The effects of mountain ridge soil characteristics, canopy cover, and ground cover on the native and introduced plant communities in Mo'orea, French Polynesia

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Abstract. Introduced plant species in the Society Islands have drastically changed the plant communities that exist on Mo'orea, French Polynesia. Many Polynesian and post European arrival introduced plants have penetrated in to the native flora in lower elevations. Remaining populations of native plant communities are found on nutrient poor lateritic ridges. This study aimed to quantify the plant compositions that develop on mountain ridges with lateritic and eutrophic soil types. Furthermore, soil comparisons were made by evaluating nitrogen content, phosphorous content, pH and organic matter. A sapling growth study was conducted to observe the differences in abilities of introduced species saplings to survive and grow in lateritic versus eutrophic soil types. I also investigated the canopy and ground cover in the different ridge types to detail their relationships with introduced vegetation. It was found that native plants are more abundant on lateritic ridges compared to eutrophic ridges, where Polynesian introduced plants dominated. Furthermore, eutrophic soils were measured to have more nitrogen content and a less acidic pH, which can explain the success of introduced plant species. Finally, the relative abundance of non-native plant species positively related to the canopy cover and negatively related to the ground cover. Understanding the ridge characteristics can provide insight on why introduced plant species do not dominate in lateritic ridges and explain the remnant relic population of native plants in Mo'orea, French Polynesia.

Key words: lateritic soil, eutrophic soil, mountain ridges, plant composition, native species, Polynesian introduced, recently introduced, Mo'orea, French Polynesia, canopy cover, ground cover

INTRODUCTION

The dominance of introduced species over native species is an issue that is common in many regions of the Pacific. In the Society Islands of French Polynesia, there are two time periods when new species were introduced. The initial Polynesian settlers of the Society Islands arrived at around 600 AD and brought with them vegetation for sustenance and medicinal purposes. These included the bread fruit tree *Artocarpus altilis*, the noni plant *Morinda citrifolia*, and the Tahitian chestnut *Inocarpus fagifer* (Meyer and Florence 1996). When the first Europeans arrived in the 18th century, they brought with them another wave of foreign plant species. Since then, over 1500 non-native species have been introduced either intentionally as horticulture and ornaments or accidentally by human transport (Meyer and Florence 1996). Many of these non-native species have become self-propagating in the wild, and some have been able to penetrate into the native biota of these islands.

Non-native species are sometimes so proficient at establishing populations that the native vegetation must struggle to attain the limited resources that are available. When these new species are able to aggressively infiltrate undisturbed regions of native communities, they become an invasive species. This intrusion by invasive species can alter native plant populations if the non-native plants are able to establish and alter the resources and disturb the community assembly (Tilman 2004).

This new source of competition often causes the realized niche of the native flora to shrink, usually to an area significantly smaller than its fundamental niche. Remnant populations of native species are often confined to marginal habitats with inhospitable environments, as is observed with the endemic serpentine plants in California (Murphy and Ehrlic 1989; Huenneke 1990). Even within these relic native sites, native plants have the greatest concentration in harsh microhabitats such as crevices and rocky hammocks (Gram 2004). Studying the habitat environment in which these plants reside can provide insight on the retreat of native vegetation to certain marginal regions. There are several factors that can dictate the quality of a habitat and whether or not it is suitable for plant establishment, including canopy cover, ground cover and soil quality.

Canopy cover and ground cover can have a large impact on plant communities. Ultimately, the architecture of trees with significant canopies can affect the soil and vegetation underneath (Schmidt 2002). Canopy can lead to the disruption of native vegetation by blocking out sunlight and altering the chemical content of the underlying soil through leaf litter (Madsen 1991, Isichei 1992, Vitousek 1982). The degree of soil exposure can also be affected by canopy cover, which can alter the environment that plant communities must grow on. Furthermore, a study on the germination of *Metrosideros sp.* showed that ground cover by ferns can prevent the germination of seeds (Wickland 1999). Thus, both variables can determine the plant compositions in different habitats.

In addition to canopy and ground cover, previous studies have demonstrated that abiotic factors, such as soil characteristics, play an important role in determining the survival of native species and the resistance of existing native populations to invasive plants (Stromberg and Griffin 1996; Corbin and D'Antonio 2004). Soil contents such as nitrogen, phosphorous, water, metals, and organic matter can alter the establishment of a plant community. For example, previous studies have illustrated the critical role that water content in soil has on the proliferation of invasive plant species C*entaurea solstitialis* (Briones 1998; Morghan and Rice 2006). Furthermore, studies have demonstrated the importance of nitrogen and phosphorus plant biomass development (Powell 2009, Vitousek and Farrington 1997). Nitrogen is the primary nutrient that determines plant growth in a region because of the high demand for nitrogen in plant metabolism and photosynthesis (Chapin et al. 1987).

In soils with limited amounts of essential nutrients, abnormal pH or low organic content, plants must compete for the finite resources. An example of a low nutrient environment is lateritic soil mountain ridges, which are formed in tropical regions that have frequent precipitation. These soils are highly weathered and do not receive additional nutrients from rock fall or talus (Jordan 1981 and Tardy 1997). On the contrary, mountain ridges with ample amounts of nutrients at the optimal pH and moisture conditions are called eutrophic ridges. These sites create an environment where plant establishment is less restricted. Nutrition-rich soils often receive periodic rock fall or are replenished with organic material such as leaf litter. Past studies on continental plant communities have demonstrated that non-native plants that normally grow in these eutrophic regions cannot encroach upon regions with poor soil types because they cannot cope with the nutritional deficit (Grime 1979). Similar to the relic native plant populations in serpentine communities of California, lateritic soils in tropical climates may offer a similar refugium for its native plants.

Mo'orea, French Polynesia contains mountain ridges that have both lateritic and nutrient rich soils and thus is a fitting location to study the effects of introduced plants on native plant distributions. There are several goals for this study: (1) To compare the plant compositions of lateritic mountain ridges with those of eutrophic mountain ridges. I assessed the percent compositions of native plants, Polynesian introduced plants, and recently introduced plants at each study site. (2) Evaluate the soil characteristics at each field site. Soil samples were analyzed to compare differences in soil content between lateritic and eutrophic soils. (3) To experimentally determine the effects of soil type on the viability and growth of introduced plant species saplings. (4) Investigate relationships between canopy cover and ground cover of mountain ridges with its associated plant types. The hypothesis was that invasive plant species are not as well adapted to growing in poor quality soil with low amounts of essential nutrients. As a result, on the less hospitable lateritic ridges, introduced species cannot establish a community and native species are able to maintain a population with minimal competition. However, in regions where introduced plant species are a strong competitor to native plants, such as eutrophic ridges, the native flora will shrink in abundance. In addition, it was hypothesized that canopy cover is more extensive on eutrophic ridges and that it increases with the abundance of introduced species. Ground cover was predicted to decrease in eutrophic ridges and increase with the percentage of native plant species.

METHODS

Study Sites

Study sites were selected on the trail between Trois Pinus and Trois Cocotiers on the higher slopes of the Opunohu Valley due to the abundance of both lateritic and organic ridges along the trail (Saquet 2003). The sites consisted of five lateritic ridges and five eutrophic ridges within the elevation band of 170 to 400 meters. All of the sites have similar annual precipitation (Laurent et al. 2004). General environmental observations were noted and UTM coordinates were recorded for mapping purposes.

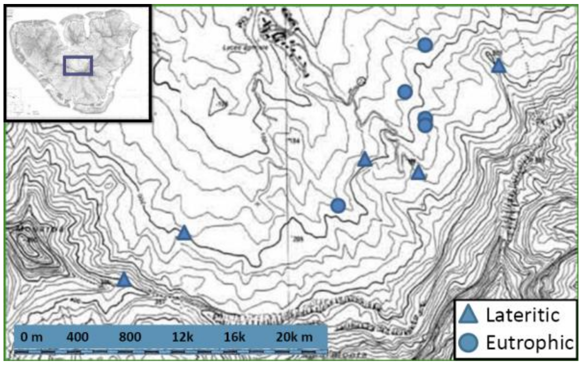

FIG. 1. Map of study sites between Trois Pinus and Trois Cocotiers. Triangles represent lateritic field sites and circles represent eutrophic field sites

Study Sites	Soil Type	Elevation
Post Stream (PS)	Eutrophic	180 m
Banyan Tree Site (BT)	Eutrophic	170 m
Pre Trail Junction (PrTJ)	Eutrophic	175 m
Post Trail Junction (PoTJ)	Eutrophic	225 m
Hibiscus Arch (HA)	Eutrophic	225 m
Trois Pinus (TP)	Lateritic	305 m
Belvedere Ridge (BR)	Lateritic	250 m
Second Belvedere (SB)	Lateritic	180 m
Pre Trois Cocotiers (PTC)	Lateritic	200 m
Trois Cocotiers (TC)	Lateritic	400 m

TABLE 1. A list of all field sites with their corresponding soil types and elevations

Plant Plots

Plots on study site ridges were set up using a transect tape. The areas of the plots at each of the sites were 150 m^2. The perimeter of the plots varied between study sites because of physical ridge differences. Within each plot, the number of each species of woody plants was recorded. In this project, the term woody plant was defined as a plant that can grow more than 2 m off the ground and all of its associated saplings.

Soil Pit and Soil Characterization

One soil pit was dug at a non-random place within the plant plot at each site. The position of the pit was chosen based on convenience and ease of digging. Using a spade and a pick axe, a soil pit with an area of one square foot and a depth of approximately 40 cm was dug. Leaf litter, characteristics of each horizon, depth of horizons, soil texture, as well as any other observations were recorded. The soil color was described using the Munsell Soil Color Chart.

Soil Collection

Using a hand shovel, samples were taken from each horizon of the soil pit starting at the bottom-most horizon to prevent soil mixing. The collected soil was placed in a gallon-sized zip-lock bag and transported to the laboratory for further analysis. For the sapling growth study, soil from the top horizon of three lateritic study sites and three eutrophic study sites were collected. The sites were: Banyan Tree Site, Pre Trail Junction, Hibiscus Arch, Pre Trois Cocotiers, Belvedere Ridge, and Second Belvedere.

Lab Soil Analysis

Soil samples for laboratory analysis were dried in the dry oven for at least 48 hours to prevent soil nutrient consumption by microorganisms. The samples were manually mixed intermittently to ensure complete dehydration. A homogeneous mix of each sample was allocated for different soil tests.

Organic Matter

A muffle oven was used to determine the amount of organic material in the collected samples from each study site. The loss-on-ignition method was applied, in which the organic material in the soil sample was burned off at 450 F. Five grams of a homogeneously mixed soil was grounded into fine grains with a mortar and pestle. The prepared sample was placed in an aluminum cup and burned in the oven for three hours. The samples were weighed before and after combustion and the mass percent of organic material was recorded.

Nutrient Extraction

Chemical tests were water based so a protocol to extract nutrients from the soil using water was used. 50 mL of 1 molar potassium chloride solution was shaken with 13.33 g of ground soil sample for one hour. The soil and KCl mixture was then placed through a Whatman® filter. The filtered water from each sample was used for additional water-based tests.

Nitrogen Content

The LaMotte® nitrogen test kit was applied to the filtered water from the KCl extraction. Nitrogen content was recorded in units of parts per million for each soil sample from the study sites.

Phosphorous Content

The LaMotte® phosphorous test kit was applied to the filtered water from the KCl extraction. Phosphorous content was measured in units of parts per million for soil samples from each of the study sites.

pH

The pH of the soil solution was measured with a pH probe on the filtered water from the KCl extraction. These values were recorded for each of the soil samples from all the study sites.

Sapling Growth Study

A sapling study was conducted to experimentally determine the growth potential of introduced plants in two different soil types. 12 *Miconia calvescens* and 12 *Spathodea campanulata* saplings were collected from the field and soil samples from three lateritic ridges and three organic ridges were taken. The three lateritic ridges were: Pre Trois Cocotiers, Belvedere Ridge, and Second Belvedere. The three eutrophic ridges were: Banyan Tree, Pre Trail Junction, and Hibiscus Arch. The saplings were transplanted from the field using ziplock bags, some soil, and water for temporary hydration. These were placed into cups once at the Gump station. All but one leaf are cut and discarded from the saplings to prevent excessive energy expenditure on leaf maintenance. The plants were placed next to the wet lab under a roof to prevent flooding from rainfall. Initial sapling heights were measured. These saplings were watered daily with 50 mL of tap water. After 28 days, the final sapling measurements were taken. The days that each sapling died were also recorded. Sapling death was noted by the total loss of green pigmentation in the leaves.

Canopy Cover

Canopy cover was measured using a spherical densiometer within the plant plots at all of the test sites. The 150 m^2 plant plot was subdivided in to 10 equivalent subplots and a densiometer measurement was taken in each subplot. Canopy cover was recorded in percent cover and the average of the 10 replicates was scaled up to the average canopy cover of the study site.

Ground Cover

Ground cover was measured in a similar method as canopy cover. The 150 m^2 plant plot was divided into the same 10 equivalent subplots as the canopy cover subplots. A one square meter quadrat was used at each subplot and the ground vegetation cover was recorded in percent. The average value of the ten samples of ground cover was scaled up to the average ground cover percentage of the study site. Ground cover excluded leaf litter and rocks cover and only took in to account live vegetation.

Statistical Analysis

The t-test statistical method was applied to the collected plant data to compare the plant compositions between lateritic and eutrophic ridges. Comparisons between the average percent native, Polynesian introduced, and recently introduced plant species of the two types of ridges were made in order to determine statistical significance of the observed variations. The t-test was also used to compare the mean values of pH, organic matter, nitrogen, and phosphorous contents of lateritic sites versus eutrophic sites. This helped determine which variables were statistically significant when comparing the two types of ridge soils. The t-test was also applied to check for significant differences in the growth and survival rates of the saplings.

To analyze all of the plant species and different study sites with multiple variables, a detrended correspondence analysis (DCA) on an ln(x+1) transformed species abundance data was applied. The variables that were taken in to account were nitrogen content, phosphorous content, organic matter, pH, and elevation of the study sites.

To measure the relationship between canopy cover and the non-native vegetation of all the study sites, a logarithmic regression analysis was applied. A curve of best fit was used to assess the degree of correlation between the two factors. The same statistical method was used to observe any correlations between ground cover and non-native vegetation on the ridges.

RESULTS

Plant Plots

The data collected from the plant counts at my study sites illustrated that there are observable differences in plant composition between eutrophic ridges and lateritic ridges (Fig. 2). The results from the t-tests demonstrated that on average, lateritic ridges contained a higher percentage native plant species (p=0.015) and eutrophic ridges contained a higher percent Polynesian introduced species (p=0.023) (Table 2). The population of Polynesian introduced plants in lateritic study sites is drastically less than that of eutrophic sites.

Soil Characterization

The A horizons of the study sites illustrated differences in the soil chemical contents (Fig. 3a). The collected data also showed that organic matter differed between lateritic and eutrophic sites (Fig. 3b). A t-test on the mean values for nitrogen, phosphorous, pH, and organic matter for lateritic and eutrophic sites revealed a significant difference in average nitrogen content (p=0.019) and pH (p=0.0050) between the two ridge types (Table 3). Despite the observable differences, organic matter and phosphorous content were not significantly different. Most differences between the two soil types were observed in the A horizon. The B horizon only showed a significant difference for pH (p=0.035) and insignificant differences for other variables (Table 4).

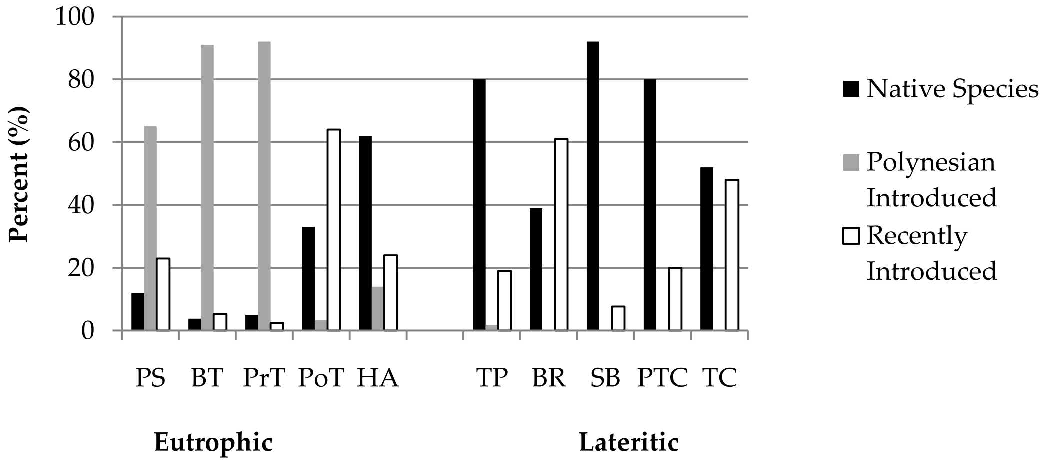

FIG. 2. The percentage of native plant species, Polynesian introduced plant species and recently introduced plant species at each of the study site ridges.

Variable	Lateritic Ridge Mean (STD)	Eutrophic Ridge Mean (STD)	p-value
% native	69 (22)	23 (25)	0.015*
% Polynesian introduced	0.38 (0.85)	53 (42)	0.023*
% recently introduced	31 (22)	24 (25)	0.65

*statistically significant

TABLE. 2. The mean percentage and standard deviation of the three plant categories of lateritic ridges and organic ridges. The t-test was applied to assess differences in mean values.

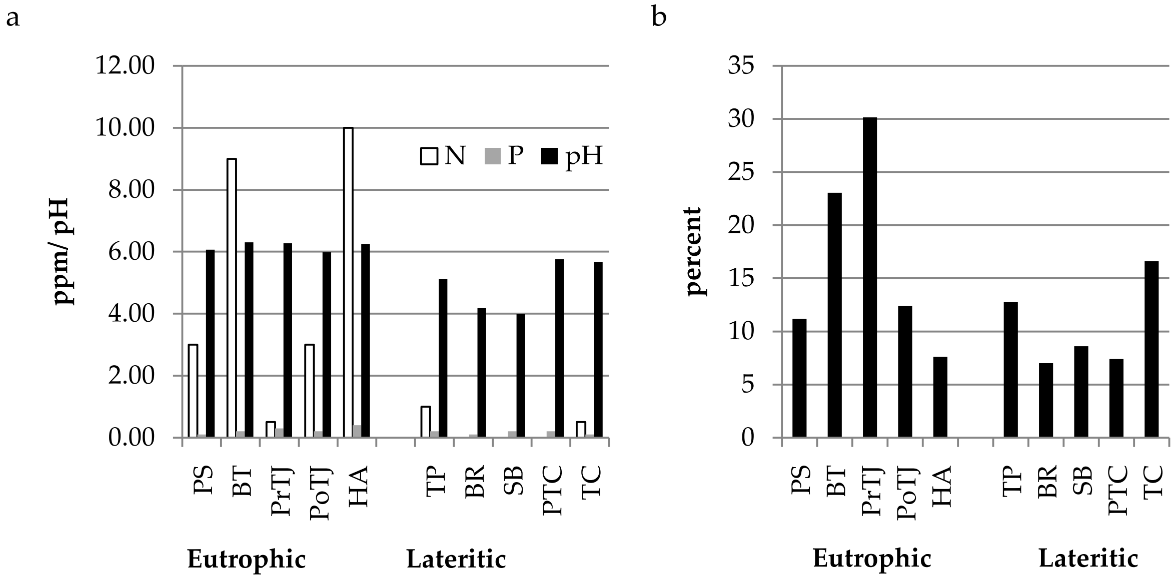

FIG. 3. a) The nitrogen content, phosphorous content, and pH of the A0/A1 soil horizons at each study site. b) The organic matter in percent mass of the A0/A1 horizons at each study site.

Variable	Lateritic Ridge Mean (STD)	Eutrophic Ridge Mean (STD)	p-value
Nitrogen	0.30 (0.45)	5.1 (4.2)	0.019*
Phosphorous	0.16 (0.055)	0.24 (0.11)	0.14
pH	5.0 (0.82)	6.2 (0.14)	0.0050*
Organic Content	10 (4.1)	17 (9.4)	0.13

*statistically significant

TABLE 3. The mean pH, nitrogen, phosphorous, and organic contents of the A0/A1 soil horizons of lateritic ridges and eutrophic ridges. The t-test was applied to assess statistical significance of mean values.

Variable	Lateritic Ridge Mean (STD)	Eutrophic Ridge Mean (STD)	p-value
Nitrogen	0 (0)	0.5 (0.71)	0.12
Phosphorous	0.12 (0.084)	0.16 (0.055)	0.35
pH	4.4 (0.40)	5.4 (0.92)	0.035*
Organic Content	6.4 (2.7)	9.3 (4.5)	0.21

*statistically significant

TABLE 4. The mean pH, nitrogen, phosphorous, and organic contents of the B soil horizons of lateritic ridges and eutrophic ridges. The t-test was applied to assess statistical significance of mean values.

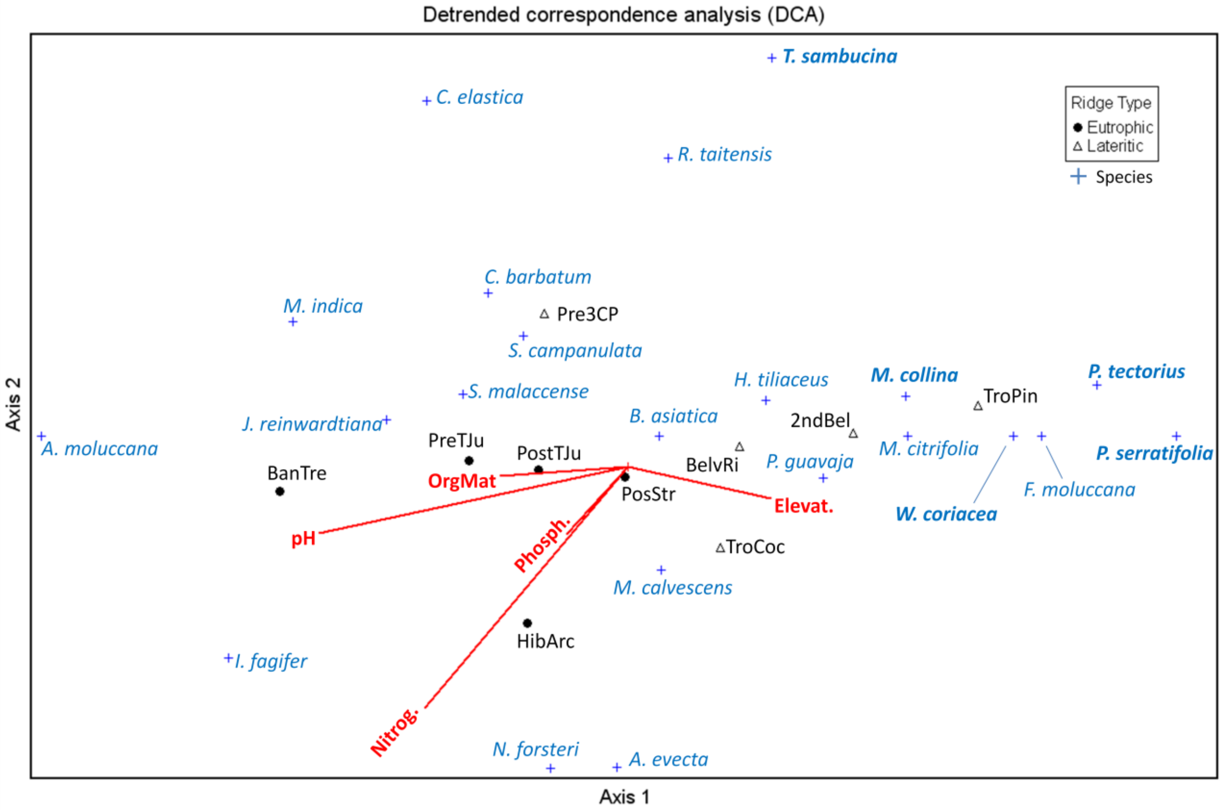

FIG. 4. A detrended correspondence analysis (DCA) of study sites and plant species with the following parameters: organic material, pH, phosphorous, nitrogen, and elevation. This shows clusters of study sites that are similar and the plant species that grow in relation to the environmental factors of those study sites.

Detrended Correspondence Analysis

Using a detrended correspondence analysis (DCA) with an ln(x+1) transformation on the plant plot data, clusters of study sites with similar characteristics can be elucidated (Fig. 4). Figure 4 shows that lateritic sites cluster together and are distinguishable from eutrophic sites. The nitrogen content and pH are the main differentiating parameters between the two types of ridges. It can also be seen that the organic ridges tend to have more organic material and phosphorous content while lateritic ridges are generally higher in elevation. The species distribution show that native plant species generally found in higher elevations cluster close to the lateritic ridge study sites. These plant species are in bold in figure 4: *Pandanus tectorius, Tarenna sambucina, Metrosideros collina,* and *Wikstroemia coracea*.

SaplingViability and Growth Experiment

The sapling growth experiment showed that there are no statistically significant differences in the change in height or viability of the invasive saplings grown in lateritic versus eutrophic soils (Table. 5). A graph of surviving saplings at each day of the experiment showed that more invasive saplings died in lateritic soils than in eutrophic soils (Fig. 5). All *S. campanulata* in eutrophic soils survived the entire duration of the experiment compared to the 66% survival of the saplings in lateritic soils. All of the *M. calvescens* saplings in lateritic soils did not survive through the entire duration of the experiment, while the *M. calvescens* saplings

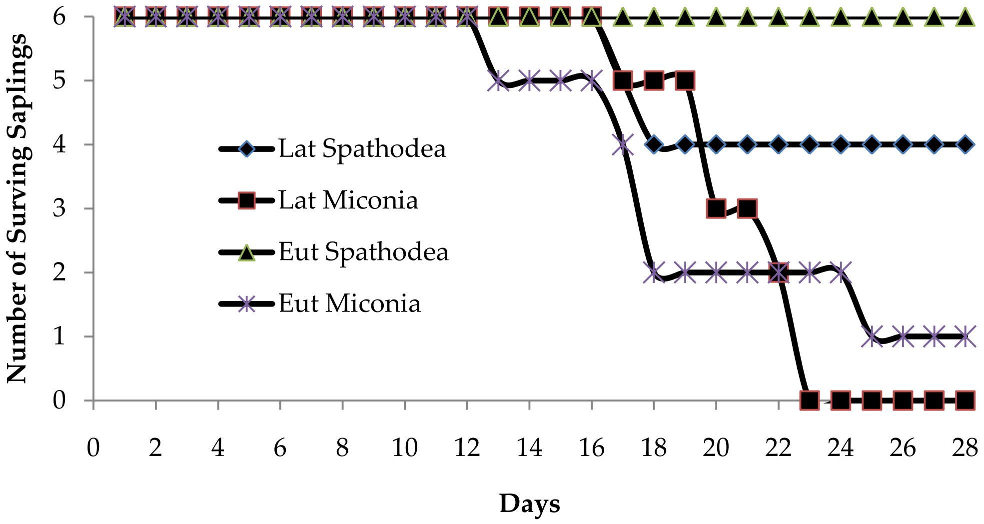

FIG. 5. A graph of the viability of *S. campanulata* and *M. calvescens* saplings in lateritic versus eutrophic soils. There is a general decline of saplings throughout the course of the experiment.

	Lat Avg ΔH	Eut Avg ΔH	p-value	Lat Avg survival	Eut Avg survival	p-value
Spathodea campanulata	0.1 (3.0)	0.83 (0.34)	0.91	25 (5.4)	28 (0)	0.2
Miconia calvescens	0.38 (1.4)	0.38 (0.33)	1	21 (2.3)	20 (5.6)	0.69
Total	0.24 (2.2)	0.61 (0.40)	0.69	23 (4.4)	24 (5.7)	0.74

TABLE 5. The mean change in height and average life duration of *S. campanulata, M. calvescens* and both species grown in lateritic soil and in eutrophic soil. The t-test was applied to compare the mean values for each soil type.

grown in eutrophic soils had a 17% survival rate. Moreover, it could be seen that *M. calvescens* died at a faster rate than *S. campanulata* in both types of soils (Fig. 5).

Canopy and Ground Cover

Figure 6 shows extensive canopy cover in eutrophic ridges while ground cover is more prevalent in lateritic ridges. A logarithmic regression on the percentage of non-native plants and the percent canopy cover demonstrates a moderate relationship between the two factors (R^2=0.60) and a weaker correlation between percent non-native plant species and percent ground cover (R^2=0.41) (Fig. 7a and 7b).

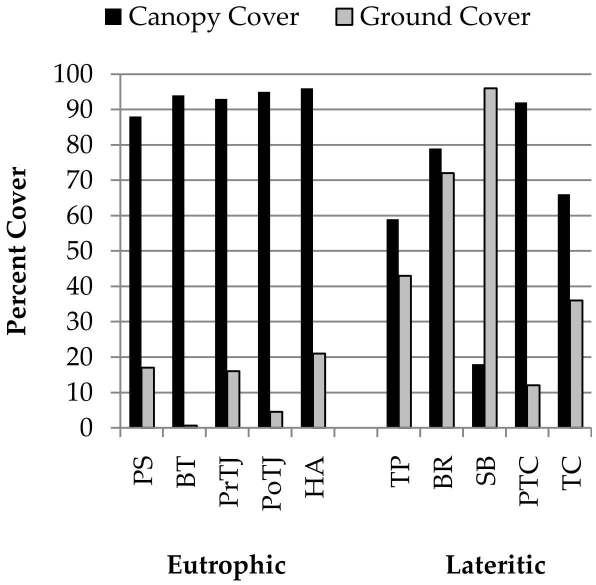

FIG. 6. The percent canopy and ground cover at each of the study site ridges

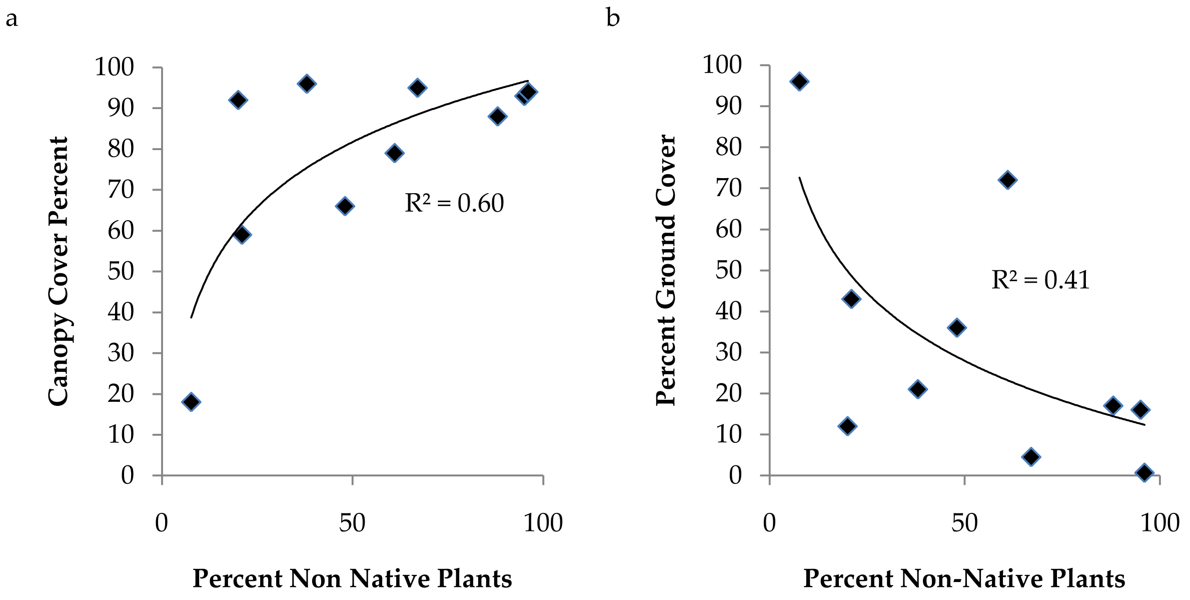

FIG. 7. a) A logarithmic regression of percent non-native plants versus percent canopy cover ($R^2 = 0.60$). b) A logarithmic regression of percent non-native plants versus percent ground cover ($R^2 = 0.41$)

DISCUSSION

This study shows that plant composition on different soil types are not uniform across the mountain ridges in Mo'orea. It has been observed that there are higher concentrations of native plant species on certain ridges on the island, and this study aims to quantify this phenomenon. The results from the plant counts at the study sites illustrate the different plant communities that exist on lateritic versus eutrophic sites (Fig. 2). Soil analyses of the samples taken from each study site illustrated different soil characteristics between the two ridge types, which suggest that the soil content play a role in determining the composition of plant types (Fig. 3).

Eutrophic ridges generally contained a higher percentage of non-native plants and many are dominated by Polynesian introduced plant species such as *S. malaccense* and *I. fagifer*. Among high concentrations of other nutrients, the abundant nitrogen content of eutrophic soil (5.1 ppm compared to 0.30 ppm of lateritic soil) can provide a means by which these non-native plants are able to establish such successful communities (Table 3). Plants require nitrogen in the greatest quantity compared to other soil nutrients and high concentrations have been shown to strongly affect the photosynthesis and growth rate of the plants (Chapin et al. 1987). Thus, introduced plants could establish a population with ease, penetrating the existing native plant communities. This could explain the diminished native plant populations in these nutrient rich soils. As a result, native populations may be forced in to nutrient poor soil types, such as lateritic soil ridges. The little variation in percent recently introduced plants between lateritic ridges and eutrophic ridges can be explained by the invasive nature of these plants. Because this category included heavy invaders such as *M. calvescens* and *S. Campanulata*, perhaps the ridge types had little effect on the growth potential of these recently introduced species.

In lateritic ridges, where the soil is relatively acidic with lower levels of nitrogen, organic matter, and phosphorous, there are higher concentrations of native plant species and an almost non-existent population of Polynesian introduced plants (Fig.3, table 3). Due to the high metal content of lateritic soils, the acidity contributes to the oxidation of aluminum present in the soil (Magistad 1925). These aluminum oxides are considered to be toxic towards plant growth (Magistad 1925). Therefore, introduced species may not be able to tolerate the higher level of metallic toxicity while native plant species are adapted to survive in such conditions. The absence of a prevalent source of invader could mediate the competition that these relic native plants must encounter to maintain a community. This supports the hypothesis that lateritic ridges provide an unsuitable environment for introduced plants which can explain why native plants are able to retreat into these ridges and maintain a population with less competition.

The DCA statistical test showed that native plant species that generally occur in high elevations appear in the same conditions as most lateritic ridges (Fig. 4). While several native plants, such as *A. evecta*, *C. barbatum*, and *B. asiatica*, do not seem to prefer lateritic soil over eutrophic soil, certain native species occur exclusively in the lateritic field sites. These species include: *Pandanus tectorius, Tarenna sambucina, Metrosideros collina,* and *Wikstroemia coracea*. Usually these species, especially *M. collina*, occur only in the "tropical montane cloud forests" of French Polynesia's high volcanic islands (Meyer). However, in this study, they are able to grow in the lateritic soils at a much lower elevation. This seems to suggest that lateritic soil is a preferred habitat for these native plants.

The sapling viability and growth experiment aimed at experimentally testing the abilities of different types of introduced plants to establish themselves in the two soil types. Though without any statistical significance, figure 5 shows both *S. campanulata* and *M. calvescens* saplings had a higher survival rate in eutrophic soils. This was expected because of the lack of non-native plant species that growth on lateritic ridges. The lack of statistical significance could be caused by experimental limitations, such as quality of equipments and sapling transplantation methods.

In addition to analyzing the soil of lateritic versus eutrophic ridges, canopy and ground cover were also studied for ridge specific traits and their relationships with plant composition. The presence of large canopies produced by introduced plant species, such as *I. fagifer*, can explain the positive exponential trend between non-native percent and canopy cover (Fig 7a). The leaf litter produced by these canopies can produce additional nitrogen and organic matter for the soil (Isichei 1992). This replenishment of nutrients further encourages plant growth of introduced species and can therefore explain the prominence of non-native plants in eutrophic ridges. Moreover, the extensive shade produced by such canopies can effectively block out crucial sunlight that is necessary for the viability of native plant species, which are generally smaller than introduced plants.

An opposite relationship was observed with percent non-native plants and the percent ground cover (Fig 7b). Study sites with less non-native plants and more native species tend to have higher ground cover. A lot of the ground cover in lateritic ridges consists of *Dicranopteris linearis,* a weedy native fern that is able to dominate the ground cover vegetation. Fern coverage such as this can prevent the germination of plant seedlings (Wickland 1999). This poses as an obstacle for non-native plants to encroach on the lateritic ridges and may contribute to the maintenance of native populations on those ridges.

All experiments conducted within this study could be improved by using more replicates to increase the statistical power of the collect data. The plant plot study would benefit from an increase in plot area in order to attain a more accurate depiction of the plant compositions at each of the study sites. Future work would be to conduct the sapling viability and growth experiment more extensively using both native and introduced saplings. In addition, a seedling germination study should be attempted using various soil types to assess both the feasibility of germination as well as sapling survival. It would also be interesting to manipulate individual components of the soil to isolate variables and study their effects on the growth patterns of native and non-native plants. Another area for future work is to extend the study sites to more than just mountain ridges, but to also take in to account valleys in various elevations. Moreover, comparative work can be done looking at similar native plant refugium phenomena in other islands or continental vegetation.

While there are many factors that influence plant communities on Mo'orea, this study attempted to study a few important environmental variables that could explain the native species distributional trends that are observed. Introduced species are a large threat to the native biota in all islands of the Pacific, and understanding the environmental factors that explain where native plant species can grow successfully helps with conservation efforts. This study showed that abiotic factors such as soil nutritional content play an important role in mediating competition in lateritic mountain ridges. Furthermore ridge characteristics such a canopy and ground cover can also affect plant populations. With enough knowledge on such characteristics and their effects on native plant compositions, we can solidify our understanding of the invasive ecology of introduced plants and combat the diminishing populations of native plants in the Pacific islands.

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