramidal.

Alahe´e is drought resistant; however, it requires regular watering and fertilizing after planting. After established, plants requires less or no irrigation and fewer fertilizing (Bornhorst, 2005).

During the first months of evaluation, the plants showed very slow development (figure 92). This period coincided with fall and winter. However, in late spring, the plants started to show vigorous growth and very healthy foliage. Plants grew definitively better in Waimanalo and Waiakea compared to Poamoho (figures 44, 45, 46, and 92). This difference is likely related to the low water availability in Poamoho added to the sun exposure, since alahe´e is usually found in the understory of moist forests and coastal vegetations. The mortality rate was very high in Poamoho, 90%, and the only plant that survived was being shaded by a larger tree next to the experimental plot.

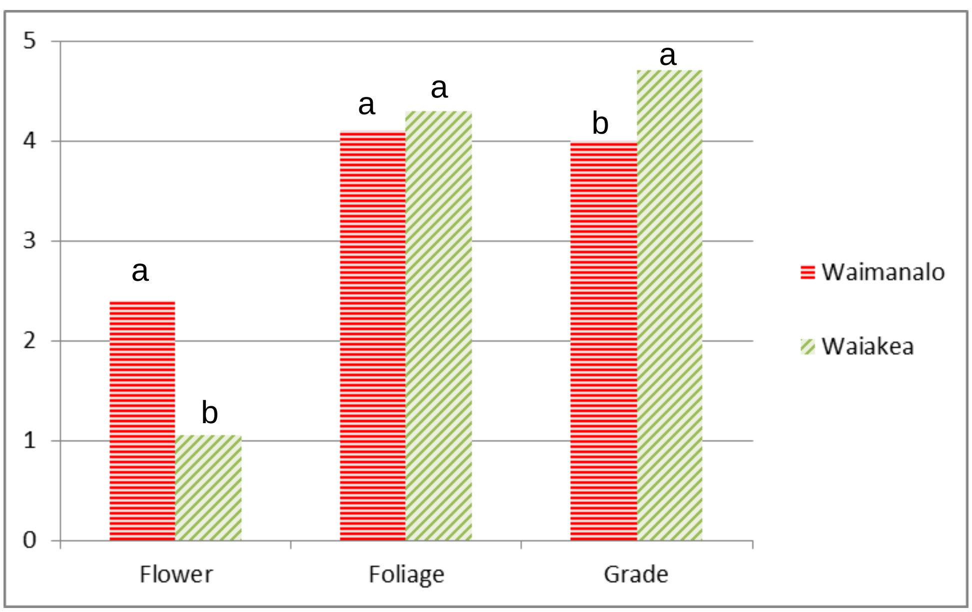

Figure 91. Comparison of visual evaluations of *P. odorata* in different locations.

Figure 92. *Psydrax odorata* specimens after one year of evaluation in Waimanalo (left), Poamoho (center), and Waiakea (right).

Figure 93. *Psydrax odorata* specimens after three years of evaluation in Waimanalo (left), Poamoho (center), and Waiakea (right).

Myoporum sandwicensis – Naio

Alternative to Thevetia peruviana

This native plant, endemic to Hawai´i, is a large shrub or small tree and is growing very well in all three locations. The canopy is dense and it would work fine as 4 to 5 foot tall screen or hedge, with fragrant flowers that smell like honey. The foliage is dark green and very though.

The results were very similar in the three locations (figures 94 to 96).

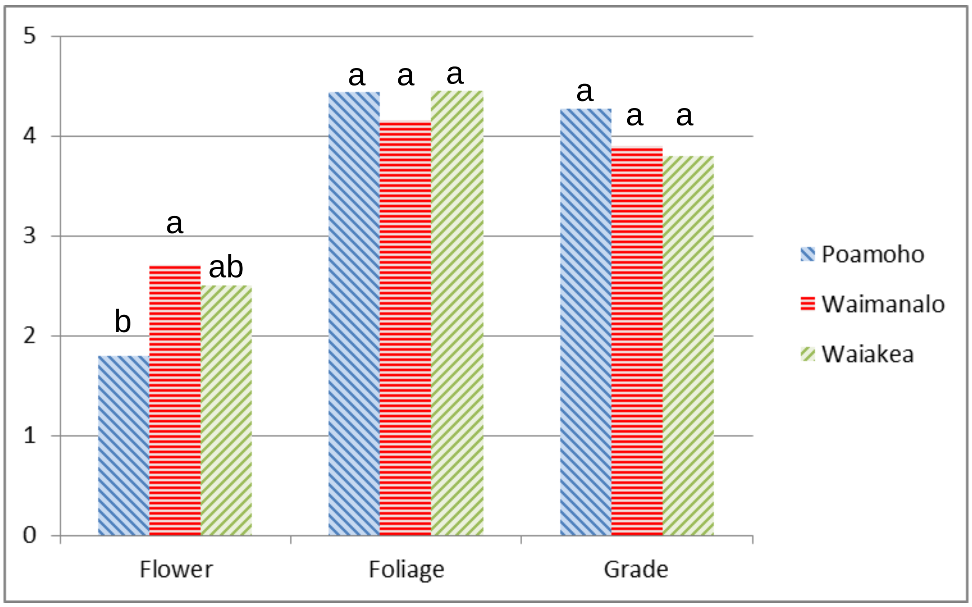

Figure 94. Comparison of visual evaluations of *M. sandwicensis* in different locations.

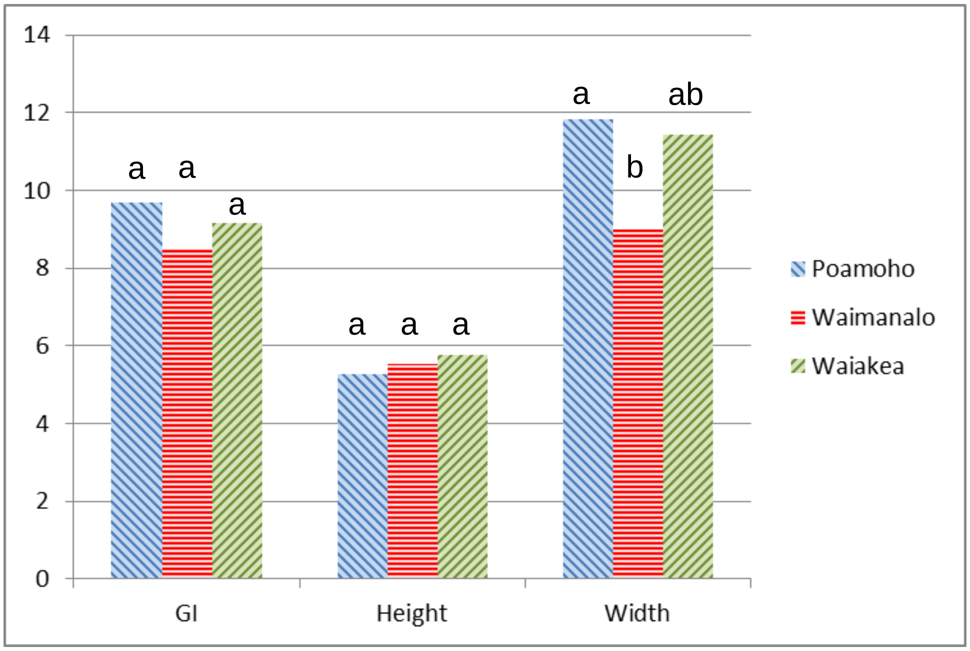

Figure 95. Comparison of growth evaluations of *M. sandwicensis* in different locations.

Figure 96. *Myoporum sandwicense* specimens after one year of evaluation in Waimanalo (left), Poamoho (center), and Waiakea (right).

Harpullia pendula – Tulipwood

Alternative to Pimenta dioica

Harpullia pendula is a small tree that has been used as street tree in Hawai´i, especially in sidewalks and parking lots. It has bright trunk and ornamental inflorescences, and nice foliage with reddish young leaves.

H. pendulla grew faster in Waimanalo, followed by Waiakea and Poamoho (figure 98) during the first year. However, many plants from Waimanalo were knocked down by wind, revealing many plants that were root bounded, resulting in 60% mortality rate after three years. In Waiakea, the mortality rate was 80%. After three years, the best results were from Poamoho (figure 97 and 98), with 30% mortality rate (figure 46), probably because of the soil with good drainage.

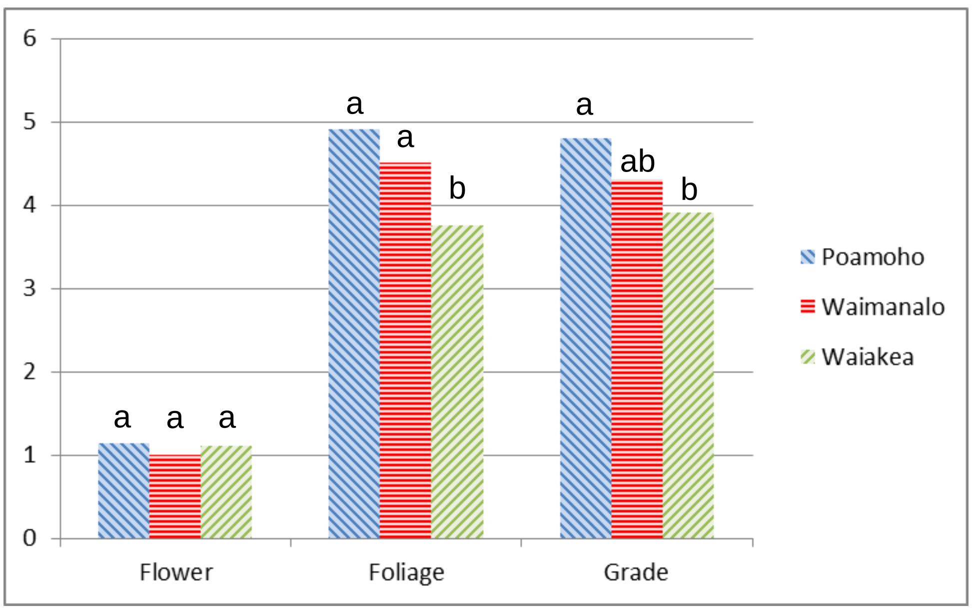

Figure 97. Comparison of visual evaluations of *H. pendulla* in different locations.

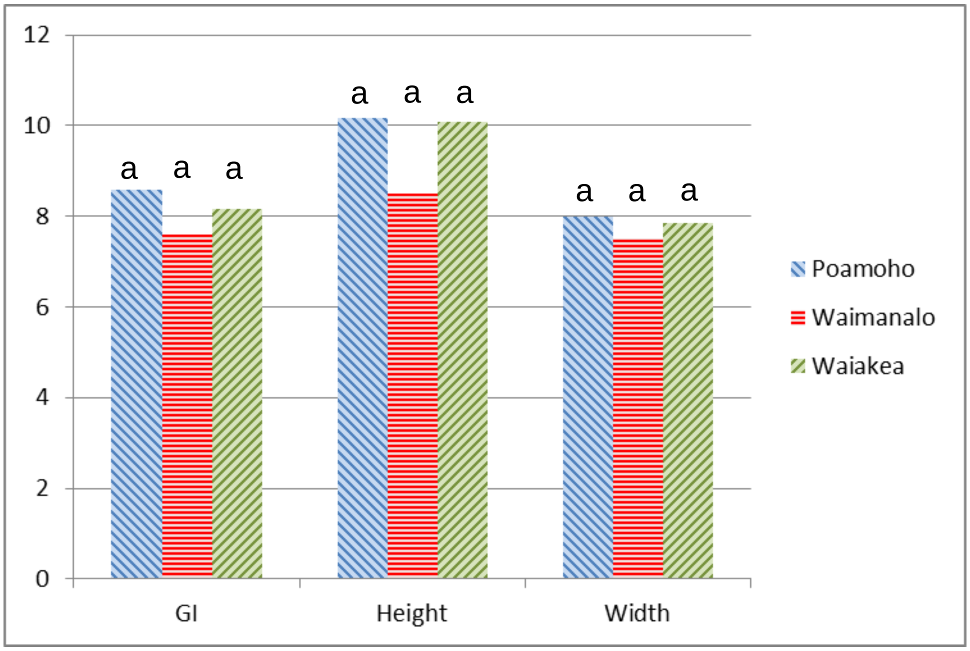

Figure 98. Comparison of growth evaluations of *H. pendulla* in different locations.

Figure 99. *Harpullia pendula* specimens after one year of evaluation in Waimanalo (left), Poamoho (center), and Waiakea (right).

Reynoldsia sandwicensis – ´Ohe makai

Native alternative to *Psidium cattleyanum*

Reynoldsia sandwicensis is a native plant reaching 65 to 70 feet tall, with straight trunk and spreading canopy. It has a smooth bark and its leaves are greenish yellow with orange stems, and the young leaves are purplish. It is a tree uncommon in the urban landscape.

The trial has shown that *R. sandwicensis* is more adaptable to a mesic environment than an extremely dry or wet, since plants in Waimanalo performed better (figures 100 and 101). Despite the close averages, the mortality rates were high in Waiakea (80%) (figure 45). In Poamoho the mortality rate was lower than in Waimanalo, but the plants that survived grew better in Waimanalo (figures 44 and 46). The fact that many plants were still dormant even after three years of planting was a problem considering their use in the landscape. Figure 102 has some representative specimens from each location.

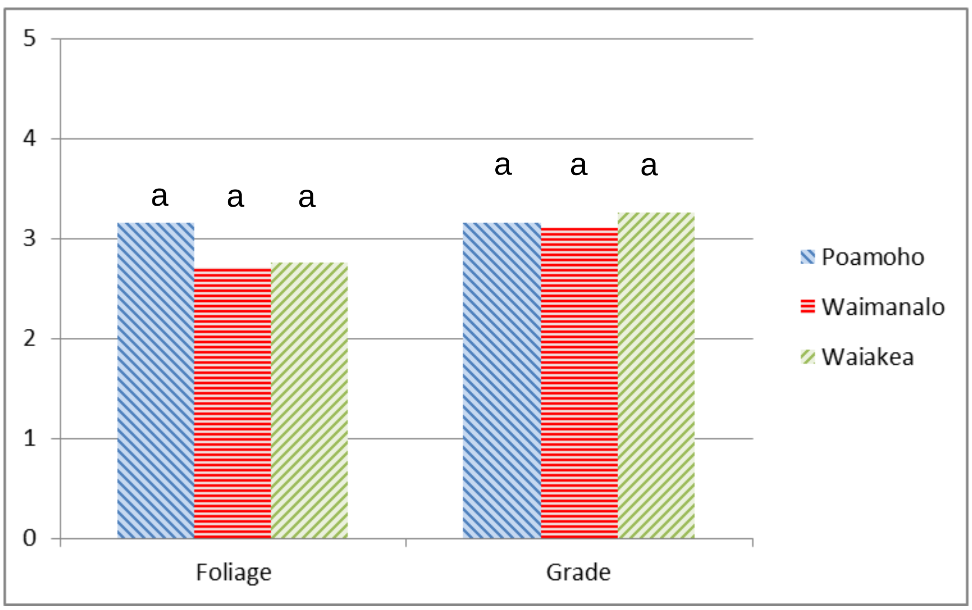

Figure 100. Comparison of visual evaluations of *R. sandwicensis* in different locations.

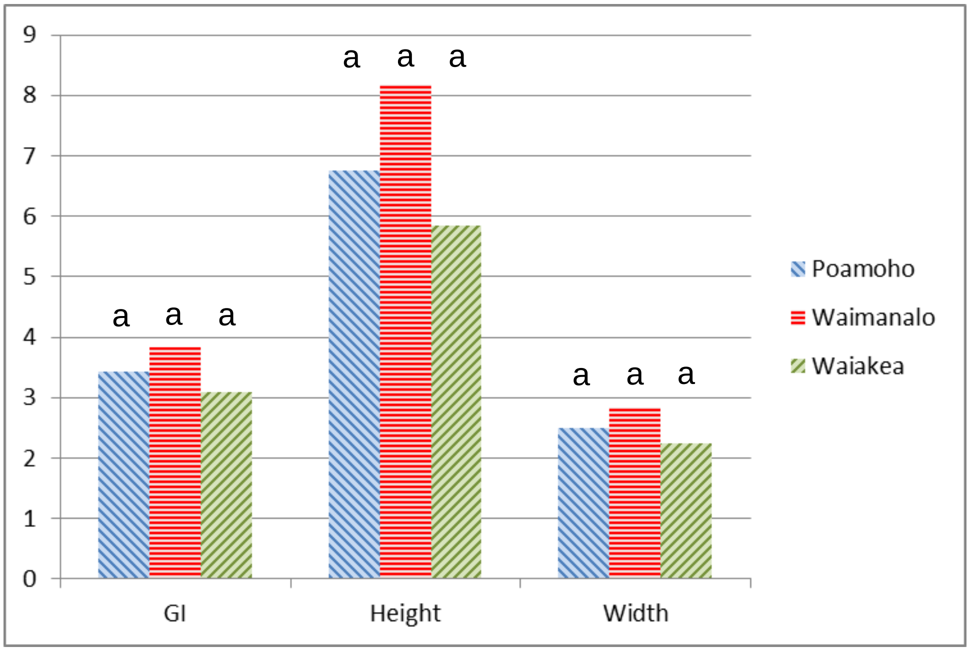

Figure 101. Comparison of growth evaluations of *R. sandwicensis* in different locations.

Figure 102. *Reynoldsia sandwicensis* specimens after one year of evaluation in Waimanalo (left), Poamoho (center), and Waiakea (right).

Stemmadenia littoralis – Lechoso

Alternative to Psidium cattleyanum

Lechoso is a tree native from Central and South America and it has been cultivated in Hawaii as a small or medium tree, up to 40 ft tall. Because of its vase-like trunk shape, Lechoso could be used as an alternative to Strawberry guava. The fragrant white flowers are very ornamental and are produced year round.

The plants being tested are growing well in all stations. However, the best results were obtained in Waiakea, were water is abundant (figures 103 and 104). Poamoho had similar results, followed by Waimanalo. Based on these results, *S. littoralis* could be used in a wide range of environments and water regiments.

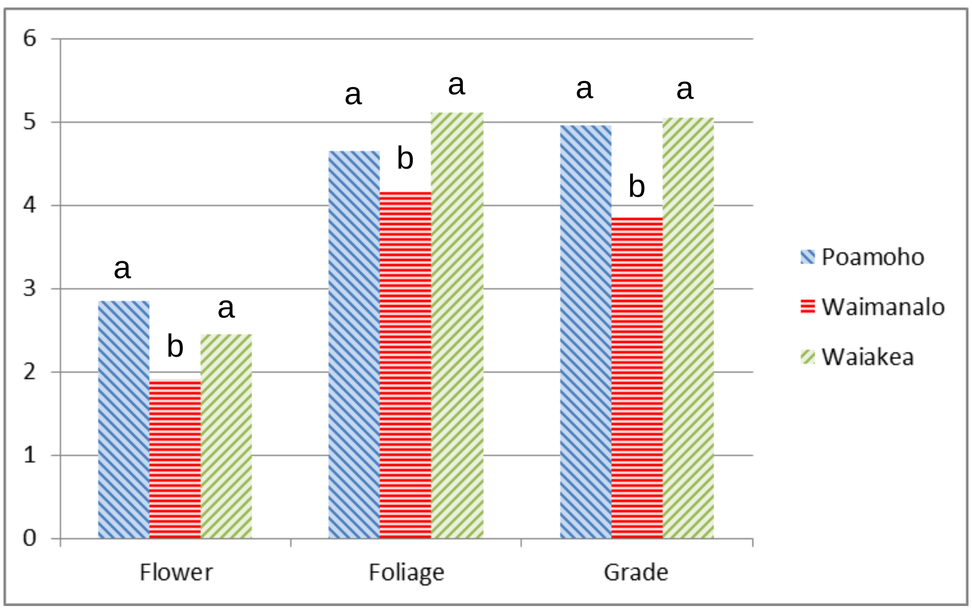

Figure 103. Comparison of visual evaluations of *Stemmadenia littoralis* in different locations.

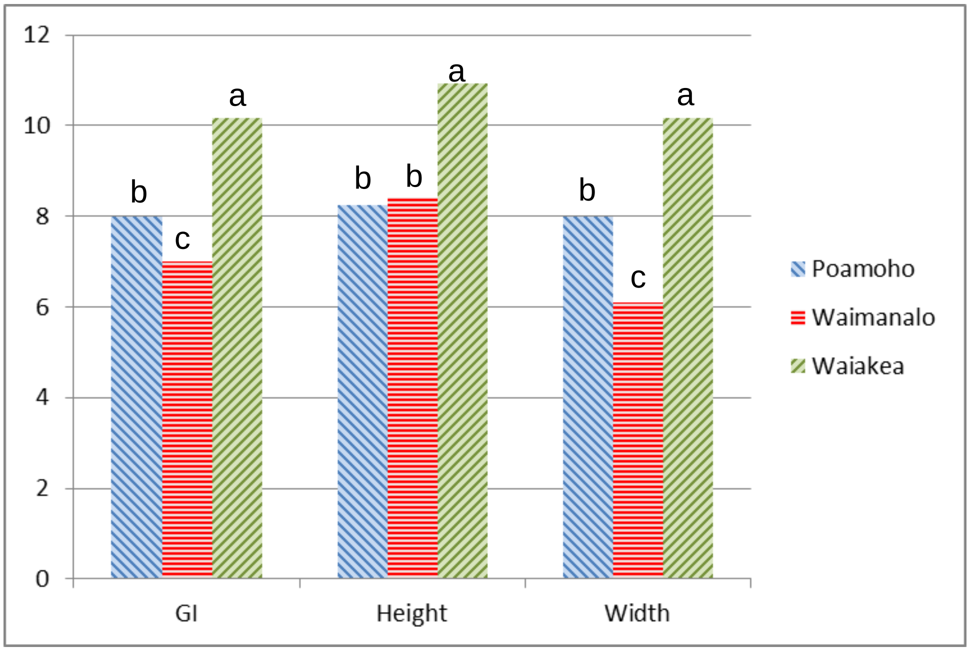

Figure 104. Comparison of growth evaluations of *Stemmadenia littoralis* in different locations.

Figure 105. *Stemmadenia littoralis* specimens after one year of evaluation in Waimanalo (left), Poamoho (center), and Waiakea (right).

Field Day

The project committee organized a Field Day at the UH/CTAHR Waimanalo Research Station on July 27, 2012, led by the project team represented by the Principal investigator Dr Andy Kaufman and the Graduate Assistant Alberto Ricordi. An invitation letter were delivered by email to members of local organizations representing professionals related to the landscape industry in Hawaii - the American Society of Landscape Architects Hawaii Chapter (ASLA Hawaii), the Landscape Industry Council of Hawaii (LICH), Oahu Nursery and Growers Association (ONGA), and the Waimanalo Agricultural Association. The invitation letter with the Field Day agenda is presented in Appendix N.

All participants of the Field Day received handouts introducing the project, including partial results and conclusions (figure 106). After going through the handout, there was a short session for questions and answers about the project. Most of the questions were related to the methods of research, such as plant material selection and evaluation. Following the questions, the research team led the participants through the experimental field and discussed their findings about each species evaluated, including recommendations of landscape use for each species (figure 107). The interest was noticeably higher for native plants, some of them unknown to some participants. After going trhough the plants, participants were asked to complete a survey, included in Appendix N. Survey participation was voluntary and asked participants about their professional activities, background related to invasive species, and opinion about the project. The results of the survey are presented below.

Figure 106. Dr Kaufman introducing the project to participants during Field Day and inviting participants to complete a post-survey.

Figure 107. Graduate Research Assistant and participants during field day at the Waimanalo Research Station.

Figure 108. Participants filling survey during field day at Waimanalo Research Station.

Question 1 - Occupation

There were 10 participants in the field day at Waimanalo. The majority of the participants were Landscape Architects (70%, seven of ten) and three of them were ASLA members. There were also three arborists, two landscape contractors and two nurserymen.

Question 2 – Background about invasive species

Ninety percent of the participants believe that: More non-invasive ornamental/landscape plants are needed on Oahu; Invasive landscape plants are a large risk on Oahu, and; they (I) would like to learn more about invasive plant species. These results indicate that the participant were aware of the importance of invasive plants and the need to have more non-invasive species available in the marker, and also showed interest to learn more about it.

Question 3 – Relevance of this project

All participants responded that this research and field day project help to address the problems of invasive ornamental plant species on Oahu.

Question 4 – Issues for using non-invasive species in landscapes in Hawaii

Plant availability was voted the most important issue relative to the use of non-invasive plants in landscapes in Hawaii, and cost was voted the least important factor. Figure 109 shows the average of responses, rated from 1 to 5, where 1 indicated the most important issues and 5 the least important issues.

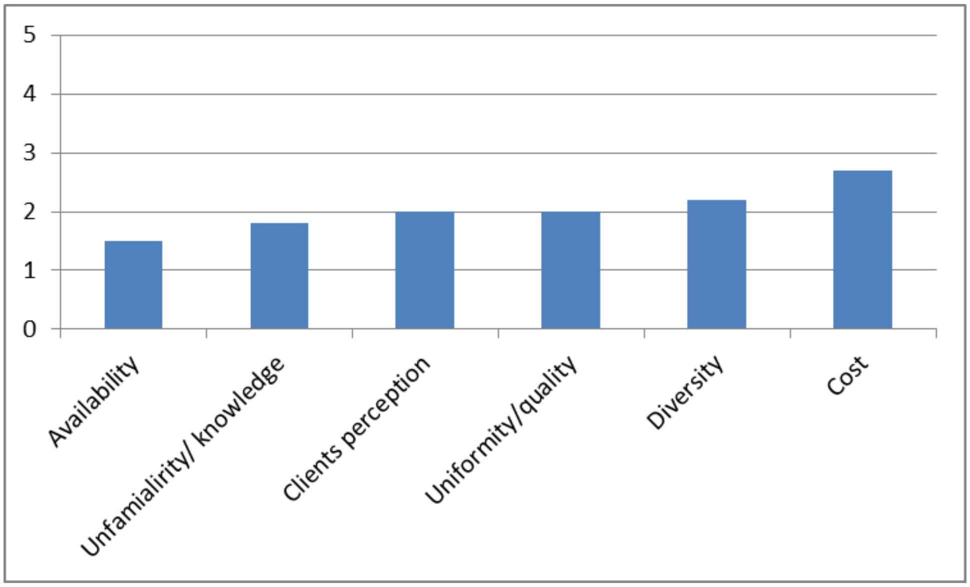

Figure 109. Average responses of field day participants asked to rank issues for using non-invasive species in landscapes in Hawaii (1 the most important and 5 the least important issues).

Question 5 – Delivery of research results through a website

All participants believe that a website showing the final results of this research and field study would be helpful to the industry.

Question 6 – Types of landscape plants

Participants were asked which kind of alternative landscape plants they would like to see more of, and ground covers were the most voted, receiving 9 of 10 possible votes (figure 110). One participant showed interest on “more alternatives for drought tolerant ground covers which have attractive floral display.”

Ground covers were followed by trees (with 8 of 10 votes) and edible plants (7 of 10 votes). Ferns did not receive as many votes, but one of the respondents included the comment “Especially ferns because of the spore dispersal, edible plants and nitrogen fixing trees to have attractive edible/ functional plants”. Another respondent included “black mondo grass”, probably indicating his/her interest into the plant.

Finally, one participant left a very positive comment: “I am really appreciative of this wealth of information that we can definitely use to help facilitate the growth of this field.

Our goal is to become more self sustainable & to teach our customers how to become one by themselves due to the demands of our customers. I am definitely willing to help this program succeed in any way possible. Contact info is on the front."

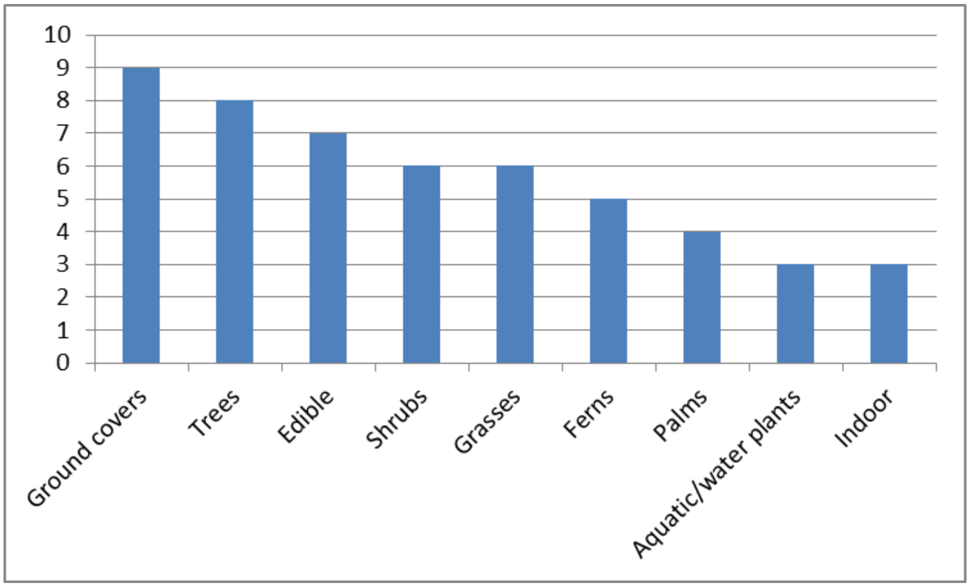

Figure 110. Total number of votes of field day participants asked to check which alternative plant types they would like to see more of (each bar represents the number of votes for each plant type).

Question 7 – About the continuity of this project

All participants voted that they would like to see more efforts like this research project/ field day addressing invasive landscape plant species in Hawaii, and that this project should continue.

Question 8 – Willingness to substitute current invasive plants

Nine of the ten participants voted that they would be willing to substitute the current plants they are using that are invasive for alternative non-invasive landscape plants. Only one participant did not mark either “Yes” or “No”, but created his own checkbox “Maybe” and added the comment that he/she “Will wait til report comes out and decide when results are verified.”

Nine of the ten participants left comments. There were comments saying that some of the plants have already been used in the industry, and some of them were not successful. It is a valid point considering that all plants were available in the market when they were purchased for this project, and most of the plants did not perform well in all environments. Thus, this research would be important to help better understand the environments which these plants are successful and which they don’t, and the proper maintenance. Also, some participants left comments about the importance of educating the public about invasive species, which is not within the scope of this project, but very important. One comment said that “I would be willing to use these plants because there is information/research showing they are successful”, showing again the importance of evaluating the plants in different environments (different research stations).

Question 9 - Suggestions

Eight of the ten participants provided comments.

Five of the eight comments mentioned that more plants should be tested, indicating the importance of continuing this trial. An additional comment demonstrated interest to have annual field visits to the trial. There were comments about the importance of continued funding for this project, ‘spread the word’ to the community, public education, and comments that that the plants were attractive. One participant recommend to use more common landscape practices (pruning, trimming, pest control, fertilizer); another comment asked to test more plants tolerant to brackish water, and more ground covers.

Survey Outcome

In general, the participants were actively involved in the field day, with several questions and comments as we walked through the field. Most of the participants requested a copy of the final report, and strongly supported continuation of this project.

Conclusion

This research project successfully addressed the use of ornamental invasive species by the landscape industry in Hawaii, one of the major environmental issues in the State. Several non-invasive species were evaluated and industry feedback confirmed that “this research and field trial project helps to address the problems of invasive species on Oahu”, according to anonymous and voluntary surveys completed after participation of Research Station field day.

This project demonstrated that the diversity of non-invasive species readily available for use by the landscape industry is limited to the inventory of local nurseries due to Hawaii’s geographical isolation, and general limitation of such a small arena of production. Although there are several desirable non-invasive species in Hawaii’s urban landscape, many of these species were not available to purchase in volume from local nurseries. This fact gives light to the importance of extension services to educate the industry about the availability and applications of these non-invasive species in the landscape.

The performance of the tested species was variable. Location seems to be the major factor affecting growth rates and visual appearance of tested plants, while fertilizing treatments affected mostly growth rates of some species. Most of the plants performed better in Waimanalo, representative of a mesic environment, followed by Waiakea (wet), and Poamoho (dry). Although most of the shrubs had high mortality rates in Poamoho, most of the trees had satisfactory results, very similar to the other research stations. These results indicate that some tested trees were suitable to a wide range of environments. An extension of the project could evaluate the maintenance requirements of there species.

The field day was an effective way for delivering information gained through this project and to receive industry feedback. Most of the participants demonstrated strong interest in having this project continued and mentioned that more plants should be tested, especially more native and exotic species, ground covers, brackish water tolerant and salt tolerant plants. There was interest having annual field visits to the trial. All participants agreed that a website showing the final results of this research and field study would be helpful to the industry, and some mentioned the importance of public education.

The Hawaii Weed Risk Assessment (HWRA) is an important tool to identify invasive species. Since certain species considered invasive by the HWRA have non-invasive cultivars, such as the seedless *Lantana camara* ‘SunGold’ tested in this project, the HWRA should not be used alone to decide whether or not to avoid certain species. However, the HWRA should always be considered before introducing new plant m aterials in Hawaii.

In summary, based on collected data and industry feedback, this research project achieved its goal of promoting a more sustainable landscape industry in Hawaii. In addition, it received support from the industry to continue observations on the current plants, as well as adding more species.

Acknowledgements

We thank (in alphabetical order): Roxanne Addams, Rick Barbosa, Kevin Eckert, Dennis Kim, Joshlyn D. Sand, and all others who shared their knowledge about native plants and other non-invasive species during this project. We also want to thank Chuck Chimera and his HWRA team for their assistance providing weed risk assestment ratings. We want to thanks the staff from Waimanalo, Poamoho and Waiakea Research Stations for their valuable efforts keeping the experimental plots well maintained. We want to thank the numerous volunteers that assisted with data collection and plot maintenance. Finally we thank the Hawaii Invasive Species Council for the grant that funded this project.

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Appendix A. Email sent to landscape architects with list of invasive plants

Subject: Need your Help for Alternative Plants

Aloha,

I need your help as I am working on a research project with the Hawaii Invasive Species Council (HISC) to introduce some alternative ornamental plants for our industry.

Could you please take a few minutes and pick from the attached list 5 of the trees listed in green that you would like alternatives for. Also, pick 5 of the shrubs listed in blue that you would like alternative for.

Just list the number of the plant in the spaces below.

Mahalo for your time.

- Andy

Trees (Listed in green)

____

____

____

____

____

Shrubs (Listed in blue)

____

____

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____

____

Appendix B. List of Invasive species provided to Landscape Architects for voting.

1	Acacia auriculiformis	Darwin black wattle
2	Acacia crassicarpa	Northern wattle
3	Acacia farnesiana	Sweet acacia
4	Acacia longifolia	Sidney golden wattle
5	Acacia mearnsii	Australian acacia
6	Acacia melanoxylon	Australian blackwood
7	Acacia nilotica	Gum Arabic tree
8	Acacia parramattensis	Parmatta green wattle
9	Adenanthera pavonina	Peacock tree
10	Albizia chinensis	Chinese albizia
11	Bauhinia monandra	Pink orchid tree
12	Bischofia javanica	Bishopwood
13	Buddleja davidii	Orange eye butterfly bush
14	Buddleja madagascariensis	Smokebush
15	Casuarina cunninghamiana	Cunninghamia beefwood
16	Chrysophyllum oliviforme	Satin leaf
17	Cinchona pubescens	Red cinchona
18	Cinnamomum verum	Cinnamon tree
19	Citharexylum spinosum	Fiddlewood
20	Cloredendrum buchananii	Red clerodendrum
21	Clerodendrum quadriloculare	Bronze leaved clerodendrum
22	Corymbia citriodora	Lemon-scented gum
23	Cryptostegia madagascariensis	Madagascar rubbervine
24	Dalbergia sissoo	Indian rosewood
25	Elaeagnus umbellata	Autumn olive
26	Eucalyptus grandis	Rose gum
27	Eucalyptus paniculata	Grey ironbark

28	Falcataria moluccana	Albizia
29	Fraxinus uhdei	Tropical ash
30	Grevillea banksii	Red silk oak
31	Grevillea robusta	Silk oak
32	Lantana camara	Lantana wildtype
33	Leptospermum scoparium	Broom teatree
34	Ligustrum sinense	Chinese privet
35	Melaleuca quinquenervia	Paper bark tree
36	Pimenta dioica	Allspice tree
37	Psidium cattleianum	Strawberry guava
38	Senna surattensis	Kolomona
39	Thevetia peruviana	Be-still tree
40	Washingtonia filifera	California fan palm
41	Washingtonia robusta	Mexican fan palm

Appendix C. Matrix with characteristics of trees selected for this study.

Botanical name		Pimenta dioica	Psidium cattleianum	Citharexylum spinosum	Thevetia peruviana	Cassia surattensis
Common name		Allspice	Strawberry guava	Fiddlewood	Bestill	Golden senna
WRA		7	18	7	9	
Family		Myrtaceae	Myrtaceae	Verbenaceae	Apocinaceae	Fabaceae
Origin		India, Americas	Brazil	West Indies	Mexico/ Central america	SE Asia /Australia
Growth		Slow	Aggressive	Fast	Fast	Fast
Drought		Tolerant	Tolerant	Tolerant	Tolerant	Tolerant
Salt			Not tolerant	Tolerant		Low tolerance
Height		40'	20'	50'	25'	15'
Width			15'		25'	11'
Foliage	Habit	Moderate	Dense Rounded	Piramidal	Round dense	Round
	Per/Dec	Evergreen	Evergreen	Deciduous/Orange fall	Evergreen	Semi decidous
	Color	Bright green	Dark green	Bronze / Ochre colour	Dark green	Evergreen
Flower	Showy	Yes	Irrelevant		Regular	Yes
	Color	White	Write	White	Yellow	Yellow/Gold

	Size	Inflorescence	Small	Inflorescence 10"	2"	1.5"
Fruit	Edible	Spice	Yes	No/ Ornamental	No	No
	Color	Dark purple/brown	Purple/Red or Yellow	Red / Orange	Green/black	Brown
	Size	0.25"	1"	Inflorescence		Legume 7"
Trunk structure		Thin	Thin	Piramidal	Relevant	Relevant
Bark		Gray	Light brown/Purple/Green	Light gray/fissured	Purple gray	Silver gray
Propagation		Seed	Seed	Seed; Cutting	Seeds	Seeds
Ladscape use		Street, Accent, Herb	Fruit tree, Container, Accent	Street, Container	Container, Street, Hedges, Accent, Screen, Shade	Container, garden, street, street

Matrix with characteristics of shrubs selected for this study.

Botanical name		Tibouchina urvilleana	Lantana camara	Ligustrum sinense	Clerodendrum buchananii	Clerodendrum quadriloculare
Common name		Glorybush	Lantana	Chinese privet	Red clerodendrum	Starburst
WRA		24	21	11	7	11
Family		Melastomataceae	Verbenaceae	Oleaceae	Verbenaceae	Verbenaceae
Origin		Brazil	Americas and Africa	China	Tropical asia/ Pacific	Tropical asia/ Pacific
Growth		Medium	Fast	Fast	Fast	Fast
Drought		Tolerant	Tolerant	Moderate	Tolerant	Tolerant
Salt						
Height		6-15'	2-6'	5-10'	6'	6-12'
Width		10'	8'	10'	-	6'
Foliage	Habit	Rounded	small shrub/ groundcover	Dense shrub	Rounded	Oval/rounded
	Per/Dec	Evergreen	perenial	Perenial	Evergreen	Semi-evergreen
	Color	Dark green	green	Green/Variegated	Dark green	Dark green/ Burgundy
Flower	Showy	Yes	yes	Yes	Yes	Yes

	Color	Purple	white/yellow/red/orange	White	Red	White/ Pink
	Size	medium	inf 2"	Small	Big inflorescences	Big inflorescences
Fruit	Edible	No	No	No	No	No
	Color	Tan	Irrelevant	Dark	Irrelevant	Irrelevant
	Size	Irrelevant	Irrelevant	Small	Irrelevant	Irrelevant
Trunk structure		Small	Irrelevant	Abundant, arched		Erect/Arched
Bark		Irrelevant	Irrelevant	Gray	Irrelevant	Tan
Propagation		Seeds	Seeds	Produce suckers	Cuttings	Cuttings
Ladscape use		Container, Cut flower, Accent, Screen, Edge	Ground cover, cut flower, borders	Container;Hedges; borders	Container, Accent, Screen, Edge	Container, Accent, Screen, Edge

Appendix D Allspice alternatives.

Code	Botanical name	Common name	Landscape uses	WRA	Attributes	Height/ Habit
Inv1	Pimenta dioica (Staples & Herbst, 2005) (Starr et al. 2003) (Rauch and Weissich, 2000)	Allspice	Specimen, container, street	7	Light bark contrasting leaves. Leaves with spicy odor and white flowers.	25-40' Small/medium tree
Ex1	Caesalpinea ferrea (Lorenzi 2002)	Brazilian Ironwood	Specimen, street, shade.	-3	Smooth cream/white pealing bark contrasting with leaves. Slow growth, but the final size is a huge tree if not managed.	60 - 80' Medium/Large tree
Ex2	Harpullia pendula (Staples & Herbst, 2005)	Tulipwood tree	Street, shade	-4	Gray bark and small size. The tree has been already used in Hawai'i with considerable success (Leeward).	25' Small tree
Ex3	Aglaia odorata	Chinese rice	Screen,		Light bark and attractive	20'

	(Staples & Herbst, 2005)	flower	specimen, container, shade/small tree		inflorescences.	Big shrub/ small tree
Ex4	Resnova sp.				Interesting bark, silver and golden	
Nat1	Psydrax odorata (Staples & Herbst, 2005) (Hawaiian electric company et al, 2002)	Alahe'e	Specimen, screen, container		White and fragrant flower, light grey/white bark, dark leaves, drought tolerant	6 – 30' Small tree/ Dense shrub

Appendix E. Psidium alternatives.

Code	Botanical name	Common name	Landscape uses	WRA	Attributes	Height/ Habit
Inv2	Psidium cattleianum (Staples & Herbst, 2005) (PCA 2005) (Gilman & Watson, 1994)	Strawberry guava	Specimen, container, shade	18	Smooth brown peeling bark, dark leaves, can be pruned to create statuesque effect. Glossy dark green leaves and edible fruits.	H: 25' Small to medium tree
Ex1	Lagerstroemia tomentosa	Crape myrtle	Street, specimen, shade	-	Small tree with interesting bark and purple flower	20-25' Small tree
Ex2	Myrciaria cauliflora (Staples & Herbst, 2005) (Lorenzi 2002)	Jabuticaba	Street, specimen, container	-	Interesting bark and edible fruits. The tree can be pruned for desirable structure. Slow growth.	8-20' Small to medium size tree
Ex3	Lagerstroemia speciosa	Crape myrtle	Street, specimen, shade	-4		
Ex4	Stemmadenia	Lecheso	Street, shade,	-5	White flowers	20'

	littoralis		specimen			Small tree
Ex5	Erythrina abyssinica	Lucky bean tree	Street, specimen, shade	5	Interesting shape and bark. Same structure as Lagerstroemia.	12’ Small tree
Ex5	Guaiacum officinale	Lignum viteae	Street, specimen, shade, container, street	-6	Gray and green bark and attractive yellow seeds, year round. Drought tolerant. Very slow grow, fit *C. surattensis* use.	15 – 35’ Small tree
Nat1	Reynoldsia sandwicensis	´ohe			Smoth bark; reddish shoots	

Appendix F. Bestil alternatives.

Code	Botanical name	Common name	Landscape uses	WRA	Attributes	Height/ Habit
Inv3	Thevetia peruviana (Staples & Herbst, 2005) (Rauch and Weissich, 2000)	Bestill tree	Street, screen	9	Bright green leaves and yellow flowers year round	3-25’ Dense shrub/ small to medium tree
Ex1	Thevetia thevetioides (Staples & Herbst, 2005)	Giant thevetia	Street, screen	1	Very similar with *T. peruviana*, but is harder to propagate.	30’
Ex2	Mussaenda spp. (philippica and x ’Dona Luz’) (Rauch and Weissich, 2000)	Kahoy dalaga	Screen, specimen, container.	-3	Spreading shrub with white	15’ Spreading shrub
Ex3	Brunfelsia densiflora	Serpentine hill raintree	Street, screen, speciment (based on		Shrub to small tree with yellow flowers.	15’

			Ho'omaluhia)			
Nat1	Dodonea viscosa (Hawaiian electric company et al, 2002)	A'ali'i	Street, screen, specimen,		Dense shrub with bright green leafs and red or green attractive.	25' Dense shrub or small tree

Appendix G. Fiddlewood alternatives.

Code	Botanical name	Common name	Landscape uses	WRA	Attributes	Height/ Habit
Inv4	Citharexylum spinosum (Staples & Herbst, 2005) (Rauch and Weissich, 2000)	Fiddlewood	Street, container, shade	9	Suitable to any condition and very fast growth,	50’ Medium tree
Ex1	Thespesia grandiflora (Staples & Herbst, 2005)	Maga	Street, shade	-1	Regular canopy with large pink flowers	50’ Small to medium size tree
Ex2	Tabebuia impetiginosa (Lorenzi 2002) (Rauch and Weissich, 2000)	Pink ipe	Specimen, street and roads.	-2	Deciduous, rounded canopy, pink flowers	25-40’ Medium size /Large tree
Ex3	Lagerstroemia speciosa (Institute of Horticulture Hong Kong, 2005) (Rauch and Weissich,	Giant/Queen Crape Myrtle	Street, specimen	-4	Peeling gray trunk, with purple inflorescence very attractive.	50’ Medium/Large tree

	2000) (Staples & Herbst, 2005)					
Ex4	Stemmadenia littoralis (Rauch and Weissich, 2000) (Staples & Herbst, 2005)	Lecheso	Street, shade, specimen	-5	White flowers	20’ Small tree
Ex5	Moquinia tomentosa		Street, shade		Medium size tree	30’ Medium tree
Nat1	Sapoindus	Ho’awa			Bronzed leaves	15’

Appendix H. Cassia alternatives.

Code	Botanical name	Common name	Landscape uses	WRA	Attributes	Height/ Habit
Inv6	Cassia surattensis (Hawaiian electric company et al, 2002) (Institute of Horticulture Hong Kong, 2005)	Golden senna	Screen, specimen, street	9	Small tree with showy yellow flowers. Drought tolerant. Year round flowering.	10-25' Small tree
Ex1	Guaiacum officinale (Hawaiian electric company et al, 2002)	Lignum viteae	Street, specimen, shade, container, street	-6	Gray and green bark and attractive yellow seeds, year round. Drought tolerant. Very slow grow, fit *C. surattensis* use.	15 – 35' Small tree
Ex2	Rondoletia odorata (Rauch and Weissich, 2000)	Rondoletia	Screen, specimen, street	-4	Dark green with showy orange blooms year round, is wind tolerant and partially drought tolerant.	8'
	Ixoras from	Ixora	Screen, specimen, street		Many colors	6 - 8'

	Ho'omaluhia					
Nat2	Gardenia brighamii	Nanu	Street, shade, specimen, container		Glossy dark green leaves, white fragrant flowers. Suitable for street and parking planting, the main use of *C. surattensis.*	9' Small tree

Appendix I. Lantana alternatives.

Code	Botanical name	Common name	Landscape uses	WRA	Attributes	Height/ Habit
Code	Botanical name	Common name	Landscape uses	WRA	Attributes	Height/ Habit
Inv1	Lantana camara	Lantana	Groundcover, small shrub, specimen	21	1’’ yellow clusters	1-3’ Groud cover/ Small shrub
Ex1	*Lantana* ‘New gold’	Lantana (cultivar)	Groundcover, small shrub, specimen		Seedless cultivar of lantana with year round blooming and propagation by cuttings, don’t set seeds.	1-3’ Groud cover/ Small shrub
Ind	Sida fallax	‘Ilima, ‘Ilima papa	Ground cover, small shrub, specimen		Creeping and spreading groundcover, has yellow flowers and is highly drought and salt tolerant	1-3’ Ground cover/small shurb
Nat2	Wikstroemia uva-ursi	Akia	Groundcover, small shrub, specimen		The yellow flowers and the red or orange fruits are showy, almost year	1-3’ Ground cover/small

						round, and the plant is drought tolerant.	shurb

Appendix J. Tibouchina alternatives.

Code	Botanical name	Common name	Landscape uses	WRA	Attributes	Height/ Habit
Inv2	Tibouchina urvilleana	Glory bush	Specimen, border, hedge	10	Purple flowers	3-12’
Ex1	Alyogyne huegelii	Blue hibiscus	Specimen, screen		Dense shrub with delicate purple flowers	6’
EX2	Lavatera maritima (San Marcos growers)	Tree mallow	Specimen, screen		Fast growing evergreen with big pink/purple flowers.	6-8’
Nat1	Hibiscus furcellatus		Specimen, medium/big sized shurb		Tall shrub with purple flower	7’

Appendix K. Ligustrum alternatives.

Code	Botanical name	Common name	Landscape uses	WRA	Attributes	Height/ Habit
Inv3	Ligustrum sinense	Chinese privet	Hedge	11	Dense foliage	
Ex1	Thunbergia erecta	Bush thumbergia	Screen, specimen, container	-2	Dense shrub with discreet purple flowers. Easy controlled as wall or short barrier by pruning.	6 – 15’
Ex2	Acalypha spp.	Acalypha	Hedge, shrub	-7 to +2	Many cultivars	
Nat1	Osteomeles anthyllidifolia	Ulei	Short screen		Dense shrub with dark glossy leafs. White flower.	3 - 5’
Nat2	Nototrichium humile	Kului	Not same color		Light green/silvery leafs.	5 - 7’

Appendix L. *Clerodendrum buchananii* alternatives.

Code	Botanical name	Common name	Landscape uses	WRA	Attributes	Height/ Habit
Inv5	Clerodendrum buchananii	Red clerodendrum	Screen, specimen, container	7	Evergreen with brilliant red flowers	12’
Ex1	Mussaenda sp.	Red mussaenda	Specimen, screen, container	-4 to 0		12’
Ex2	Calliandra haematocephala	Red powderpuff	Specimen, screen	0	Fast growing with showy red inflorescences.	16’
Ex3	Malvariscus penduliflorus	Turk’s cap	Specimen, screen, pruned	-9	Dark green leaves and abundant red flowers produced year round	15’
Nat1	Dodonea viscosa (Hawaiian electric company et al, 2002)	A’ali’i	Street, screen, specimen,		Dense shrub with bright green leafs and red or green attractive.	25’ Dense shrub or small tree

Appendix M. *Clerodendrum quadriloculare* alternatives.

Code	Botanical name	Common name	Landscape uses	WRA	Attributes	Height/ Habit
Inv6	Clerodendrum quadriloculare	Bronze leaved clerodendrum	Specimen	11	Shrub with purple leafs on the underside and pink/cream inflorescences. The overall aspect is a purplish shrub with creamy to purple blossoms	5-9' Big shrub
Ex1	Acalypha spp.	Acalypha, collection near Pope and many Botanical gardens	Specimen, screen	-7 to 2	Many cultivars	
Ex2	Ixora sp. (Ho'omaluhia)	Ixora	Specimen, screen		Compact shrub	
Nat1	Hibiscus arnottianus	Kokio ke'o ke'o	Specimen, screen		Evergreen shrub with dark green leaves, purple stamens and white flowers produced year round.	8' Small tr shrub

Appendix N. Invitation letter and survey delivered during field day at Waimanalo Research Station on July 27th, 2012.

College of Tropical Agriculture and Human Resources
Department of Tropical Plant and Soil Sciences

UNIVERSITY of HAWAI'I MANOA

June 12, 2012

Aloha,

The Tropical Landscape and Human Interactions Lab run by Dr. Andy Kaufman would like to invite you for a Field Day in Waimanalo at the University of Hawaii's CTAHR Research Station on Friday Jule 27th .

The project has evaluated over 17 species of non-invasive landscape plants as replacement to common invasive species in Hawaii. This has been made possible through a research grant from HISC. As the project is nearing its completion, we would like to share some of the intial results, as well as gain your vauable feed back.

The field day will run from 8:30 am to 11: 00 am.

Date: July 27th, Friday
Agenda:
8:30 - 9:00 am – Check in
9:00 - 9:45 am – Presentation of the project
9:45 - 10:30 am – Visit the field and check plants.
10:30 - 11:00 am – Discussion and closing remarks

Location: Waimanalo Research Station, 41-698 Ahiki Street, Waimanalo, HI, 96795

We hope you can make it!   Water and Shade will be provided.

Please RSVP via email to Alberto Ricordi (Graduate Student) at albertoh@hawaii.edu by July 25 @ 5pm.

Mahalo,

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(808) 956-7958

HISC Field Day JULY 27, 2012 **SURVEY**

Aloha, we would appreciate if you would take a few minutes and complete this quick survey. Participation in this survey is voluntary and your answer will be confidential with only the overall results will be shared. Your responses will greatly help the landscape industry. All responses from this survey are anonymous.

1) I am a (check all that apply):

☐ Landscape architect

☐ ASLA member

☐ Landscape contractor

☐ LICH member

☐ Nurseryman

☐ Other: ____________________________________

2) I have the following beliefs about invasive and non-invasive landscape plants (check all that apply):

☐ Invasive landscape plants are not a large risk on Oahu

☐ More non-invasive ornamental/landscape plants are needed on Oahu.

☐ No more non-invasive ornamental/landscape plants are needed on Oahu.

☐ Invasive landscape plants are a large risk on Oahu.

☐ I would like to learn more about invasive plant species.

3) Do you believe that this research and field trial project helps to address the problems of invasive species on Oahu?

☐ Yes, this project helps addressing the problems of invasive species on Oahu.

☐ No, this project is not effective addressing the problems of invasive species on Oahu.

4) Please rate the importance of each issue relative to the use of non-invasive plants in landscapes in Hawaii:

Issue	**1 – Very important**	**2- Important issue**	**3- Some importance**	**4- very little importance**	**5- Not important at all**
Availability					
Diversity					
Unfamiliarity/ Knowledge					
Clients perception					
Cost					
Uniformity					
Other (specify):					

5) What would you recommend to make this project more effective?

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6) Do you believe that a website showing the seasonal plant evaluations would be helpful to the industry?

☐ Yes

☐ No

7) In which of the following landscape plant types would you like to see have more alternatives? Is there any specific type of plant that you would like to see more alternatives? Please add any comment if you wish. (check all that apply)

☐ Shrubs	☐ Palms	☐ Grasses
☐ Ground covers	☐ Trees	☐ Edible
☐ Ferns	☐ Aquatic/ water plants	☐ Indoor

8) Would you like to see more efforts like this addressing invasive species landscape plants in Hawaii?

☐ Yes, this project should continue.

☐ No, this project should not continue.

9) After learning about these plants at the field day trial, would you be willing to substitute the current plants that are invasive for alternative non-invasive landscape plants, and why?

☐ Yes ☐ No

Why:

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You finished the survey. Thank you!