El Caño Archaeological Park: Biodiversity Past and Present

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ABSTRACT

Panama's El Caño Archaeological Park documents a process of cultural evolution resulting in stratified social structures in Pre-Columbian societies. To better understand the specific culture of this region, Fundación El Caño, the foundation conducting research at the archaeological site, has undertaken a comparative study of flora specimens found in archaeological contexts and flora currently present in the park. To aid with their study, over 40 unique species were identified in the park and many of them were preserved as herbarium specimens through approved botanical and archival techniques. Flora specimens were collected, pressed and dried, mounted, identified, labeled, and prepared for curation at Museo El Caño as a comparative collection for future reference and continued study.

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Our team would like to acknowledge the help and consideration of those who advised and contributed to the success of the project. We extend our warmest gratitude and thank those who guided the project to fruition.

We would first like to extend our thanks to Alexa Hancock and all the employees who provided an opportunity to work at El Caño Archaeological Park. With Alexa's help and guidance, we were able to gain an understanding of our deliverables to the foundation and the scope of our work. Moreover, she directed us with a tour of the park, pointing out where we could find the most biodiverse regions.

We would also like to thank Rick Montanari and the rest of Footprint Possibilities for supplying hardware necessary for our project that would have been difficult to source within Panama. The pieces of hardware given to us, such as heavy-duty clamps, a vacuum sealer, and a Garmin GPS, were all pivotal in allowing us to successfully document and preserve our procured samples. Weekly meetings with Rick have also helped us stay on a tight schedule and pushed us to attempt different preservation methods, which ultimately inspired us to create large-scale plant presses inducing more force, halving the projected drying time for plant specimens.

The project would not have been possible without the help of our advisors Prof. James A. Chiarelli and Prof. Aaron R. Sakulich. Our advisors provided us guidance, assistance, and general help whenever needed for the completion of our project. Prof. Chiarelli, in addition to directing our D-Term ID 2050 seminar, provided us with his valuable time and guidance in helping our project develop from a prompt to a complete deliverable for our sponsors. Prof. Sakulich provided us with constructive criticism on our project and guidance in helping our project meet all the requirements of an IQP. Moreover, Prof. Sakulich and the WPI Civil Engineering department also provided generous financial support for the supplies and equipment necessary for carrying out our fieldwork.

Our team would like to extend our gratitude to the WPI Global Projects Program for affording us this opportunity to go abroad for the completion of our IQP. Our team is grateful for the comfortable stay in Panama and the assistance provided by the program for the successful completion of the project.

AUTHORSHIP

Connor Bourgeois:

Connor created the folder filing system to organize the images of the plants in a clear manner, adding ID numbers to group each plant and facilitate species identification. He also helped in the field with collecting samples, taking photos of the team working, and tracking the GPS location. Connor identified a few plants. He assisted in the construction of the plant press.

Lokesh Gangaramaney:

Lokesh collected most of the samples in the field. He identified several plant species. Lokesh created labels for the herbarium specimens, printed them out, and helped Jax attach them to the specimens. He also wrote several sections of the paper, including the Abstract, Acknowledgements, Executive Summary, parts of the Background, and the Appendices. Lokesh contributed largely to the poster, particularly the format. He researched materials for the herbarium collection and sourced the scrapbook and page protectors.

Jax Sprague:

Jax served as the primary author of the paper, having contributed to the Abstract, Executive Summary, Introduction, Background, Methodology, Results, and Conclusions. She also proofread the paper and poster. In the field, Jax recorded data in a notebook about each plant and took pictures of the team working. She identified the majority of the plant species. She researched materials for the project and helped source them. Jax pieced together the herbarium collection, mounting them and placing them in the scrapbook with Luke and attaching labels with Lokesh. Jax and Luke created the final presentation for the project. She researched most of the plant species' cultural significances.

Luke Trujillo:

In the field, Luke collected GPS data, measured the height, and took photos of each plant. He discovered alternate methods to construct the plant press. Luke aided in mounting the specimens to herbarium paper and placing them in the scrapbook. He created the spreadsheet containing all the information about the plants and transcribed the information from the notebook to the sheet, which was formatted into the labels. Additionally, he created a map of the GPS location of each plant species and figures detailing the native, non-native, and invasive species. For the paper, Luke contributed to the Executive Summary, Results, and Conclusion. He researched some of the plant species' cultural significances.

EXECUTIVE SUMMARY

Background

El Caño Archaeological Park in Panama documents a long history of socio-cultural evolution during the Pre-Columbian era. Our sponsor, Fundación El Caño, has undertaken a comparative study of the flora found in El Caño Archaeological Park today and the flora found in archaeological contexts during the excavation of Pre-Columbian tombs. By analyzing and comparing contemporary and ancient flora, archaeologists can observe how the environment of El Caño has changed over time in response to human activities and natural processes that have altered the landscape and, possibly, climate change. This will also provide insight as to how this civilization lived, discovering the crops they used for tools, food, shelter, and clothes.

To classify the species within the park, the team learned the basic concepts of plant taxonomy - the science of finding, identifying, describing, classifying, and naming plants. The hierarchy of classification is kingdom, phylum, class, order, family, genus, and species. Genus and species are used for the species name of each plant. Panama contains approximately 10,000 unique plant species. It has a tropical climate with a wet and dry season, both spawning very different environments. Some common plants in Panama are heliconia, hibiscus, ginger, and bougainvillea.

Pre-Columbian cultures in Central America are known for their complex societal structures and advanced technologies that much of the world had yet to discover. Some Pre-Columbian cultures produced complex writing systems and developed their own literature. Their cities are recognized for their pyramids, plazas, and palaces, as well as ball courts and stone monuments. Lower status families lived in adobe homes. Homes had amenities for sleeping, cooking, eating, worship, and steam bathrooms. The nobility had similar room dedications but on a much larger and grander scale.

Methodology

To accomplish this goal, we created three main objectives guiding the project:

1. Collect information on each unique plant in El Caño Archaeological Park.
2. Use Pl@net, iNaturalist, and PictureThis applications to identify the plants.
3. Create a spreadsheet to synthesize the data.

For collecting smaller plants, specimens that possessed many of the plant's organs were chosen: stems, flowers, fruits, and leaves. The team made plant presses from two sheets of plywood layered with several additional sheets of cardboard. Newspaper lined the cardboard and the plants were situated so as to not overlap when pressed. Heavy-duty mechanical clamps secured the press, increasing pressure and reducing drying time to two weeks. From there they were glued onto moisture-absorbing, acid-free watercolor paper and placed in a page-protected scrapbook.

In order to keep the herbarium specimens scientifically significant, we recorded their scientific name, family, location, habitat, growth habit, frequency, height, color, collector's name, species determiner's name and collection date on the sheet, numbering them as they were collected. This information was recorded in a spreadsheet before transferring them onto labels. These labels were printed and taped on the page protectors of their corresponding plants.

For the trees of the park, we constructed a xiloteca. Specimens were collected by sawing off a portion of the trunk revealing the outer bark pattern. These samples were placed inside a clear briefcase and labeled with the number that corresponded to their identity in the spreadsheet. Fruits were vacuum sealed and labeled with their species name and identity number.

The team utilized the apps Pl@ntNet, iNaturalist, and PictureThis to identify flora in El Caño Archaeological Park. These apps allow the user to select an image of an organ of the plant and compare it to visually-similar plants in order to determine the species.

For data organization, we created a filing system with folders for the various family names of the identified specimens. From there, subfolders were made with the genus names. Inside the genus, folders are subfolders for the different species identified. Photos of each plant were placed in their respective species folders as they were identified.

Results and Conclusions

Initially the team set out to preserve 25 specimens and identify a total of 50 at El Caño. Upon further investigation of the biodiversity, the team preserved 32 unique specimens and identified 44 total species. From there, the specimens collected were classified into a large variety of habits. After all specimens were identified, the team investigated the origin and invasiveness of each species. Of all the specimens, 8 were found to be invasive, 23 were found to be native, and 21 were found to be non-native. Most of the specimens that the team identified were found to have a wide variety of historical and medicinal uses.

The team concluded that the environment of the park has largely changed since Pre-Columbian times due to bird droppings, landscaping, flooding, and agriculture. In addition, the biodiversity is quite different during wet and dry seasons, so the team recommends that Fundación El Caño repeat this study during the dry season to ensure all species were found.

CHAPTER 1: INTRODUCTION

El Caño Archaeological Park is one of the most important Pre-Columbian sites in Panama. Since the discovery of El Caño, excavations of the site have given historians a better understanding of the cultural evolution and social structure of ancient Panama and surrounding Central American nations in the Pre-Columbian era. Fundación El Caño, the foundation that conducts research and maintains the site, has undertaken a comparative study of the contemporary flora in the park and the ancient flora discovered during excavations of Pre-Columbian tombs. Our team identified all the park's flora and reported our findings in this document.

The identification of flora is necessary as it allows researchers to assess important rangeland and inland pasture variables that are critical to the proper management of any area or national park. With proper knowledge of a national park, management can assess range conditions, proper stocking rates, forage production, wildlife habitat quality, and rangeland trends ("Plant Identification: Is It Worth the Effort?" n.d.). Moreover, with the proper identification of flora, the management can keep track of the ecological and environmental changes within the park over time. Therefore, with the completion of the project, our sponsor would be able to conduct a study of how the park's ecology and environment have changed since Pre-Columbian times.

The team cataloged the flora of El Caño by first collecting specimens according to proper conservation guidelines. We placed the flowering plants in herbariums and woods in a xiloteca. A xiloteca is a special form of herbarium for the collection of authenticated wood specimens ("Xylarium," n.d.). Afterward, we identified the most prominent flora of the region through quantification and used plant identification software to identify individual plants. We took note of every plant's prominence and location at El Caño Archaeological Park. After thoroughly identifying and quantifying the parks flora, we compiled a spreadsheet detailing our findings and provided this to our sponsor.

The organization hosting the biodiversity project in Panama City is Footprint Possibilities, a non-governmental organization based in Panama. Footprint Possibilities' mission includes "organizing and seeking funding for local community efforts ("About Us," n.d.)." Past projects include supplying impoverished people with healthy foods and vitamins, disposing of wastewater, providing access to clean water, improving the infrastructure of local community centers, and increasing educational and cultural opportunities all with the goal of improving basic health conditions ("Welcome to Footprint," n.d.). Footprint Possibilities expanded to help those in need in other countries, such as Ghana, although most of the projects occur in Panama ("Projects," n.d.). By working with Engineers Without Borders and other collaborating organizations and institutions like Worcester Polytechnic Institute, more people may join the effort to assist those in need.

Engineers Without Borders is an organization that "[partners] with communities to meet their basic human needs ("Mission & History," n.d.)." By building sustainable structures, providing renewable energy, and digging for water, Engineers Without Borders provides opportunities for communities to thrive. Engineers Without Borders chapters from around the world engage in projects in Panama, like cleaning the Panama water supply in remote regions (Brymer, 2019). Worcester Polytechnic Institute has worked with Footprint Possibilities in the past. In 2019, they are collaborating with them on two projects: accessibility and biodiversity in El Caño Archaeological Park.

Fundación El Caño is a Panamanian foundation that works with El Caño Archaeological Park in order to preserve and study ancient heritage. Footprint Possibilities is teaming up with Fundación El Caño to make the El Caño Archaeological Park a better place for tourists to understand and appreciate Panamanian history. This is done by making the park accessible to tourists and discovering the various flora that exists around the Pre-Columbian ruins. The end goal is to make El Caño a valuable place maintained for the community's economic and cultural benefit ("Parque Arqueológico El Caño," n.d.).

The importance of this project stems from the need to compare ancient societies to those of today. By analyzing the flora today and the flora from other Pre-Columbian sites and tombs, we can see how the ecology and environment have changed over time. Based on the flora in El Caño, we can determine how the Pre-Columbian civilization lived, as we will see the types of plants they could use for tools, food, shelter, clothes, and anything else they may have used in their daily lives. Observing the El Caño plant life will increase the historical importance of the park and allow visitors to peek into the lives of ancient societies (Barlow, 2012).

CHAPTER 2: BACKGROUND

2.1 Classification of Flora

The classification of flora can be a tedious process. The science of classifying living organisms is called taxonomy by which each organism is classified into its appropriate kingdom, phylum, class, order, family, genus, and species. Using this multi-tiered classification system allows scientists and researchers to easily identify the relationship between different organisms. Organisms are given a binomial name, which is the scientific name starting with the name of the organism's genus, and the common name, which is what the organism is commonly called (Takhtadzhian, 1997).

2.2 Panamanian Flora and Climate

Panama and Central America in general form a land bridge between North and South America, creating great biodiversity. Experts estimate there to be over 10,000 species of plants in the rainforests, coastlines, and highlands of Panama. Some common flowers are the heliconia, hibiscus, ginger, and bougainvillea ("Flora and Fauna of Panama," n.d.). There are about 675 species of orchids in Panama as well ("Plants, n.d.). Other plants include cocoa pods, Arabica, and Geisha coffee cherries (Fallon, 2016). Of the 1,500 species of tropical trees, common trees include the Ceiba, Guanacaste, Strangler Fig, Cecropia, and Gumbo Limbo ("Flora in Panama," n.d.).

The vegetation near the canal mostly resides in the humid, tropical rainforest ("Plants," n.d.). A rainforest is a tall, dense jungle that receives a high amount of rainfall each year. The climate of a rainforest is very hot and humid. Rainforests contain four different layers: the emergent layer, canopy layer, understory layer, and forest floor. The emergent layer contains the tallest trees, often broad-leaved, hardwood evergreens requiring plenty of sunlight. The canopy layer forms a roof over the rest of the rainforest. Trees in this layer have smooth, pointed, ovular leaves. The understory layer does not receive much sunlight, so the leaves grow to be much larger. On the forest floor, there is almost no sunlight and as a result, very few plants. Plant matter decays quickly in this region as well ("What is a Rainforest?" n.d.)

The Pacific Coast has tropical dry forests and grasslands ("Plants," n.d.). A tropical dry forest contains a pronounced dry season during the year, provoking adaptations in plant and animal life. Many tree species are deciduous, shedding their leaves at the start of the dry season, and many plant species evolved for water retention ("Tropical Dry Forests," n.d.). Grasses dominate grasslands, which have little to no tree cover. Grasslands possess diversity in herb and grass species, despite not having trees or shrubs ("Grasslands," n.d.).

Highlands have cloud forests, the highest peaks have alpine vegetation, and the coasts have mangrove forests ("Plants," n.d.). A cloud forest is a tropical evergreen montane forest with high levels of condensation appearing as mist or cloud coverage at the canopy level. Cloud forests have 100% humidity at all times of year. In eastern Panama, cloud forests exist at an altitude of 750 meters and in western Panama, they are at 2,200 meters. Cloud forests have high levels of rainfall (Karuga, 2017). Alpine vegetation consists of plants that grow above the tree line in an alpine climate. These plants include graminoids, forbs, and mosses ("Alpine Vegetation," 2014). A mangrove forest is a group of trees and shrubs on the coastal intertidal zone (NOAA, 2018). Over 29 percent of Panama's land is protected in the form of national parks and wildlife reservations, allowing for biodiversity to prosper in these regions ("Plants," n.d.).

2.3 Archaeological Sites in Central America

In order to further understand our goals for El Caño, it is paramount to learn about other major archaeological parks in Central America - namely their history, culture, and the type of flora they host. One site that holds its rank among the wonders of the ancient world is Chichen Itza, on Mexico's Yucatan Peninsula. It was founded in the 6th century CE by the Maya, who are presumed to have occupied the region since the Pre-Classic period. Evidence shows that after the collapse of Classic Maya civilization around 900 CE, the site was invaded by foreigners, probably other Mayan speakers who had been strongly influenced by the Toltec of central Mexico. One of the significant cultural practices was the tradition of the Cult of Cenote, which involved human sacrifice to the rain god. The sacrificial victims were thrown into the city's major cenote (a body of water exposed in a sinkhole by collapsed limestone surface crust) along with their gold and jade ornaments (Britannica, 2018). The site hosts a variety of flora, mainly Yucatan Flora. It consists of Passion Fruit, Pitaya, Shaving Brush Trees, Plumeria – Frangipani Trees, African Tulip, Golden Shower Trees, and many more ("Yucatan Adventure Geo-Travel Guide," n.d.).

The second site with Maya is Copan, Honduras. Evidence of people in the Copan Valley dates to 1500 B.C. The Maya leader Yax Kuk Mo, who came from the area of Tikal, arrived in the Copan Valley in 427 CE and started a dynasty of 16 rulers that transformed Copan into one of the greatest Maya cities during the Classic Maya Period (Centre, U.W.). The site has an abundance of tall, slender trees festooned with long moss with a dense undergrowth of shrubs.

Belize is home to Caracol, the country's largest known Maya archaeological site. Caracol is not as well-excavated as many other Maya sites but has Caana – the largest Maya pyramid in the country, as well as the tallest man-made structure in Belize to this day. Guatemala's Tikal is well-excavated and restored in a tropical jungle, filled with temples, parrots, and howler monkeys. Tikal could once support approximately 100,000 people as it covered 65 square kilometers in its prime. Joya de Cerén in El Salvador provides the most accurate glimpse into ancient Maya life as the remains of the Maya village were buried under volcanic ash 1,400 years ago. Nicaragua has Huellas de Acahualinca and León, and Panama has Casco Viejo, all ruins that display the architecture and lifestyles of ancient civilizations charred by volcanoes ("The Most Intriguing Historic Sites in Central America," n.d.). In addition to Tikal, Guatemala has Yaxhá, an ancient Maya city in the jungle with many temples, and Aguateca, a city on top of a 90-meter-tall limestone bluff ("10 Top Archaeological Sites from Mexico to Peru," 2012). Although the people of El Caño were at best only distantly related to the Maya and other major Pre-Columbian peoples, ancient Mesoamerican and Central American societies shared many of the same cultural traits and traditions.

2.4 El Caño Archaeological Park

Figure 1: Worcester Polytechnic Institute students visiting El Caño Archaeological Park for the first time. Photo taken by Alexa Hancock.

El Caño Archeological Park is located on the Pacific side of Panama, west of Panama City, and near Rio Grande. The village of El Caño is in the city of Penonomé in the province of Coclé.

Comprising of different structures, the sites' excavations between 2008 and 2011 allowed the discovery of several lavish burials estimated dated between 700 and 1000 CE. The excavation also revealed data that served as a source of information on the Pre-Columbian chiefdoms and their mortuary practices. The tombs were found in multiple levels and the warriors were bathed in gold, which made the discovery one of the most significant discoveries in Central America. The analysis of the tombs reveals their society followed a form of hierarchical organization. However, the more unusual finding was the bones of very poisonous blowfish, which could have been used to kill all the people that were presumed to have been sacrificed for the chief (Johnblack, 2014). Currently, there is little to no information about the flora in the park available online; however, with this project, our team sought to change that.

Figure 2: Gold artifacts found during excavations of the tombs in El Caño Archaeological Park. Photo taken by Dra. Julia Mayo, Director of Fundación El Caño.

The village of El Caño is home to a water irrigation system used to grow staple grains like rice, maize, beans, sorghum, and soy; fruits and vegetables like mango, papaya, cashews, melons, tomatoes, red peppers, onions, squashes, and citrus; and other crops like sugarcane and forages. Rice is the predominant crop of the region. Because this land has been used for farming, soil quality has likely altered due to the use of the land for cultivating specific crops rather than what has grown natively in the region (Peccei, 1991). The archaeological site was once part of a sugarcane plantation. Fundación El Caño has stated that in 1973, the company that owned the archaeological site destroyed several mounds while working for the plantation, leading to the creation of the park to preserve the remains ("Cultural Gold Artifacts Now on Display to Public," 2019).

2.5 Pre-Columbian Civilizations

Pre-Columbian cultures in Central America are known to be surprisingly innovative and advanced, inventing many technologies that the rest of the world had yet to discover. Many Pre-Columbian cultures produced complex writing and calendrical systems and developed their own literature concerning religion, time, astronomy, history, power, legacy, mythology, and fiction. These writings say much about the interests, rituals, and focuses of the cultures ("Pre-Columbian Literature: The 8 Most Important Features," n.d.). Maya is known to have the only writing system that represented the spoken language, whereas other cultures had more pictographic written languages. Due to the trading networks, each Pre-Columbian culture influenced the others, which explains the shared characteristics of the cultures ("Distinctive Features of the Maya Culture," n.d.).

Geographically speaking, Pre-Columbian cultures occupied rainforests, savannas, arid plateaus, mountains, and swamps. This collection of landscapes gave to rich biodiversity in flora and fauna, so each civilization would have had different environments in which they built their civilizations. This creates diversity in diets, clothing, shelter, and tools ("Distinctive Features of the Maya Culture," n.d.).

From a religious standpoint, many civilizations had temples and believed in a cyclical timeline. Aztecs and Maya practiced human sacrifice to the gods to improve and ensue longevity of their society. Religion was central to their lifestyles. Religious rituals revolved around the terrestrial and celestial cycles, as well as the natural world. They believed in birth, death, and rebirth ("Distinctive Features of the Maya Culture," n.d.).

Cities are recognized for their pyramids, plazas, and palaces, as well as ball courts and stone monuments ("Distinctive Features of the Maya Culture," n.d.). Many poor families lived in adobe homes. Homes had sleeping, cooking, eating, worship, and steam bathrooms. The nobility had similar room dedications but on a much larger scale. While in an adobe home, sleeping, cooking, eating, and worship would occur in one building with a separate building for saunas, the nobility would have large rooms dedicated to each ("Aztec Culture," n.d.).

Although the people of El Caño were not Maya or Aztec, their culture was probably very similar. We know that El Caño had complex nobility structures, as did the other Pre-Columbian societies. Panama lies outside of the Mesoamerican border, but with the vast trading systems of each culture, they likely led similar lifestyles. By researching more understood Pre-Columbian societies, we can better understand what is found in the tombs and how they lived.

2.6 Maya Subsistence

The Maya were an agricultural society, and approximately 90% of their population was involved in farming in some way. Since they inhabited many locations with varying soil quality, different branches of Maya farmed in different ways. To increase soil fertility, the Maya would raise fields and create stone-wall terraces to collect fertile silt deposits. They used slash-and-burn techniques to rejuvenate land after two years of planting since deforestation would create infertile soil if nutrients were not periodically replenished. Slash-and-burn agriculture is the process of cutting down crops and burning the field ("Slash and Burn Agriculture," n.d.). The slash-and-burn technique would take about 5-7 years for soil to be ready for planting again. In highland regions, plots had to be left empty for up to 15 years. Due to the short planting period, productivity was maximized by planting squash and beans in fields of maize so the beans could climb the maize stocks and the squash would hinder soil erosion. Cities without access to large plots would trade slaves, salt, honey, metals, feathers, and shells for food. Private homes had small gardens that cultivated fruits and vegetables. After harvesting, foods were stored in above-ground wooden cradles. Water was collected in collapsed caves and cisterns and brought to fields through canals (Cartwright, 2015).

Important crops were maize, sweet manioc, beans, squash, amaranth, and chili peppers. Fruits grown were guava, papaya, avocado, custard apple, and sweetsop. They also used chocolate, honey, agave, sapodilla, breadnut, bottle gourd, copal, and cotton (Cartwright, 2015). Domesticated animals that were raised for food included dogs, doves, turkeys, Muscovy ducks, coatimundi, and deer. Over time, certain dogs became hunting companions. Since not many animals could be domesticated, wild animals were the primary source of protein. Peccary, deer, tapir, agouti, paca, squirrel, rabbit, manatee, chachalaca, crested guan, turkey, and curassow were some wild animals and birds taken for meat. Some birds were taken for their plumage as feathers were important trade items: Scarlet Macaw, quetzal, and other parrots were not eaten but still captured and killed. Fish were likely captured with cotton nets, although the remains were mostly deteriorated due to their acidity (Smith, n.d.).

Gaining an understanding of the subsistence of other Pre-Columbian societies, particularly the crops they grew, creates an idea of what may be found within the park. The flora currently in the park may be descendants of what Pre-Columbian societies grew, but more likely the flora found in the tombs will match the subsistence of that era.

2.7 Modern Farming Practices in Panama

Agriculture in Panama today is faced with multiple issues. Panamanian farmers are plagued with water pollution and poor farming practices that threaten soil siltation and degrade the land. Several organizations are promoting sustainable agricultural practices in Panama to improve the land. ECOFARMS is looking to protect and restore the rainforest around Mamoni River Valley by working with local communities to reduce chemical additives and instead work with organic materials in farming processes. Planting Empowerment is rebuilding tropical forests from deforested land to maintain sustainable agriculture and improve the health of the region and make the local communities more economically independent. Women Farmers Alliance teaches farmers crop rotation, organic fertilizer, and organic pest control while training women so farming becomes gender-equal, an equal opportunity career option. Sustainable Harvest International partnered with local farmers to increase access to clean water during the dry season by developing a protected watershed preserve (DeRoche, 2018).

Crops that are commonly cultivated and exported in Panama today are avocados, mangoes, and teak wood. These crops are perfectly suited for the Panamanian climate and soil quality and have high demand globally. Harvesting them improves the Panamanian economy as they are a solid investment opportunity for foreigners. Panama is the second largest Free Trade Zone in the world, their currency is in USD, there are no restrictions on foreign ownership, and there aren't any exchange controls. With proper farming techniques, there can be up to two farming cycles per year. Overall, agriculture is a high-demand industry in Panama (DeSa, 2017).

Learning about modern farming practices in Panama shines light on how the environment of El Caño may have changed from human interference. Seeing as it was once part of a sugarcane foundation and the region has farmland, the agricultural practices currently in place will have an effect on the land today. If altered enough, the original plant life in El Caño would not be able to grow today. It is imperative to know how the land is changing to complete this comparative study.

CHAPTER 3: METHODOLOGY

The goal of this project was to identify all the flora present in the El Caño Archaeological Park in order to give our sponsors Footprint Possibilities and Fundación El Caño all the necessary information needed to conduct a study of how the area's ecology has changed over time. This study would give the sponsor a better understanding of how the Pre-Columbian civilizations lived in their era. Initially, there was little understanding of what kind of flora was present in the park, and our project addressed this. We found the following methods would be the best way to identify the flora present in El Caño archaeological park.

1. Collect data of each unique plant
2. Use Pl@ntNet, iNaturalist, and PictureThis Applications for identifying the plants
3. Create a spreadsheet for synthesizing our data

3.1 Sample Collection

Figure 3: Lokesh Gangaramaney snipping a sample of a vine to be pressed, identified, and mounted. Photo taken by Jax Sprague.

For the smaller plants, grasses, and flowers, we built an herbarium to properly analyze the data. Before collecting each species, we made sure we had the permissions to do so. This was to follow proper conservation efforts in place in Panama. Specimens that possessed many of the plants' organs - primarily stems, flowers, fruits, and leaves - were chosen. We detailed the height of the plant so the entire length of the stem would not have to be dried, but made sure to include basal, lower, and middle leaves. Fruits were vacuum-sealed, labeled, and attached to the sheet with the rest of the plant. Thick flowers were cut in half before continuing with the preservation process so they could be properly pressed, dehydrated, and mounted. In order to prevent wilting in the plants, they were immediately pressed after collection in a handmade plant press. We made the plant presses with two pieces of thick plywood layered with several sheets of cardboard. Newspaper lined the cardboard and the plants were situated so as to not overlap when pressed. To secure the press, we applied heavy-duty clamps, increasing the pressure and reducing drying time ("How to Make a Herbarium Specimen," n.d.). In order to maintain uniform pressure inside the press, the clamps were applied at the center of each edge as well as every corner. To speed up the drying process, newspaper sheets were changed every few days as they absorbed moisture from the plants (Appendix E).

Figure 4: Jax Sprague securing the clamps on the plant press to accelerate the drying process. Photo taken by Luke Trujillo.

In order to keep the herbarium specimens scientifically significant, we marked their scientific name, family, location, habitat, growth habit, frequency, height, color, and date on the sheet and numbered them as they were collected. The collector and species determiner's names were also recorded. We recorded this information in a spreadsheet (Appendix A) before transferring them onto labels. These labels were printed and glued onto watercolor paper, which we used as mounting paper. Plants were arranged on the sheets in a lifelike manner before attaching. We glued the plants to the sheets with epoxy and pressed the sheets for two hours to ensure they would not detach from the paper (Frank & Perkins, 2017). To store the individual sheets, we placed them in plastic protectors and then in a binder containing each of the herbarium specimens (Appendix B).

Figure 5: Luke Trujillo taking photos of the plant to run through the identification software and Jax Sprague recording data about the plant's location and visual description. Photo taken by Connor Bourgeois.

Figure 6: Connor Bourgeois using the GPS to determine the precise location of the plant specimen in the park. Photo taken by Jax Sprague.

For the trees of the park, a xiloteca was constructed (Appendix C). Specimens were collected by sawing off a portion of the trunk that revealed the outer bark pattern. They were placed inside of a clear briefcase so they could be easily seen. Labels were placed on the clear briefcase underneath the sample containing the same data as the herbarium. We collected fruits from trees where possible and vacuum-sealed them in plastic shrink wrap. They were labeled with the binomial name, common name, and identification number (Appendix C). From there, each of the specimens could be clearly identified.

3.2 Plant Identification

Figure 7: Connor Bourgeois, Luke Trujillo, and Jax Sprague identifying the plants based on photographs they had taken in the park using various applications. Photo taken by Alexa Hancock.

In order to answer the prompt, our group decided to utilize the Pl@ntNet, iNaturalist, and PictureThis apps to identify flora in El Caño Archaeological Park. With these apps, we could take photos of the plants, live or from the camera roll, and discover the binomial and common names. Pl@ntNet does this by having one select the organ of the plant being photographed and comparing this feature to those of similar-looking plants. From there one selects the species with which it most closely corresponds. Users can add their photos as a contribution so that others may use it for comparison as well. Pl@ntNet is a collaborative community so others will validate fellow users' flora observations to ensure that they have been identified correctly. In order to discover more information about the species, users can click the information icon and be shown links to external factsheets, as well as the family, genus, and species name. To maximize results, we took these photos of multiple organs of each plant, such as the leaf, flower, fruit, and/or stem. The app recommends taking straight-on and isolated photos of the organ to minimize interference and provide clarity for easier identification ("PlantNet Plant Identification," n.d.).

In instances where Pl@ntNet could not identify the specimen, we uploaded photos onto iNaturalist and PictureThis. Neither of these apps requires the user to specify organs, but they analyze the photo provided and make recommendations for the correct species based on visual similarities. iNaturalist proved best for identifying the genus of plants but lacked many photos of the suggested species, making it difficult to thoroughly identify the plant without further research. PictureThis only analyzes a small portion of a photograph and makes three recommendations based on the image. If none of the species match, the photo can be submitted for community analysis to determine the species.

After identifying the plants, we took note of their approximate quantity in the park. It was important to quantify them because this would help determine the number of signs necessary for the park and the prominence of individual species, which would aid in the understanding of the changing environment of the park. Other factors taken into consideration were the color and the location of each plant. Since plants of the same species can come in different shades, it was important to note these differences to avoid mislabeling them as a different flora altogether. We could then inform Fundación El Caño that these were the same plant to avoid confusion. The location of each plant was determined using a GPS system that allowed us to map its exact position in the park.

For certain plants, none of our efforts succeeded in identifying them. In these instances, we reached out to professional botanists. Before consulting experts, we would try to identify the plant at least to the genus. We would submit the herbarium specimen sheet and photos of the plant so the botanist could best identify the plant (Frank & Perkins, 2017). The botanist we contacted was Laurencio A. Martinez. We emailed him photos of our plants so he could identify them. The identified specimens were thoroughly labeled before being turned over to Fundación El Caño for curation at the end of the project.

3.3 Data Synthesis

After collecting data at El Caño Archaeological Park, the data were entered into a spreadsheet (Appendix A). This allowed us to manage, process, and compile the data set in a relatively short amount of time. We took note of the family, genus, species, and common name, the identifier's name, the identification year, region found, address, local description, latitude, longitude, growth habit, height, collectors' names, and date collected. The sheet contained task-keeping columns as well to see if the plant had been thoroughly collected, dehydrated, mounted, labeled, stored, and filed. The data in the sheet was easily transferred to a separate document, where the labels were formatted. These labels were printed and placed in the bottom corner of the herbarium sheets (Appendix E).

Another method for data organization that was instituted consisted of a photograph filing system (Appendix F). Folders were created for the various family names of the identified specimens. From there, subfolders were made with the genus names. Inside the genus folders, we created subfolders for the different species we believed the plants to be. The images were then left in the genus folder until further notice, this was done to ensure against false positives as no plant would be placed into its proposed species folder until a high enough certainty was reached.

3.4 Limitations

Our success at El Caño Archaeological Park was limited by a variety of geological and financial challenges. Given the rural location of El Caño, there was little access to an internet connection and WiFi in the park was very slow. This presented a limitation because plants had to be identified after we had left the archaeological site. There were many cases when we were unable to correctly identify a plant because of poor quality photographs. This was resolved by traveling back to El Caño Archaeological Site for resampling and taking more photographs.

In addition, our group lacks expertise and formal education in the field of botany. This presented a learning curve, slowing the group's rate of progress on certain aspects of the project. We conducted substantial research on botany and flora identification before arriving in Panama. Additionally, we made contact with multiple staff members of the Smithsonian Tropical Research Institute and various Engineers Without Borders chapters to gain information about archaeological botany, Panamanian flora, Footprint Possibilities, and Pre-Columbian Central American archaeology. While this did reduce the learning curve, there were still many things that needed to be learned on-site.

Since El Caño is a relatively large park, we concluded early on that we would not have the time to collect and press every species in the park. Pressing takes between two and four weeks to thoroughly dry the plant ("How to Press and Preserve Plants," n.d.). To facilitate the completion of the project in seven weeks, we focused primarily on collecting samples of the more significant and unique looking plants in the park. For the less significant species, like grass and weeds, we collected data to identify the species without needing to preserve them. Because of this, we were able to cover more ground and identify more plants in the timeframe of the project. To accelerate the pressing process, we applied heavy-duty clamps as opposed to a rope to increase pressure and placed the press next to a dehumidifier to absorb excess moisture. Within two weeks, the plants were ready to be mounted.

Finally, one of the greatest limitations was funding for the project. Given that Fundación El Caño and Footprint Possibilities are non-profit organizations, the amount of funding that was provided to our project was limited. We had to purchase the necessary materials and craft the presses on our own. Since the budget was non-existent, we also had to make many compromises on materials, settling for plywood instead of gridded pieces of wood, replacing blotting paper with newspaper, and using watercolor paper instead of herbarium mounting paper. Gridded wood would have allowed for more even drying ("DIY Plant Pressing," 2017), but the flat sheets of plywood were sufficient at drying the plants. Since we added heavy-duty clamps and placed the press next to a dehumidifier, they were able to dry quickly and evenly despite the different wood. An issue with the newspaper was that it left ink behind on the leaves, but these markings were small and concealed by gluing the tarnished side to the paper. Herbarium mounting paper is acid-free and made of fabric ("Herbarium Mounting Paper," n.d.), whereas watercolor paper is acid-free and made of 50% cotton ("Fabriano 5," n.d.), so it was a good, low-cost alternative.

CHAPTER 4: RESULTS

4.1 Findings

On the first trip to El Caño, the team traversed the perimeter of the park to determine its size and biodiversity. Despite there being a high volume of plants, there were few unique species. As a result, a goal was set to identify 50 plants and preserve 25 of them, including trees, shrubs, herbs, and graminoids. Over the course of two weeks, 44 plant species were identified and 32 were collected. Amongst these were 9 trees, 2 vines, 19 forbs/herbs, 3 shrubs, 6 subshrubs, and 5 graminoids.

These habits were identified from the United States Department of Agriculture's Natural Resources Conservation Service database. A tree is defined as a perennial, woody, vascular plant with a single stem. A vine is a twining, vascular plant with relatively long stems, either woody or herbaceous. A forb/herb is a vascular plant without significant woody tissue at or above ground. They can be annual, biennial, or perennial, but they always lack significant thickening and have perennating buds at or below the ground surface. Forbs/herbs include ferns, horsetails, lycopods, and whisk-ferns. A shrub is a perennial, vascular plant with several woody stems arising from or near the ground. The subshrub is a shorter shrub, never reaching more than 3 feet tall. Finally, a graminoid is a grass or grass-like plant ("Growth Habits Codes and Definitions," n.d.).

Upon discovering a new plant, the location was taken using GPS, the height was measured in feet, photos were taken displaying each of the plant's organs, a visual description of the plant was recorded, and, if selected, a sample was cut. This was repeated throughout the park until no more unique plants could be identified. An issue with this process was the number of dangerous spiders in El Caño that prevented the team from going into certain areas, meaning there may be more unidentified species. Nevertheless, the goal to preserve 25 species was exceeded.

The preservation process began with trimming the samples to size. They were then laid on newspapers that were sandwiched between layers of cardboard and plywood. Every few days the newspaper was exchanged as it had absorbed the moisture from the plants. After two weeks, the samples were ready. They were glued to watercolor paper with superglue and epoxy to ensure they would not detach. These sheets dried for a few hours before being placed in plastic page protectors. The page protectors were collected in a scrapbook with each sheet containing two herbarium specimens. Labels were taped onto the page protectors so as to not disturb the specimens.

In the case of bark, samples were sawed off the trunk and placed into a plastic briefcase with dividers for each sample. A label was placed in the unit with its corresponding specimen to clarify the identity. For fruits, they were shrink-wrapped in a vacuum sealer and labeled with a marker. They were then attached to the scrapbook that contained their corresponding flower or leaf specimen. This final product was delivered to Fundación El Caño for their use in the comparative study.

4.2 Native, Non-Native, and Invasive Species

From the plants the team identified in El Caño, there was a variety of native, non-native, and invasive species. Native species are those considered to be indigenous to a location, which in this case is Central America. Likewise, non-native species are considered to be non-indigenous but not dangerous to crop cultivation or environmental use. Non-native species were introduced to a region by human help. Invasive species are species which are non-indigenous and have a tendency to rapidly populate a region and take resources from the native plants or crops, displacing at least one native species (Nodjimbadem, 2016). Whether a species is native, non-native, or invasive has profound effects on its role in an ecosystem.

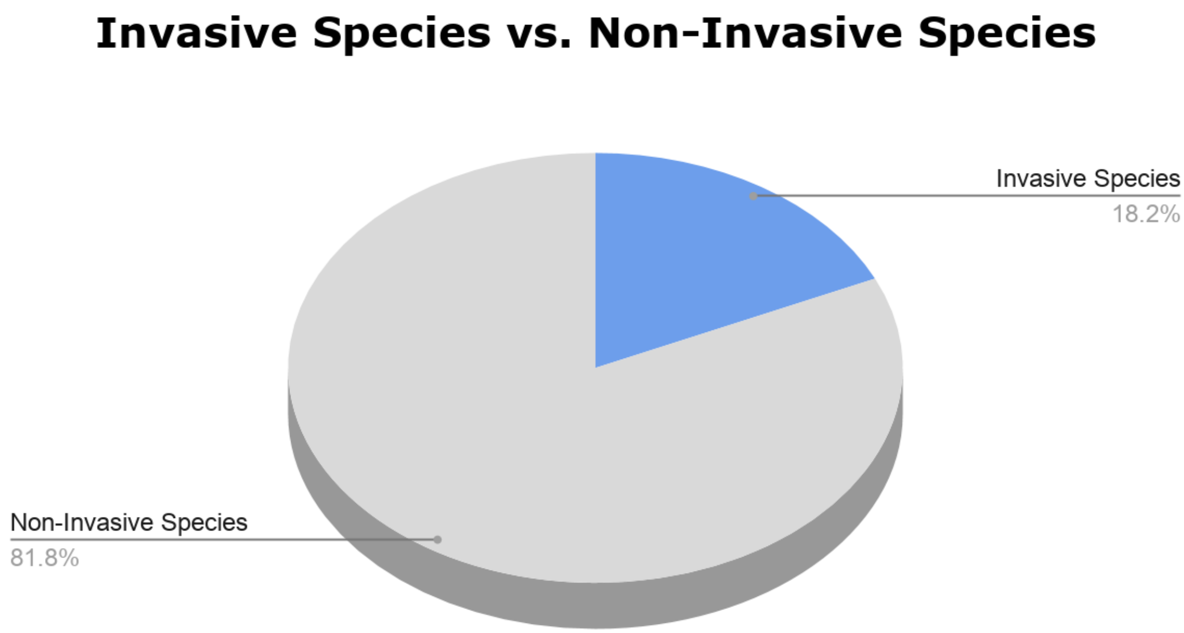

Figure 8: Invasive species vs. non-invasive species identified in El Caño Archaeological Park.

The team identified 44 different plant species in El Caño Archaeological Park. Eight of the identified species are considered to be invasive. The ratio of invasive to non-invasive species identified is illustrated in the table above. This is an important finding because invasive species tend to rapidly change the ecosystem in which they exist, indicating that it is probable that the biodiversity of El Caño is far different than the biodiversity during Pre-Columbian times.

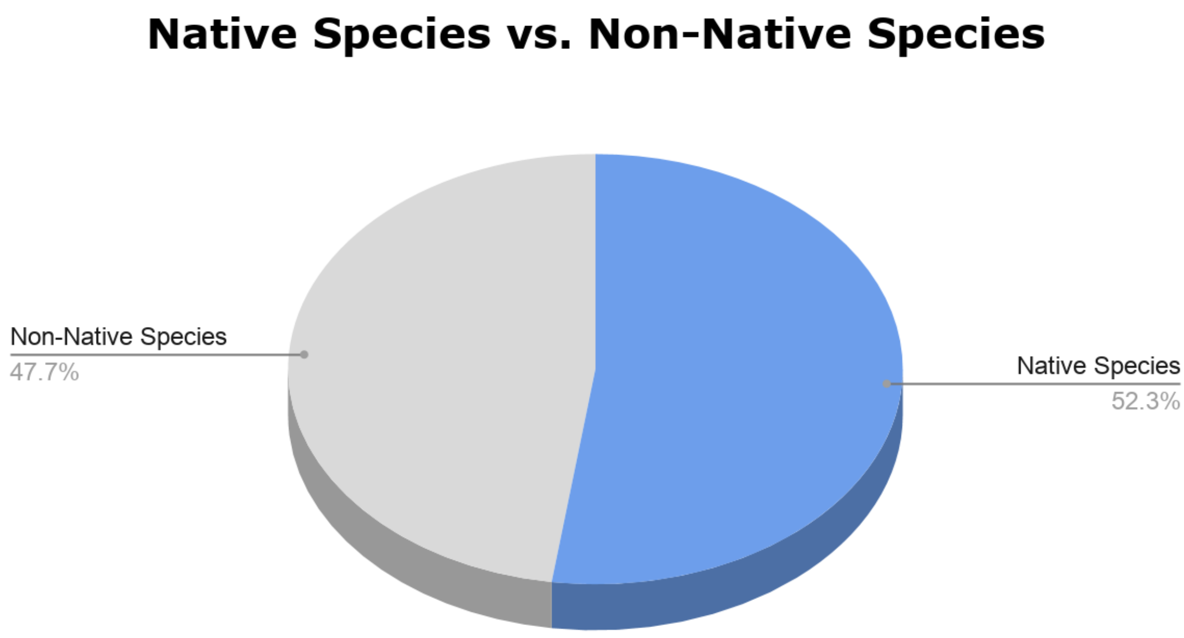

Figure 9: Native species vs. non-native species identified in El Caño Archaeological Park.

Another interesting finding was the number of non-native species found inside of El Caño. Of the 44 identified plants, 21 were found to be non-native. The ratio of non-native species to native species is shown the table above. For example, *Fagus sylvatica* or "European Beech Tree," which is a large and lightly colored tree native to parts of Europe including Sweden, France, and England. Other non-native species found are native to a variety of places: the Balkans, Africa, Southeast Asia, and Australia.

Given the volume of non-native and invasive species, the team hypothesized that the biodiversity of El Caño today is quite different than it was in Pre-Columbian time. This was further supported after discussing the findings with the El Caño staff. It was indicated that most of the trees in El Caño were planted recently in the park.

Figure 10: Map of the GPS coordinates of each plant identified in El Caño Archaeological Park.

The team recorded the latitude and longitude of each plant in El Caño Archaeological Park in degrees, minutes, and seconds using a GPS system. In order to map the location on a satellite image, they input the coordinates into an online calculator that converts the values into decimals. Using a mapping program, the decimal coordinates were overlaid onto the most recent aerial view available of El Caño. This picture was taken on April 2, 2018, dry season in Panama. In the dry season, which lasts from January to April, there is little precipitation and much of the plant life dies off. This is considered summer in Panama; it is the season when fruits sprout. For example, *Melothria pendula* had only one or two cucumbers growing in September, while in the dry season it would bloom more. Wet season lasts from May to December and is considered winter. It is marked by frequent rainfall and flourishing plant life, with many more being green. The increase of rainfall also leads to an increase in flooding, contributing to more species being brought into El Caño Archaeological Park. Figure 10 has markers where no plant life is visible, meaning the ecology is constantly changing in the park. In Appendix D, satellite imagery of El Caño was included from the years 2018, 2017, 2013, and 2012. These satellite images further highlight the rapid change in ecology that has happened in El Caño in the span of less than a decade.

4.3 Significance of Identified Species

Many of the plant species identified were utilized in traditional and folk medicinal practices. *Eclipta prostrata* was used in Indian Ayurvedic medicinal practices to alleviate the kapha dosha (Puri, 2003). Many plants also displayed antiseptic, antibacterial, antioxidant, antiinflammatory, emetic, and purgative properties. Countless conditions were treated by these plants, ranging from common colds to cancer and AIDS in the case of *Momordica charantia* ("Bitter Melon," 2019); malaria from *Delonix regia* (Fern, n.d.c), *Cassia abbreviata* (Fern, n.d.b), *Carica papaya* (Fern, n.d.a), and *Petiveria alliacea* (Hernandez, 2014); diarrhea, dysentery, urine retention, dehydration, and urogenital disorders in *Mimosa pudica* (Ahmad, Sehgal, Mishra, & Gupta, 2012), *Desmodium triflorum* (Fern, n.d.d), and *Laportea aestuans* (Fern, n.d.e); and various other disorders like diabetes, sinus infections, and stomachaches.

In addition to medicinal uses, several of these plants are integral parts of many cultures' cuisines. *Celosia argentea* is eaten in West Africa and Southeast Asia ("Lost Crops of Africa," 2006). *Amaranthus spinosus* is a valued food plant in Africa, Thailand, the Philippines, Maldives, Mexico, Bangladesh, and Manipuri (Grubben & Denton, 2004). *Ficus aurea* produces an edible fig fruit fibers that can be made into chewing gum (Harvey & Haber, 1998). Chili peppers produced from *Capsicum frutescens* are a major part of Ethiopian cuisine (Pankhurst, 1968). By cooking during the green and yellowing stages, *Momordica charantia* is eaten throughout Asia ("Bitter Melon," 2019). The fruit and seeds of *Carica papaya* can be eaten raw or cooked and are throughout the world (Titanji, Zofou, & Ngemenya, 2008). The berries of *Melothria pendula* can only be eaten when unripe and light green in color, otherwise they will have an extreme laxative quality ("Melothria pendula," n.d.). Several other plants were edible yet not an important part of cultural cuisine.

Amongst the handful of trees identified were some that could be turned into furniture, timber, firewood, and charcoal. *Fagus sylvatica* is often used in carpentry, flooring, firewood, and indoor furnishings. *Juglans regia* not only produces an edible walnut, but the wood is prized for flooring, instruments, furniture, and gunstocks (Elmore, 1944). *Hura crepitans* is used for timber and decoration, but its sap can blind people if it makes contact with their eyes ("Hura crepitans," 2018).

CHAPTER 5: CONCLUSIONS

5.1 Analysis

As seen in Figure 8, 18.2% of the plants in El Caño Archaeological Park are considered invasive to Central America. Amongst the invasive species are several trees and noxious, fast-growing weeds, including *Gleditsia triacanthos*, *Solanum carolinense*, *Talinum paniculatum,* and *Hura crepitans.* These are significant for their destructive qualities. *Gleditsia triacanthos* destroys pasture and outcompetes other crops. *Solanum carolinense* is highly toxic to consume and a troublesome, noxious weed. *Talinum paniculatum* has long, deep roots that spread easily and are hard to remove from a region. Finally, *Hura crepitans* contains a sap that can cause blindness if it comes into contact with one's eye. According to the director of Fundación El Caño, Dra. Julia Mayo, the large trees were planted in the park. They are primarily fast-growing species, which also accounts for the quickly changing ecology in photos from just one year ago.

Figure 9 shows that 47.7% of plants in El Caño are non-native species, indicating that they were integrated into the park in recent history. Non-native species can grow in a location for many reasons. For one, birds and other animals drop seeds into the park which grow and develop new plants. *Capsicum frutescens* made a singular appearance in the park and was located to the side of a tree, indicating that it likely grew from an animal dispersing some seeds. During wet season, the high levels of rainfall increase flooding in the region. Floodwaters streaming from one area to another disperse seeds throughout the park, thus changing the ecology every season. Another major factor is landscaping. Many non-native and invasive species were planted in the park for their aesthetic value, yet they do not accurately represent the nature of the El Caño region. Finally, since the village of El Caño contains a sugarcane plantation and rice irrigation system, agricultural practices are still in use ("Cultural Gold Artifacts Now on Display to Public," 2019). Cultivating crops alters the soil quality and changes what can easily grow. Depending on the exact agricultural practices of the region, the land may have degraded over time and therefore is unable to support the native plants. Since so many foreign plants are in the park, it is likely that the park today would not be suitable to grow the original species.

5.2 Moving Forward

The purpose of this project was to identify the flora in El Caño Archaeological Park to initiate a comparison study. During excavations of the tombs, archaeologists found plant matter resins. Using the data collected through the course of this project, Fundación El Caño will compare the modern environment to the plant matter identified in the tombs. This will provide compelling historical insight into the diet, agriculture, and traditions of Pre-Columbian society. It will also provide insight as to how the environment has changed over the past six centuries.

The team recommends that Fundación El Caño collect and identify more specimens in the dry season, which runs from January to April. Given the tropical climate of Panama, the environment changes dramatically between the two seasons. Identifying the species in the park during the dry season would allow for plants which only grow during this season to be catalogued, leading to a more comprehensive set of data for the comparative study.

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Image References

Figure 1: http://oda-fec.org/nata/download/bancorecursos/Noticias/noticia40-vitrinaTumba2.jpg

APPENDIX A: LIST OF PLANTS IDENTIFIED IN EL CAÑO ARCHAEOLOGICAL PARK IN THE ORDER THEY WERE COLLECTED

Family Name	Genus Name	Species Name	Common Name	Latitude	Longitude	Height (ft)	Visual Description
Amaranthaceae	*Celosia*	*argentea*	"Silver Cock's Comb"	(8,23,48.23)	(80,30,4.6)	3.42	appears frequently, purple gradient flower, leaves near base
Asteraceae	*Eclipta*	*prostrata*	"False Daisy"	(8,23,48.1)	(80,30,3.77)	1.38	small white flowers, green undeveloped buds, and many leaves
Poaceae	*Panicum*	*dichotomiflorum*	"Smooth Witchgrass"	(8,23,48.47)	(80,30,4.33)	4.58	golden brown appeared to have very small thin seeds but on a small stem; leaves were spaced throughout the stem
Amaranthaceae	*Amaranthus*	*spinosus*	"Spiny Amaranth"	(8,23,48.6)	(80,30,4.3)	3	bushy greenish-brown flowers; leaves were close to the flowers
Asteraceae	*Melampodium*	*divaricatum*	"Hierba Aguada"	(8,23,48.5)	(80,30,4.4)	2.5	small yelllow flowers; leaves throughout the flower; many flowers on

							the plant
Fagaceae	*Fagus*	*sylvatica*	"European Beech"	(8,23,48.6)	(80,30,4.8)		tree #1
Juglandaceae	*Juglans*	*regia*	"Carpathian Walnut"	(8,23,48.55)	(80,30,3.5)		tree #2
Acanthaceae	*Justicia*	*comata*	"Marsh Water-Williow"	(8,23,48.2)	(80,30,2.8)	2.67	had many small white flowers; Inflorescence; leaves were distant from the flowers
Moraceae	*Ficus*	*aurea*	"Florida Strangler Fig"	(8,23,46.4)	(80,30,5.85)		tree #4; biggest tree in the park
Urticaceae	*Laportea*	*canadensis*	"Canadian Wood Nettle"	(8,23,42.55)	(80,30,1.7)	1.5	small white flowers in clumps that are under leaves; spade shaped leaves with rigid edges
Leguminosae	*Gleditsia*	*triacanthos*	"Honey Locust"	(8,23,42.4)	(80,30,1.5)		tree #5; aligator bark
Leguminosae	*Sesbania*	*herbacea*	"Bigpod Sesbania"	(8,23,41.5)	(80,30,1.45)	7.5	straight, thin, and tall plant; leaves extended from branches; long oval shaped leaves; many leaves on each

							branch lined in a row
Solanaceae	*Capsicum*	*frutescens*	"Bird Pepper"	(8,23,40.75)	(80,30,4.95)	3	peppers (varying in color green, red, orange) in clumps with smooth club shaped leaves
Urticaceae	*Laportea*	*aestuans*	"West Indian Woodnettle"	(8,23,40.7)	(80,30,5.2)	2.5	white prickley flower; frequently appears and grows straight and tall
Leguminosae	*Mimosa*	*pigra*	"Giant Sensitive Plant"	(8,23,41,3)	(80,30,6.0)	6	fern like leaves; very small and clumped
Cucurbaticeae	*Momordica*	*charantia*	"Bitter Melon"	(8,23,41.3)	(80,30,5.9)	N/A	vines climing tree and transvering ground; with 5 point yellow flower and 5 point leas
1	*Oplismenus*	*undulatifolius*	"Wavyleaf Basketgrass"	(8, 23, 41.3)	(80,30,5.9)	1	small spear shaped crinkly leaves
Leguminosae	*Desmodium*	*triflorum*	"Three-Flower Beggarweed"	(8,23,48.1)	(80,30,4.8)	3 inches	round leaves in clumps of 3, small

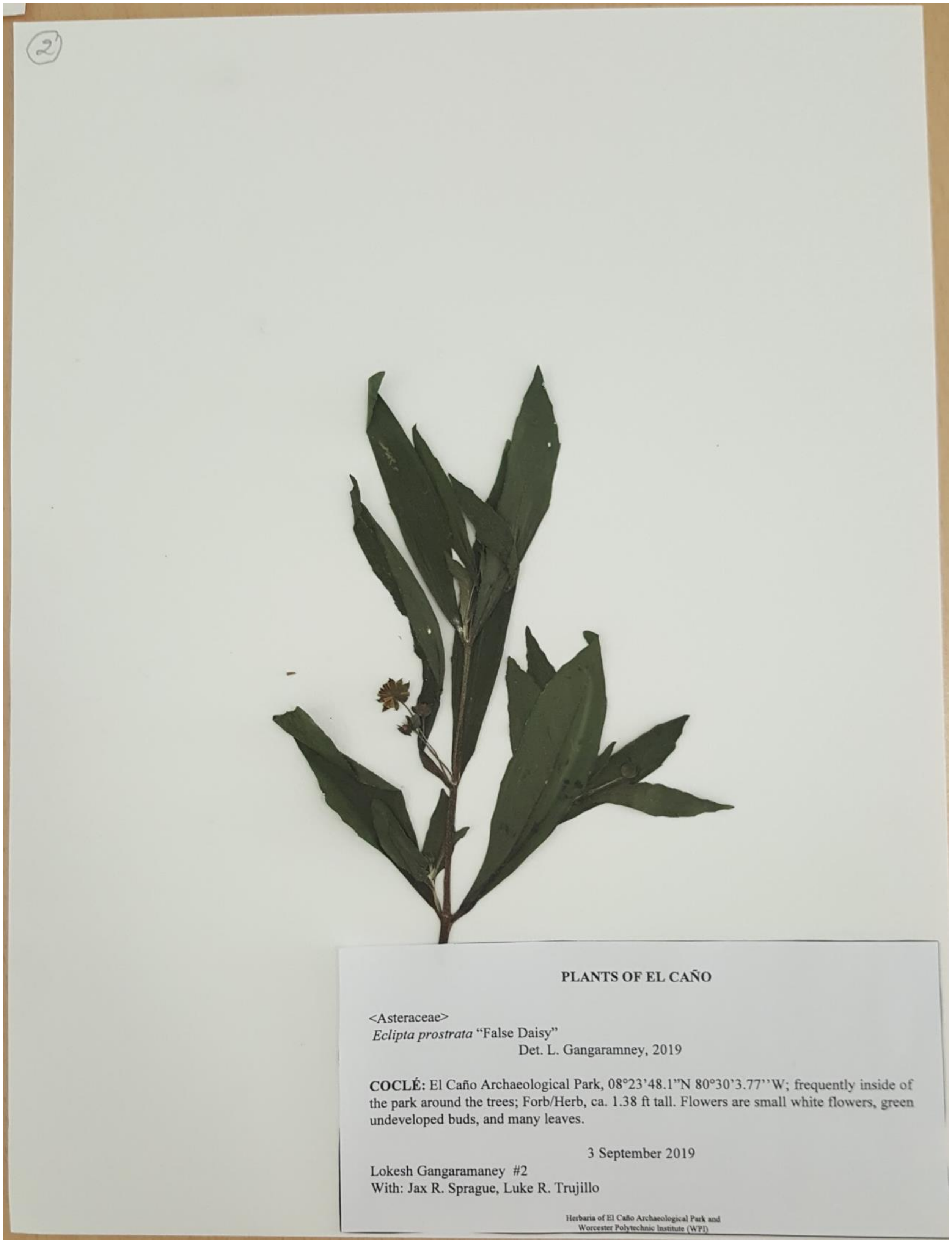
							fuschia flowers
Poaceae	*Cynodon*	*dactylon*	"Bermuda Grass"	(8,23,48.0)	(80,30,4.6)	2.5	little thingies coming from top, very thin stems
Leguminosae	*Mimosa*	*pudica*	"Sensitive Plant"	(8,23,47.9)	(80,30,4.7)	inches	small fernish like plant; closes when touched
Asteraceae	*Galinsoga*	*parviflora*	"Gallant Soldier"	(8,23,47.8)	(80,30,4.6)	inches	arrowhead shaped leaves. small white petals with a yellow center
Commelinaceae	*Commelina*	*erecta*	"Erect Dayflower"	(8,23,47.5)	(80,30,4,6)	inches	caved in leaves, purplish white flowers with yellow centers
Leguminosae	*Medicago*	*polymorpha*	"California Burclover"	(8,23,47.9)	(80,30,4.9)	inches	round leaves 3ish in a set; thin and abundant
Leguminosae	*Delonix*	*regia*	"Flamboyant"	(8,23,46.2)	(80,30,3.3)		tree #6
Leguminosae	*Cassia*	*abbreviata*	"Long-pod-cassia"	(8,23,44.7)	(80,30,3.2)		tree #7
Leguminosae	*Hippocrepis*	*emerus*	"Scorpion Senna"	(8,23,42.0)	(80,30,1.6)		tree #8, yellow flowers

Solanaceae	*Solanum*	*carolinense*	"Carolina Horse-Nettle"	(8,23,41.9)	(80,30,6.4)	8 inches	four pointed leaf edges on each side, thorns on leaves
Poaceae	*Dichanthelium*	*clandestinum*	"Deertongue"	(8,23,40.6)	(80,30,6.9)	2.5 feet	sparse seeds on flowers, long thin leaves
Caricaceae	*Carica*	*papaya*	"Pawpaw"	(8,23,40.5)	(80,30,6.9)	6 feet	tall, thin, leaves on branches with many points, fully grown has yellowish flowers and/or green fruits
Marantacea	*Calathea*	*latifolia*	"Sweet Corn Root"	(8,23,41.3)	(80,30,8.8)	5.75 ft	long, green fronds, purple flower cluster
Euphorbiaceae	*Acalypha*	*ostryifolia*	"Hornbeam Cottonleaf"	(8,23,41.3)	(80,30,8.8)	2.5 ft	nettle-like leaves, singular green sprout with purplish white flowers
Portulacaceae	*Talinum*	*paniculatum*	"Fameflower"	(8,23,41.3)	(80,30,8.9)	2.17 ft	purple flower petals with yellow centers, oval green leaves
Cecropiaceae	*Cecropia*	*obtusifolia*	"Trumpet Tree"	(8,23,41.3)	(80,30,8.8)	5 ft	leaves with 8-9 spokes
Phytolaccaceae	*Petiveria*	*alliacea*	"Garlicweed"	(8,23,41.1)	(80,30,9)	4.92 ft	small white flowers on long strip

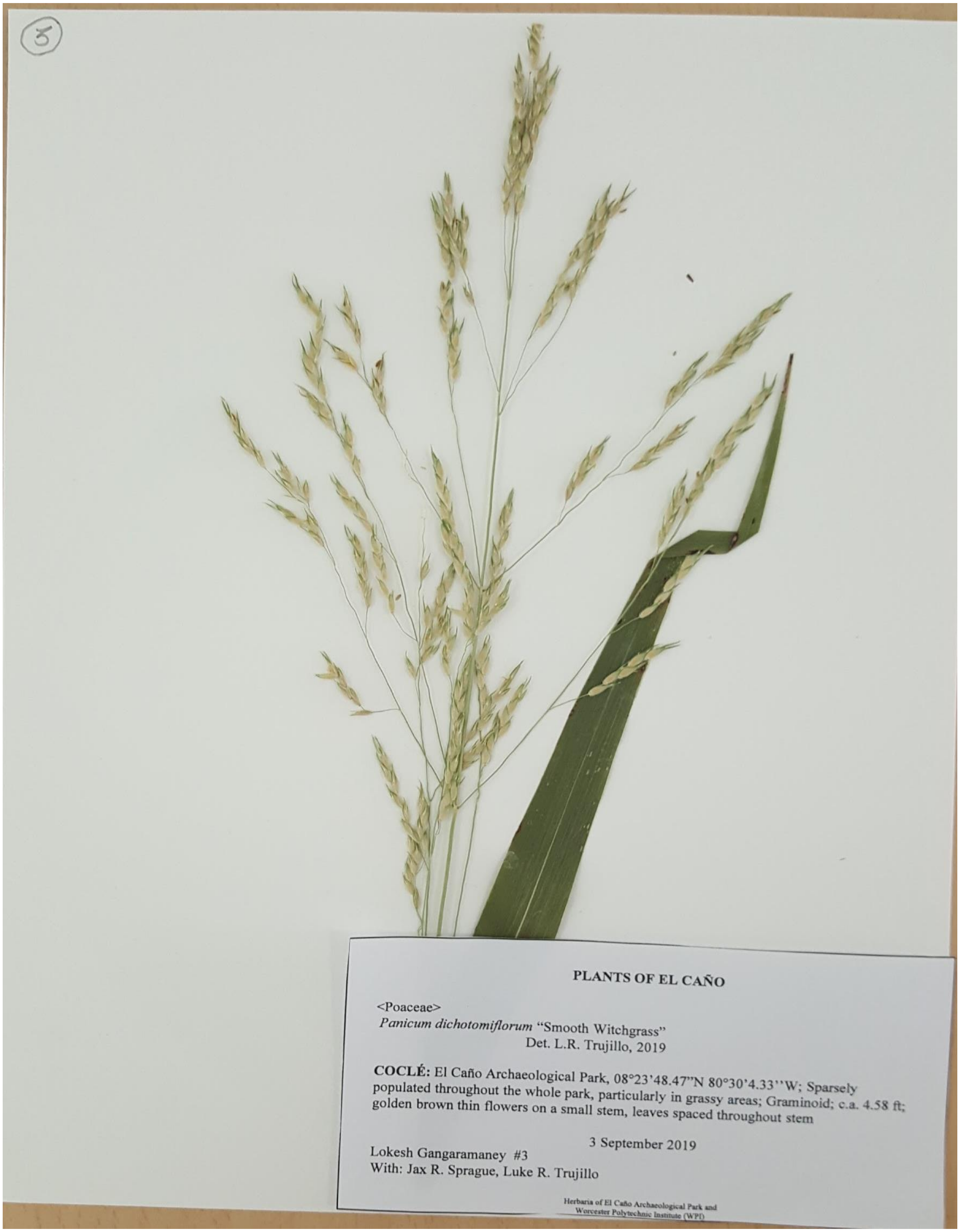
Cucurbitaceae	*Melothria*	*pendula*	"Creeping Cucumber"	(8,23,48.1)	(80,30,3.3)	4 ft	dark purple fruit, spade shaped leaves
Euphorbiaceae	*Hura*	*crepitans*	"Sandbox Tree"	(8,23,47.9)	(80,30,3.3)		thorny tree, tree #10
Euphorbiaceae	*Euphorbia*	*hypericifolia*	"Graceful Spurge"	(8,23,46.8)	(80,30,5.2)	0.67 ft	small green and white flowers, oval leaves
Compositae	*Tridax*	*procumbens*	"Coatbuttons"	(8,23,46.3)	(80,30,6.1)	1 ft	fluffy white flower, sharp green leaves, white and yellow flower before fully blooming
Asteraceae	*Emilia*	*fosbergii*	"Florida Tasselflower"	(8,23,46.3)	(80,30,6.1)	1 ft	green wrap around purple bud flower
Cyperaceae	*Cyperus*	*eragrostis*	"Umbrella Sedge"	(8,23,45.5)	(80,30,6.3)	1.33 ft	long thin leaves, blooming brown flowers
Leguminosae	*Alysicarpus*	*vaginalis*	"Alyce-clover"	(8,23,43.1)	(80,30,3.7)	3 ft	thick oval leaves
Urticaceae	*Urtica*	*dioica*	"Common Nettle"	(8,23,42.4)	(80,30,3.7)	2 ft	hairy stem, pointy green spear shaped leaves, small white flowers
Euphorbiaceae	*Acalypha*	*pendula*	"Dwarf Chenille Plant"	(8,23,41.6)	(80,30,4)		
Capparaceae	*Cleome*	*serrata*	"Toothed Spiderflower"	(8,23,42.7)	(80,30,4.9)	1ft	four white petals with yellow extensions

APPENDIX B: SAMPLES OF THE PLANTS IDENTIFIED IN EL CAÑO ARCHAEOLOGICAL PARK WITH HERBARIUM LABELS

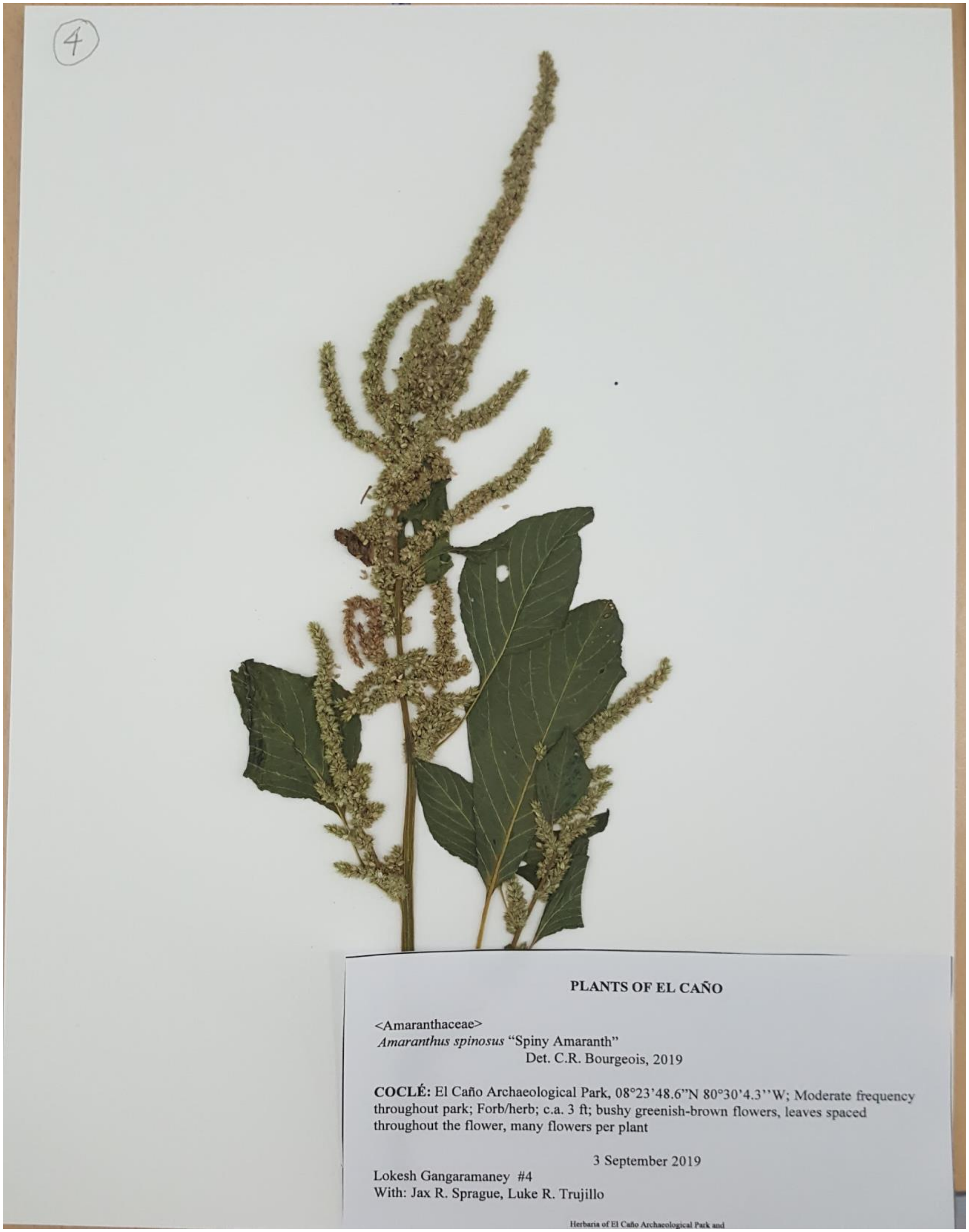
Celosia Argentea



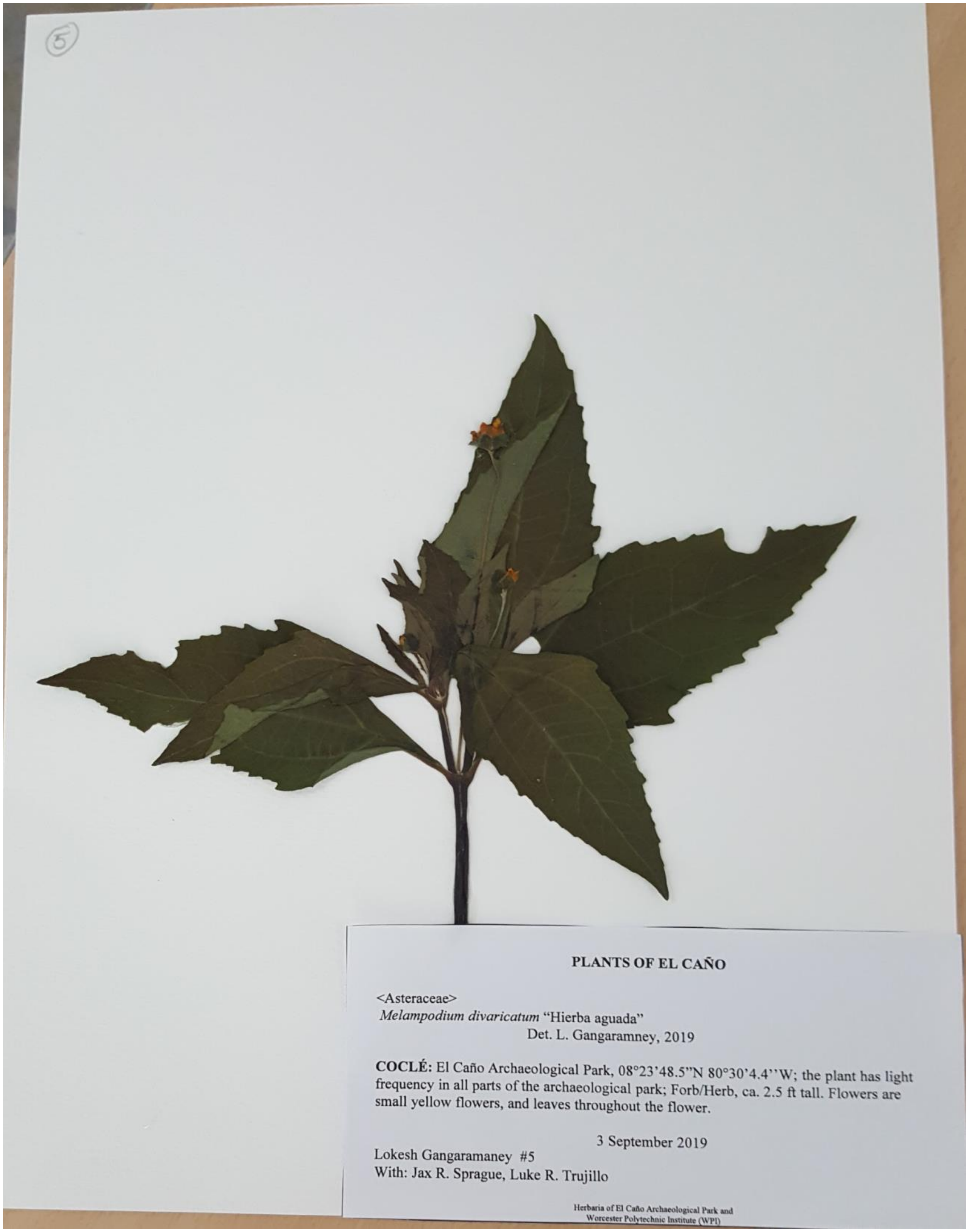
Eclipta Prostrata



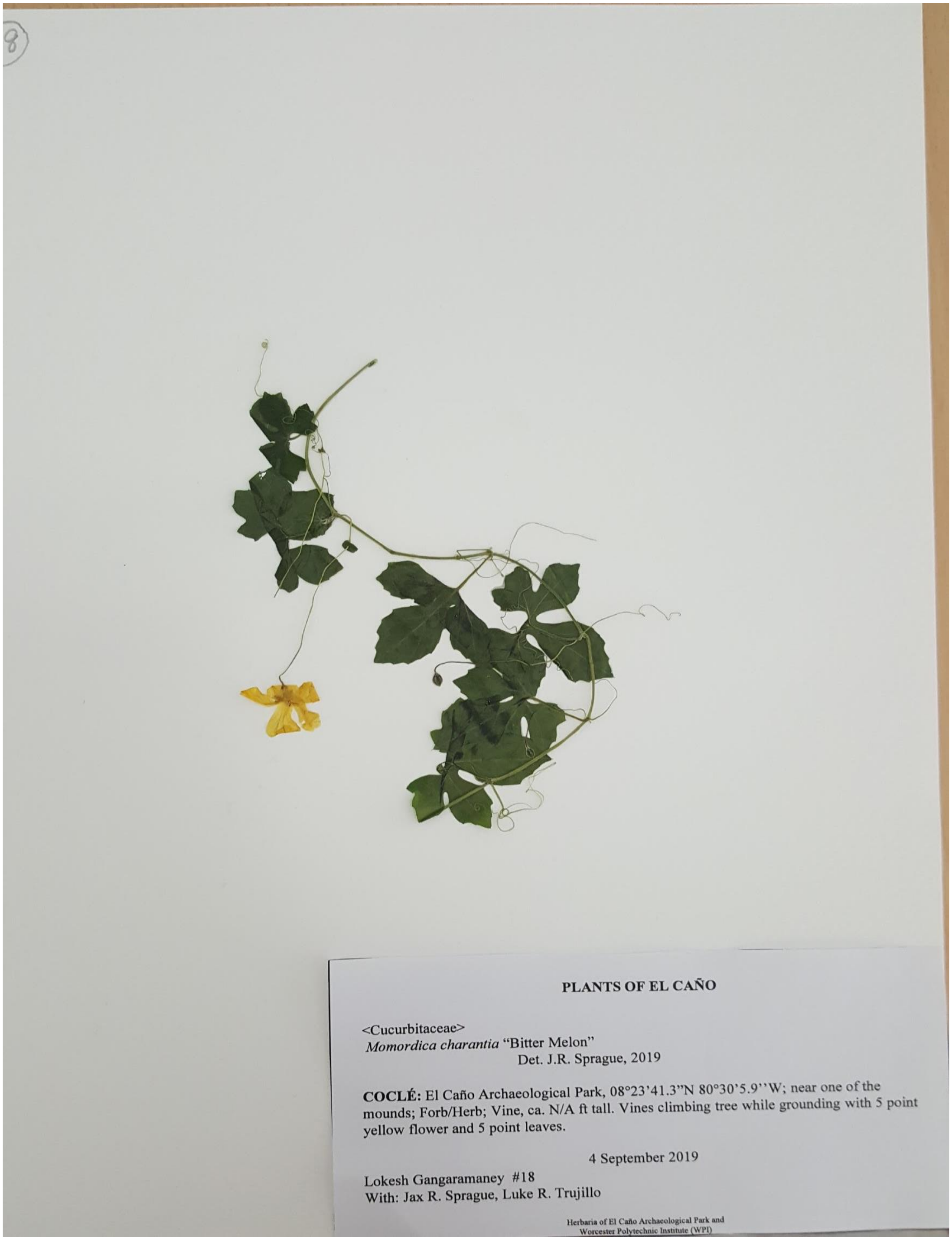
Panicum dichotiflorum



Amaranthus spinosus

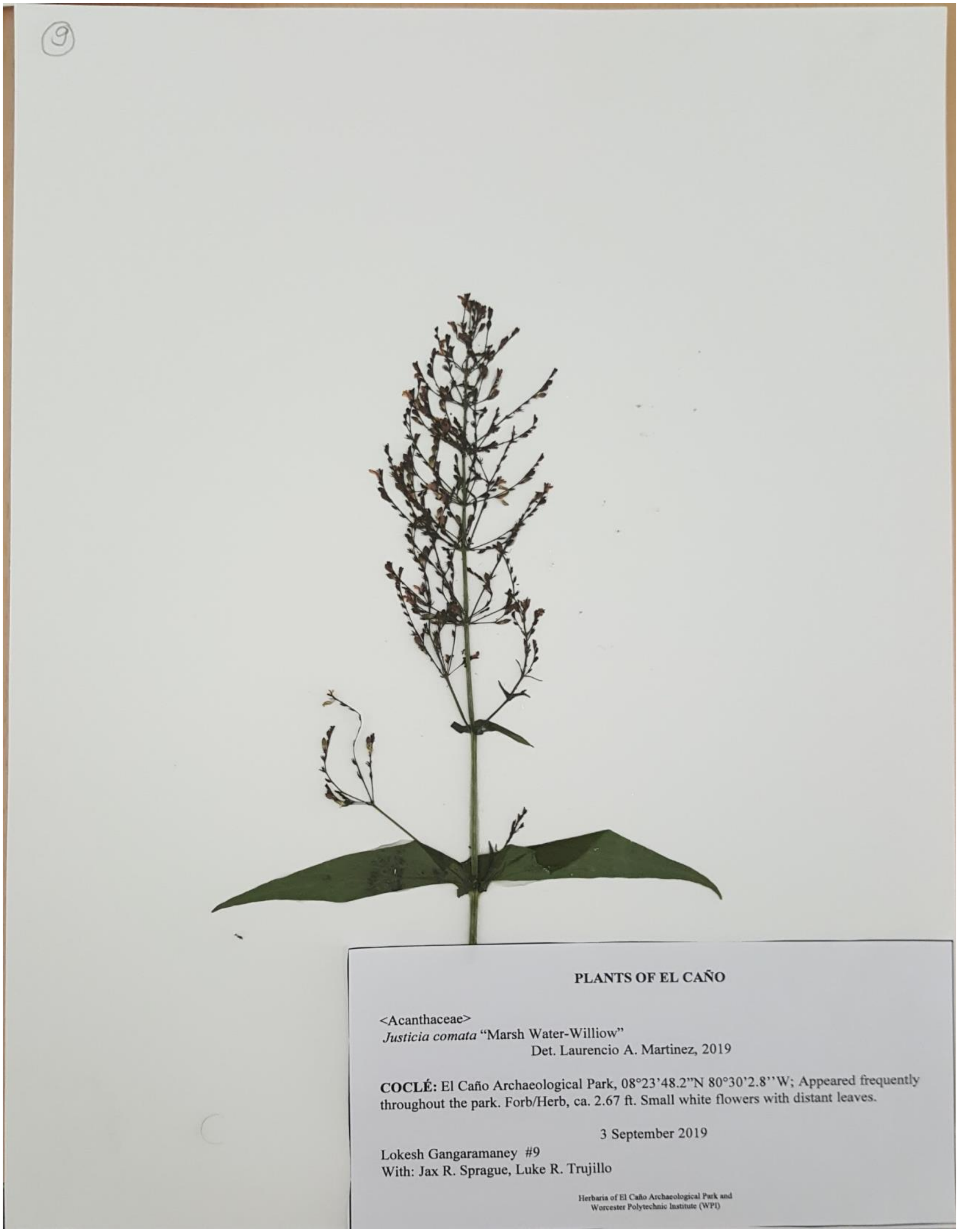


Melampodium Divaricatum

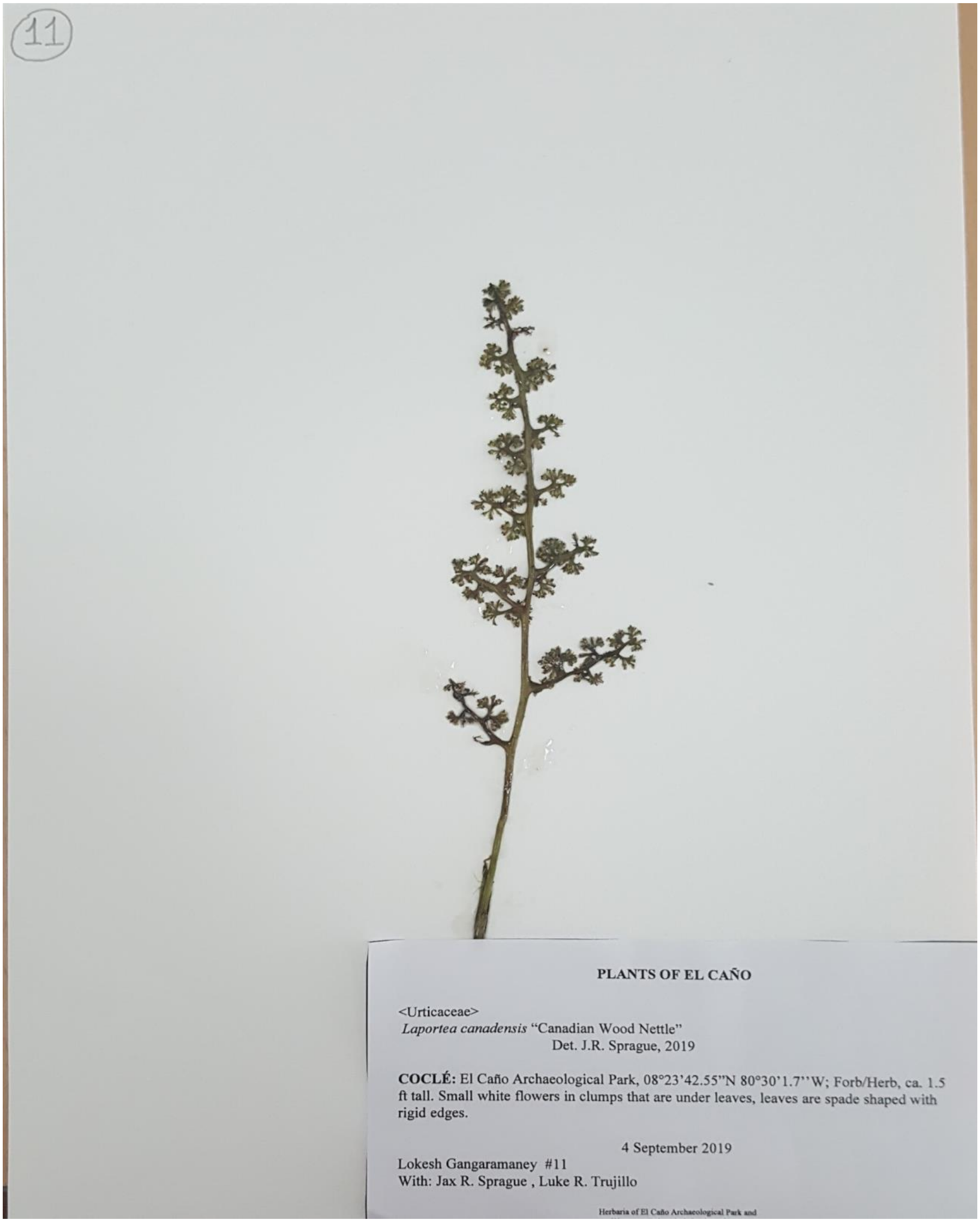


Momordica Charantia

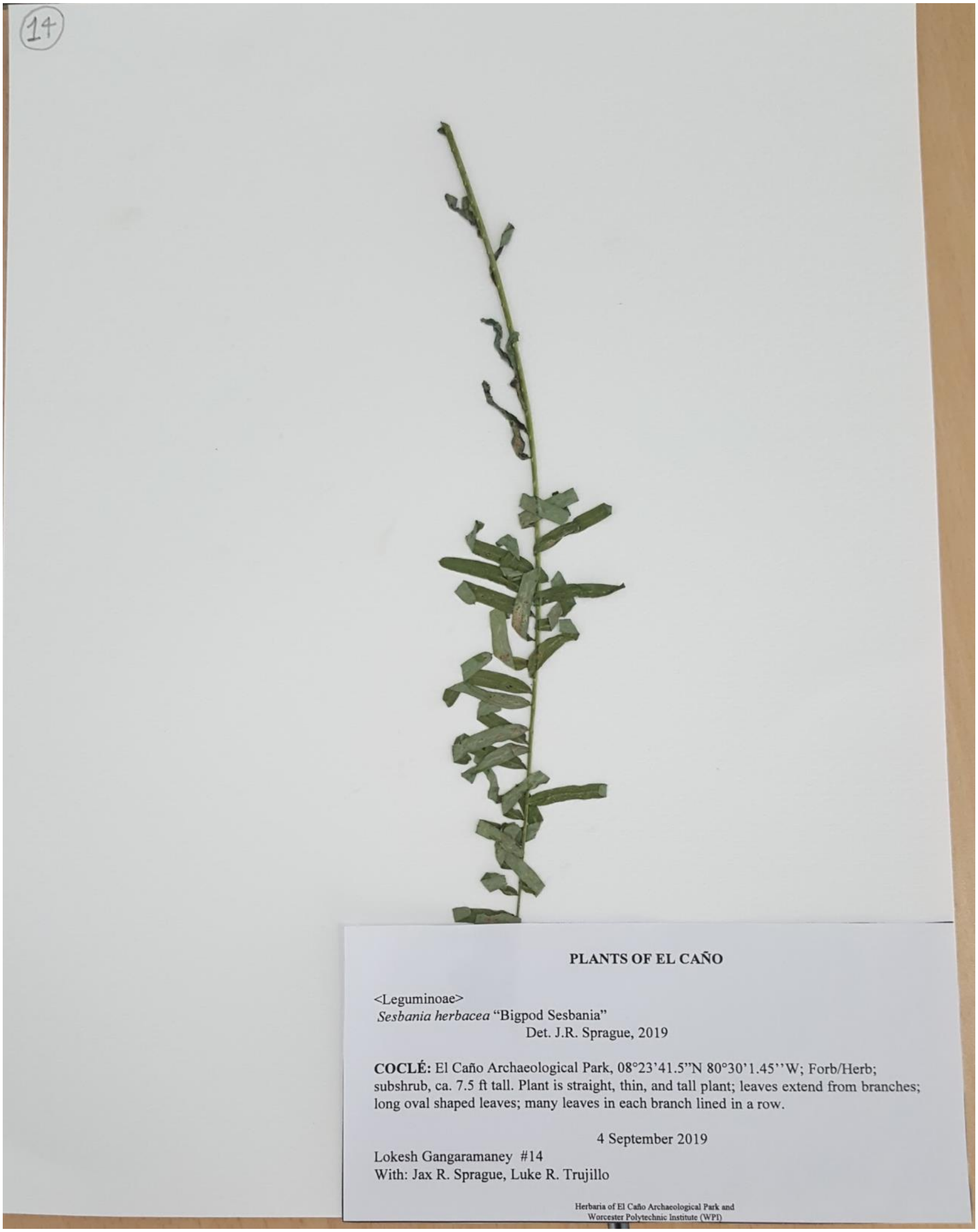
Justicia comata



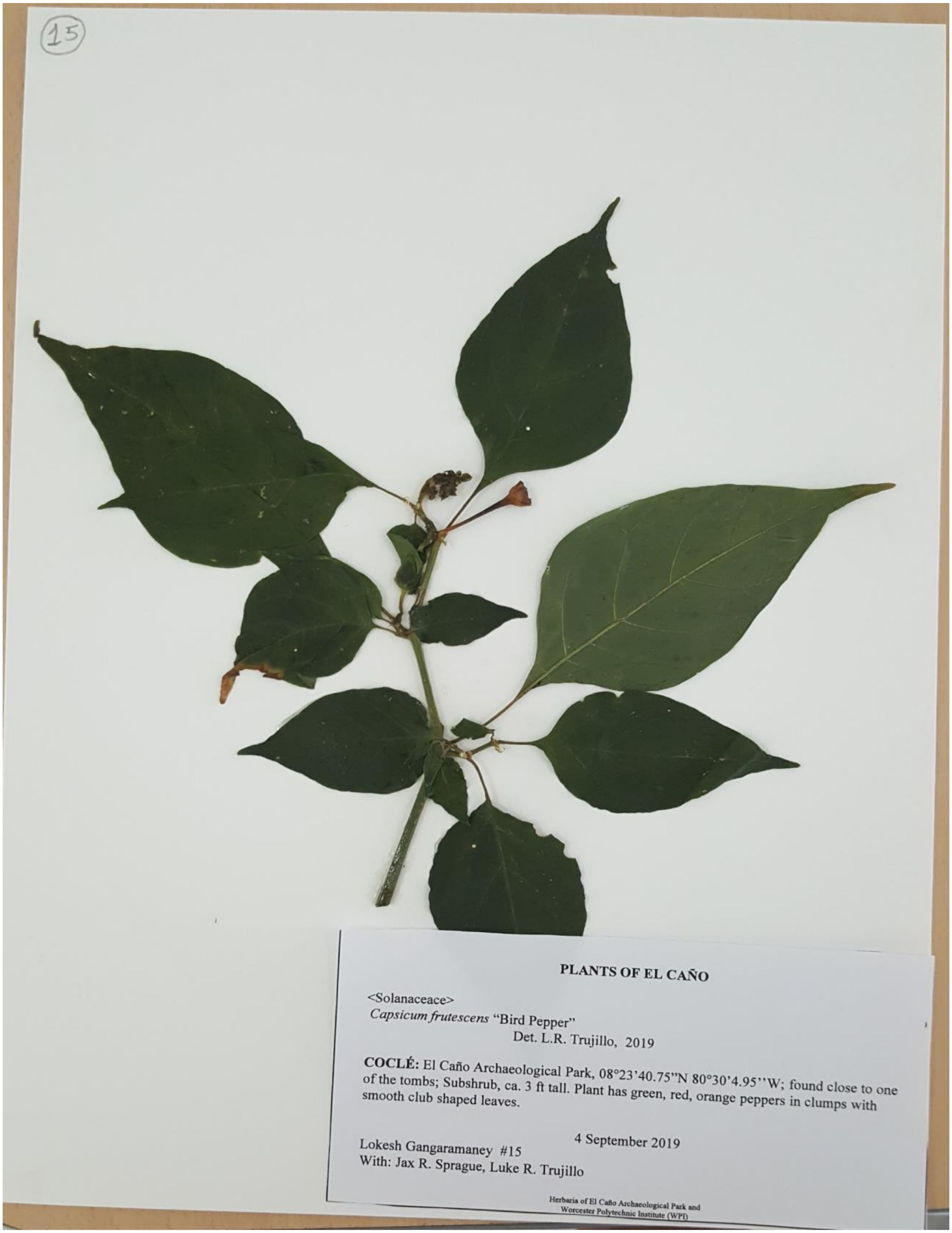
Justicia comata



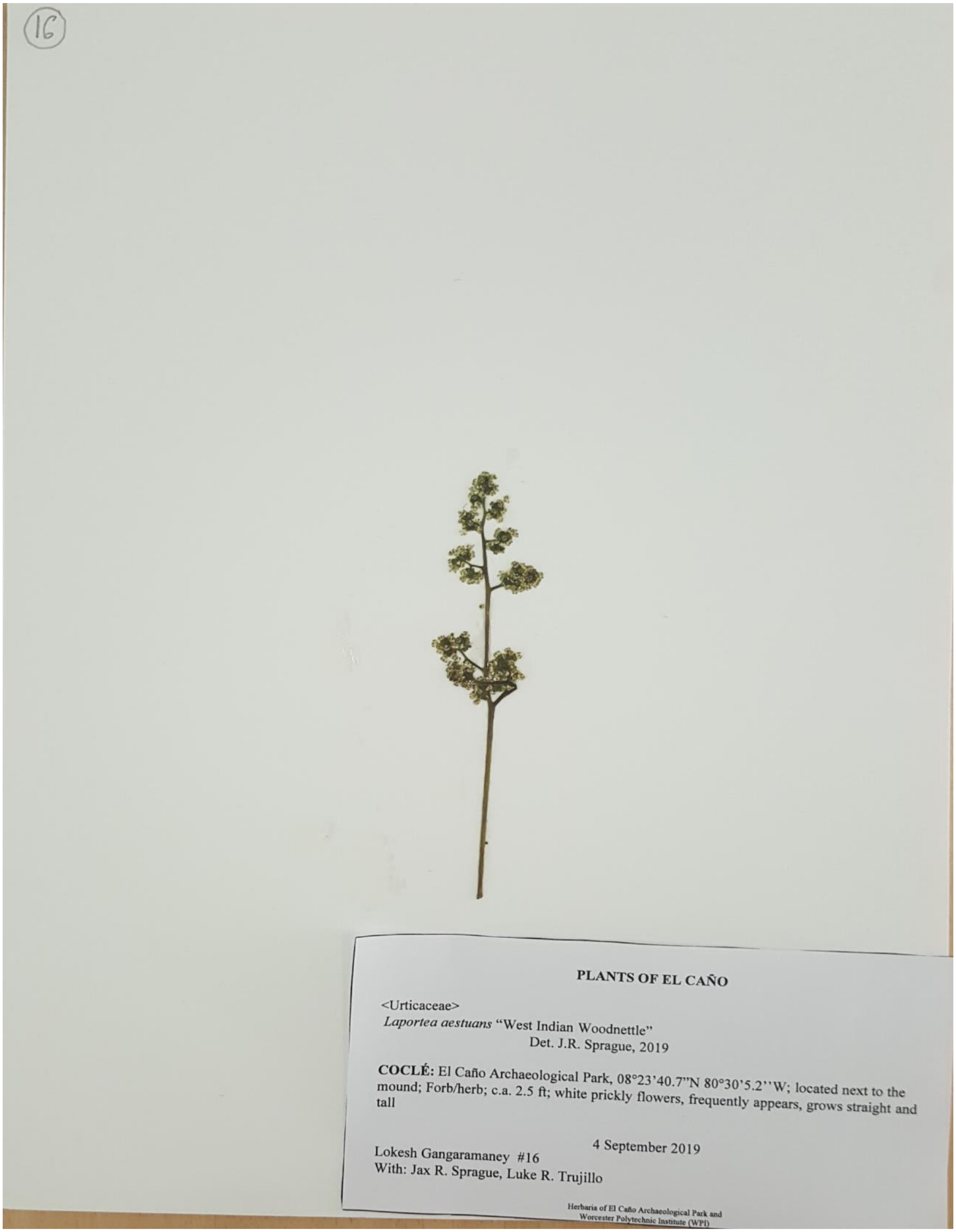
Laportea canadensis



Sesbania herbacea

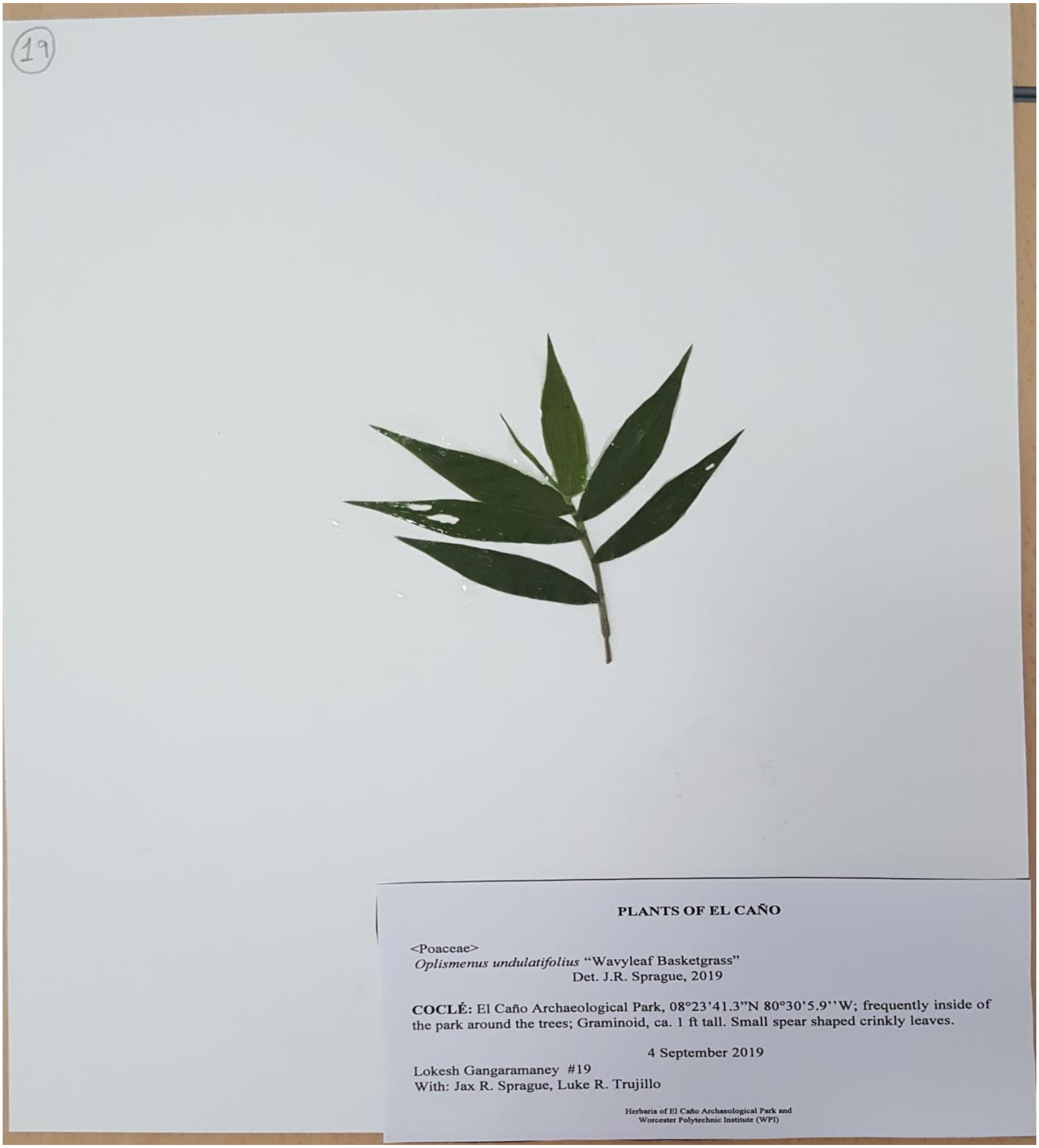


Capsicum frutescens

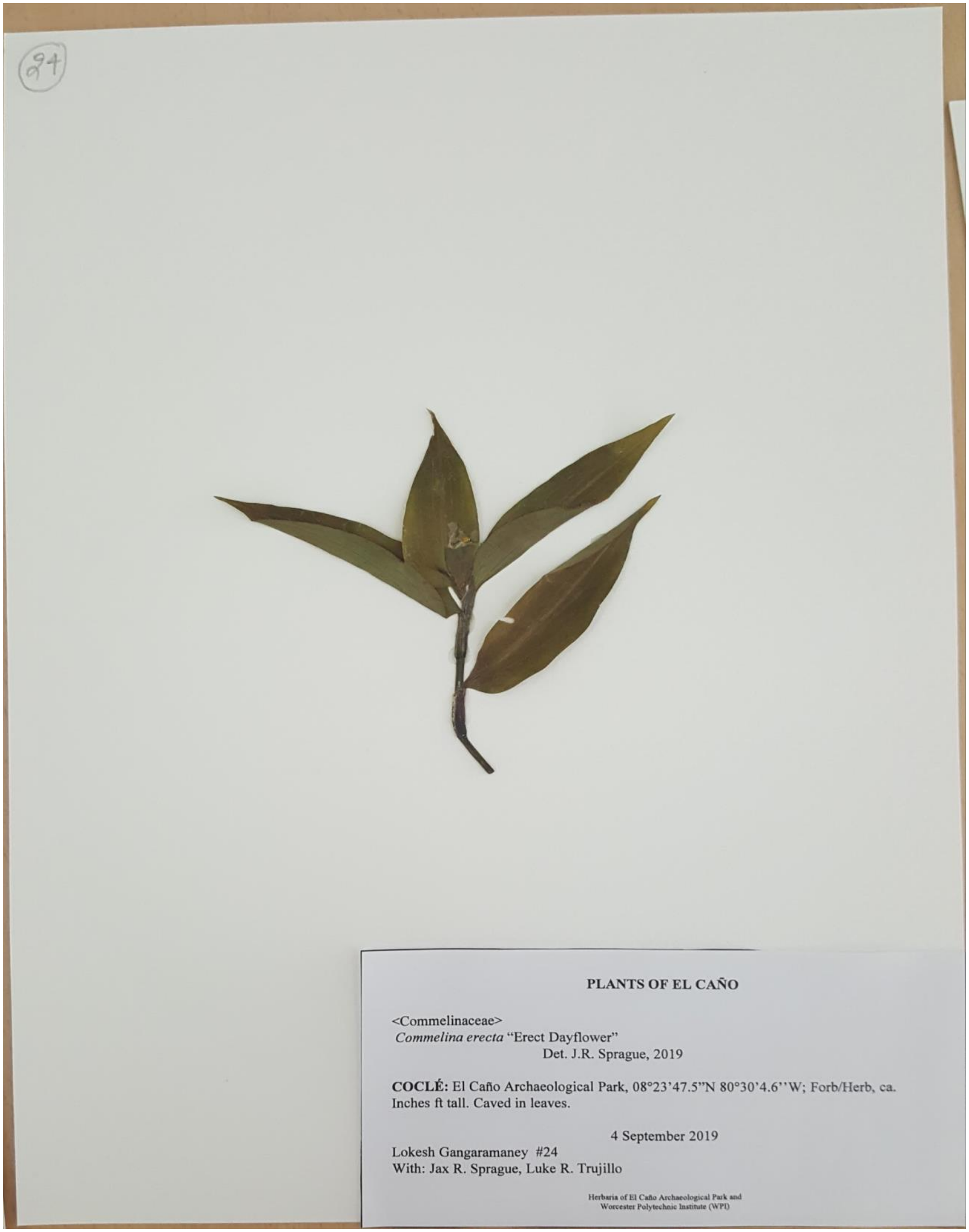


Laportea aestuans

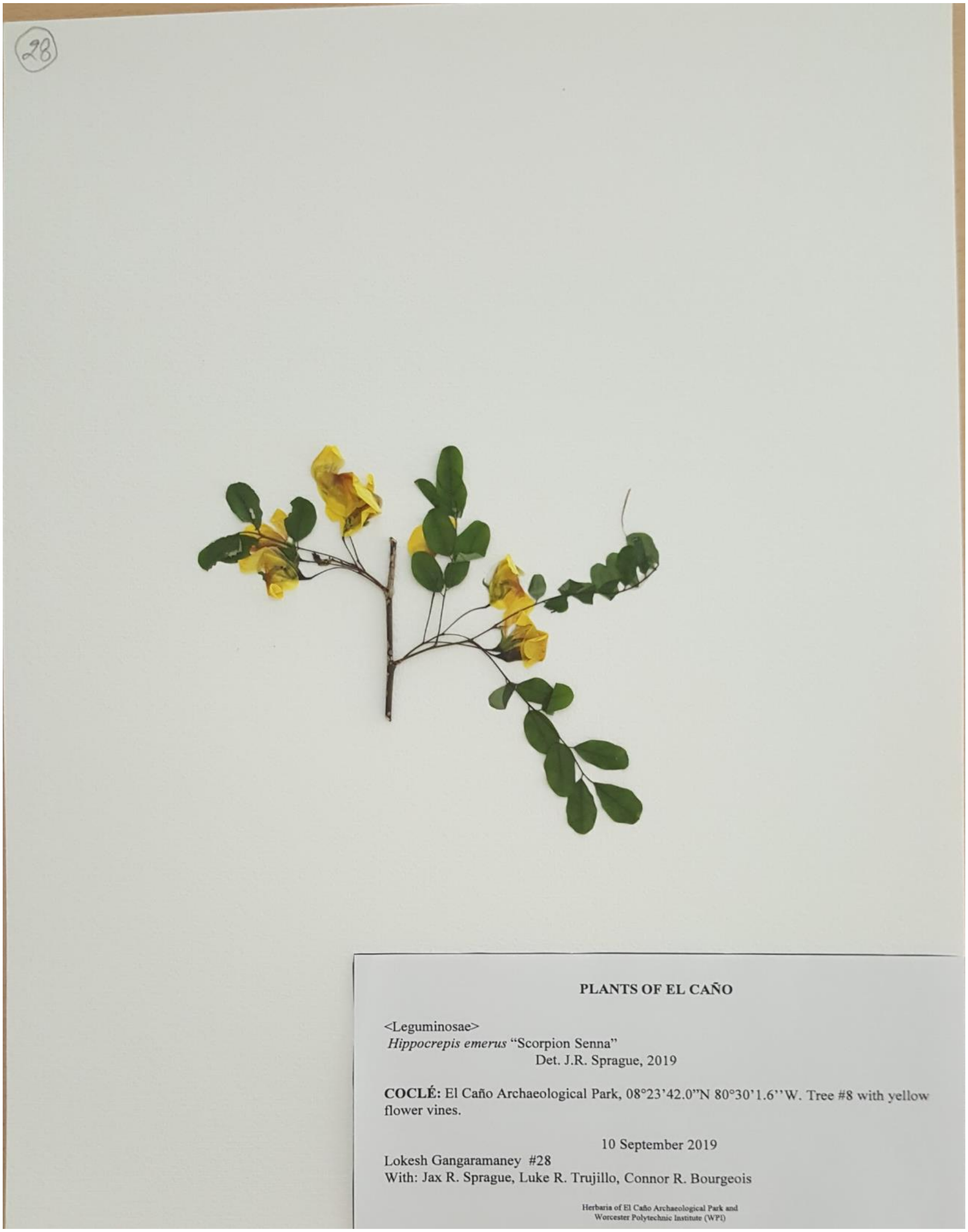
Mimosa pigra



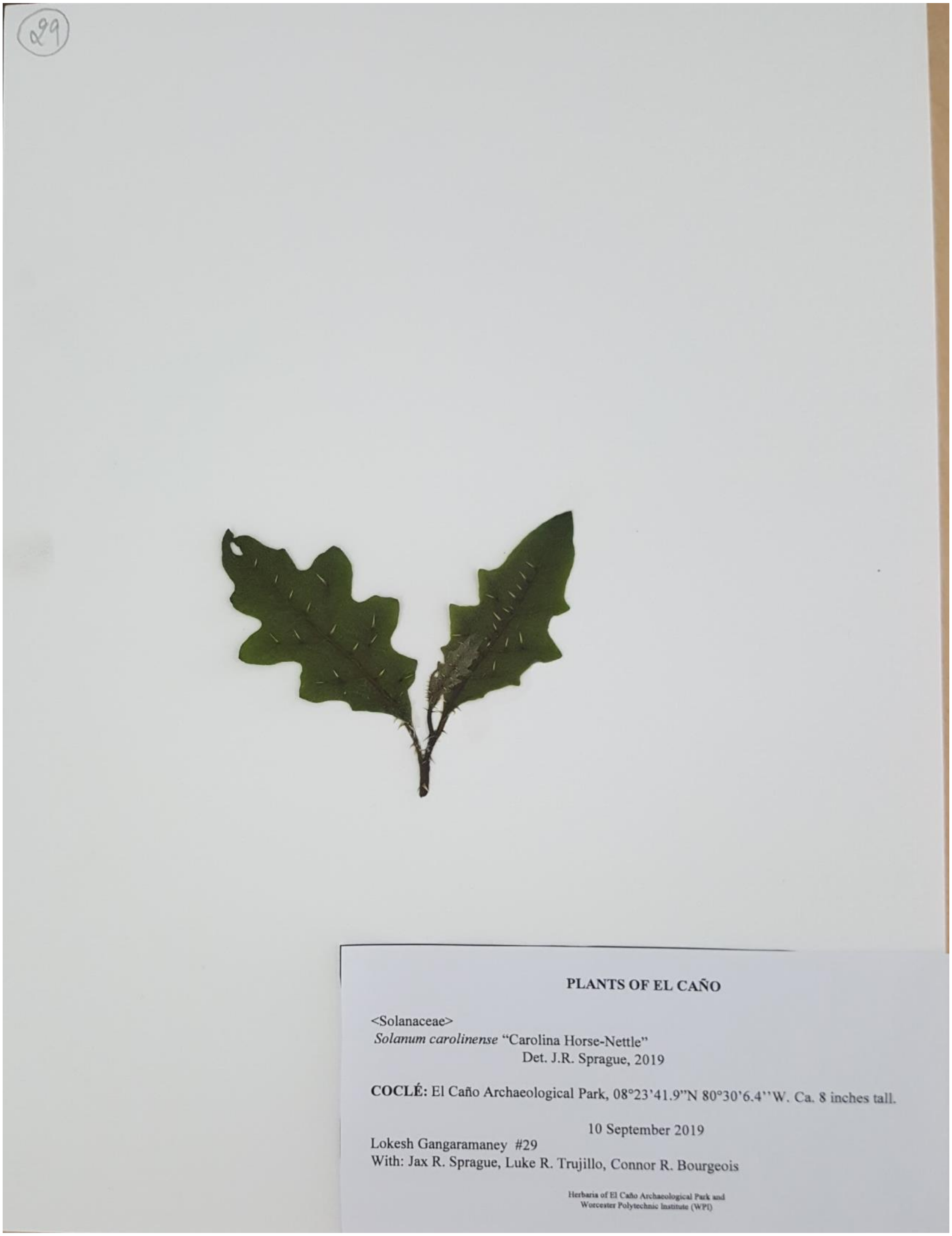
Oplismenus_undulatifolius



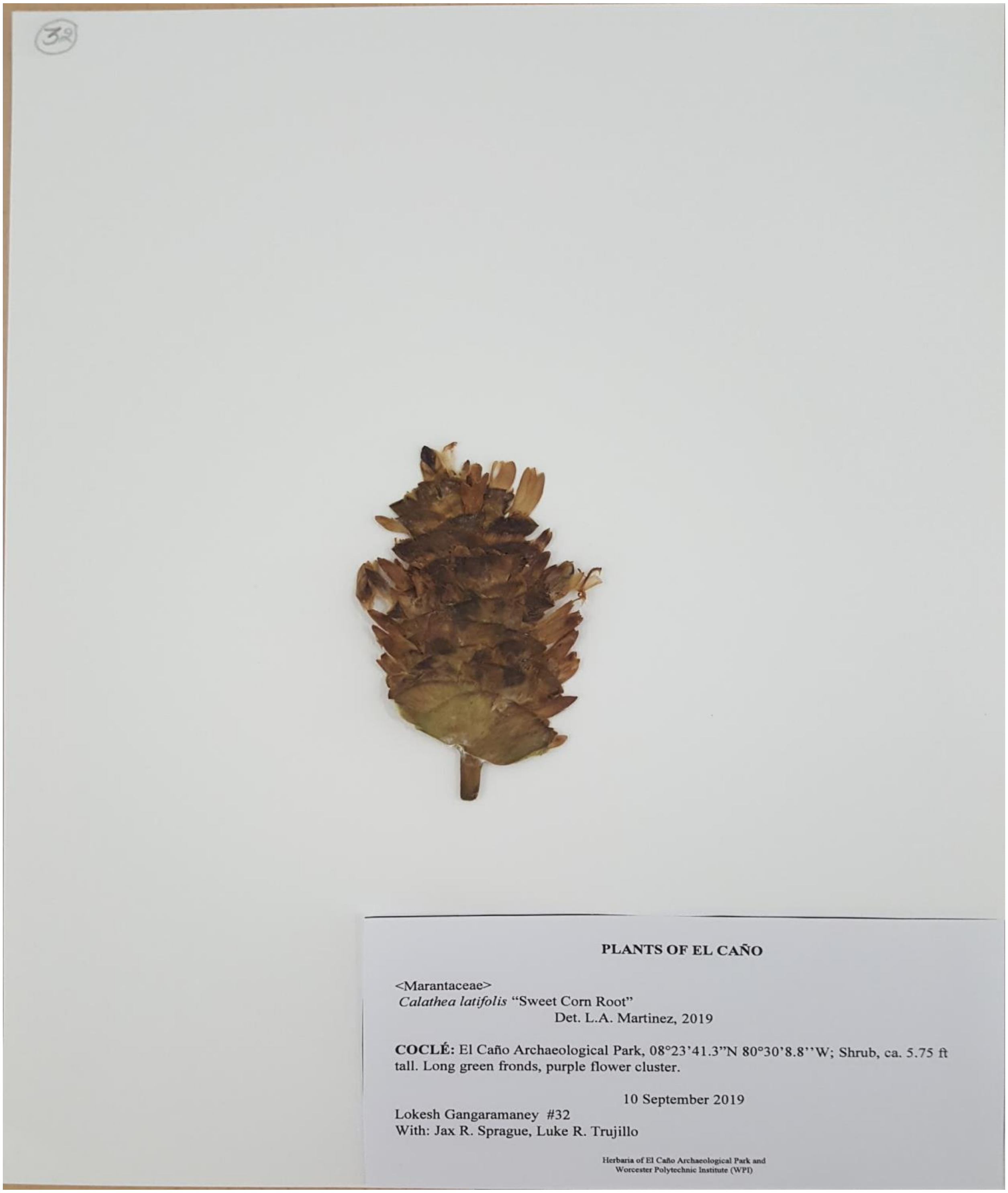
Commelina Erecta



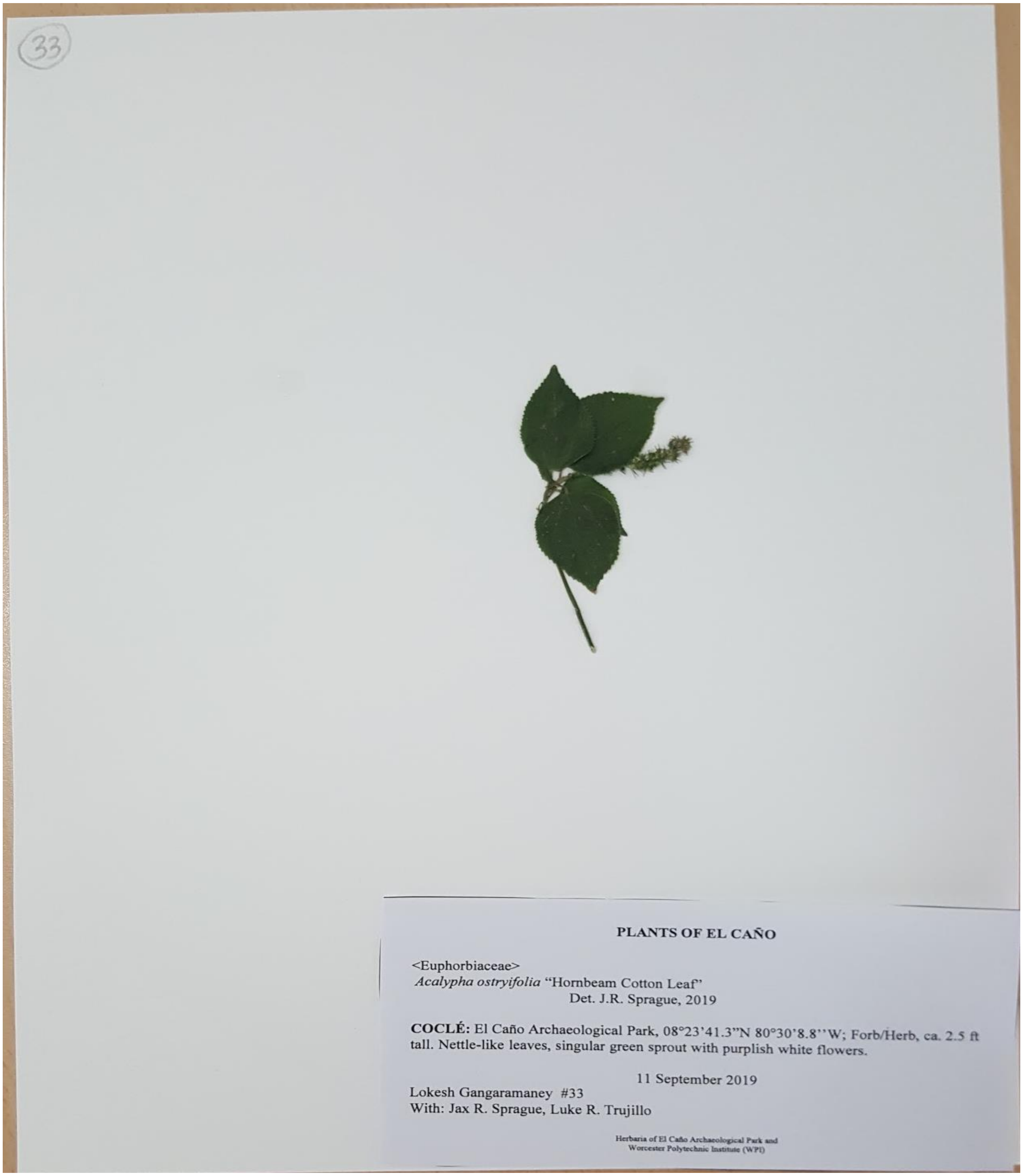
Hippocrepis_emerus



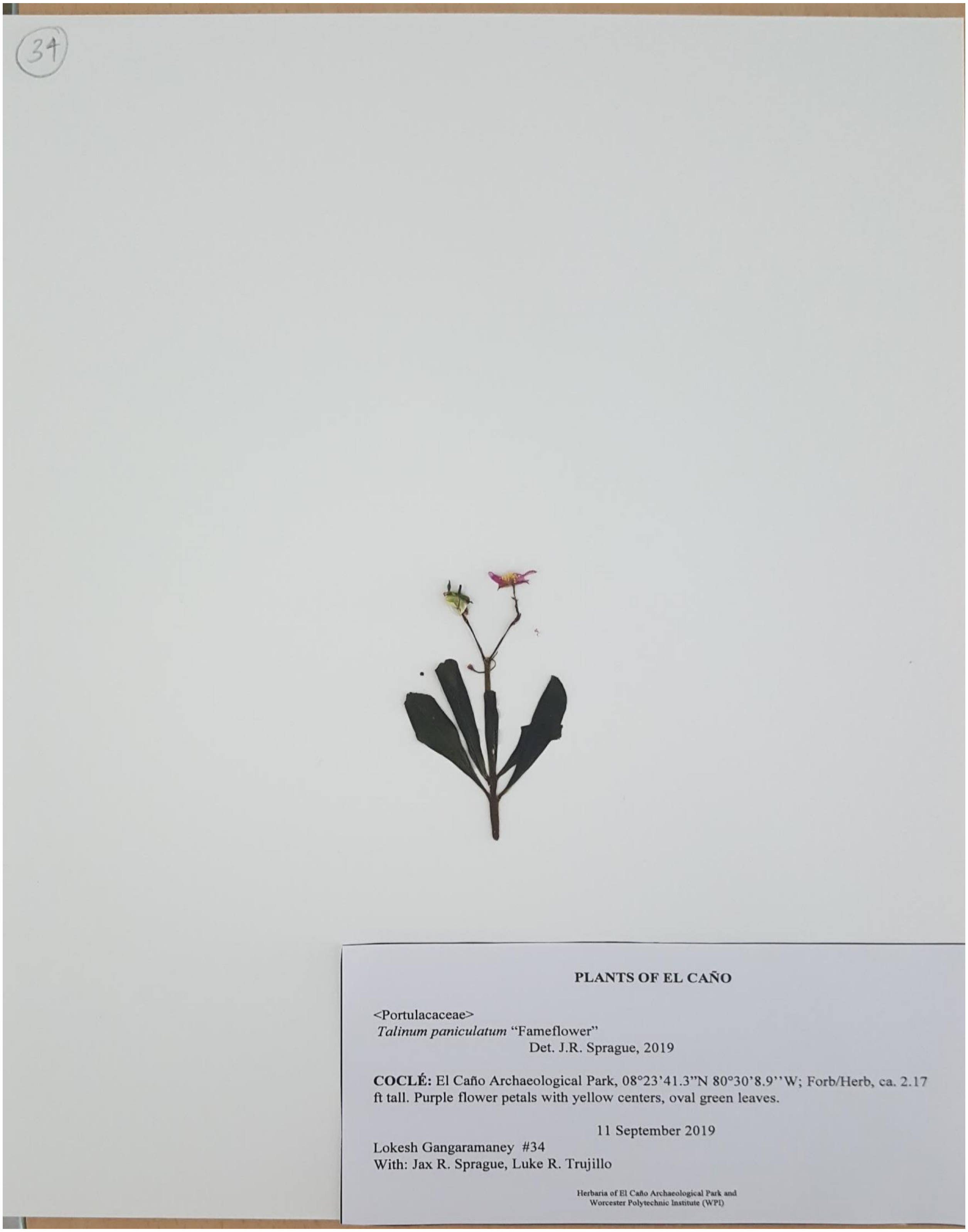
Solanum Carolinense



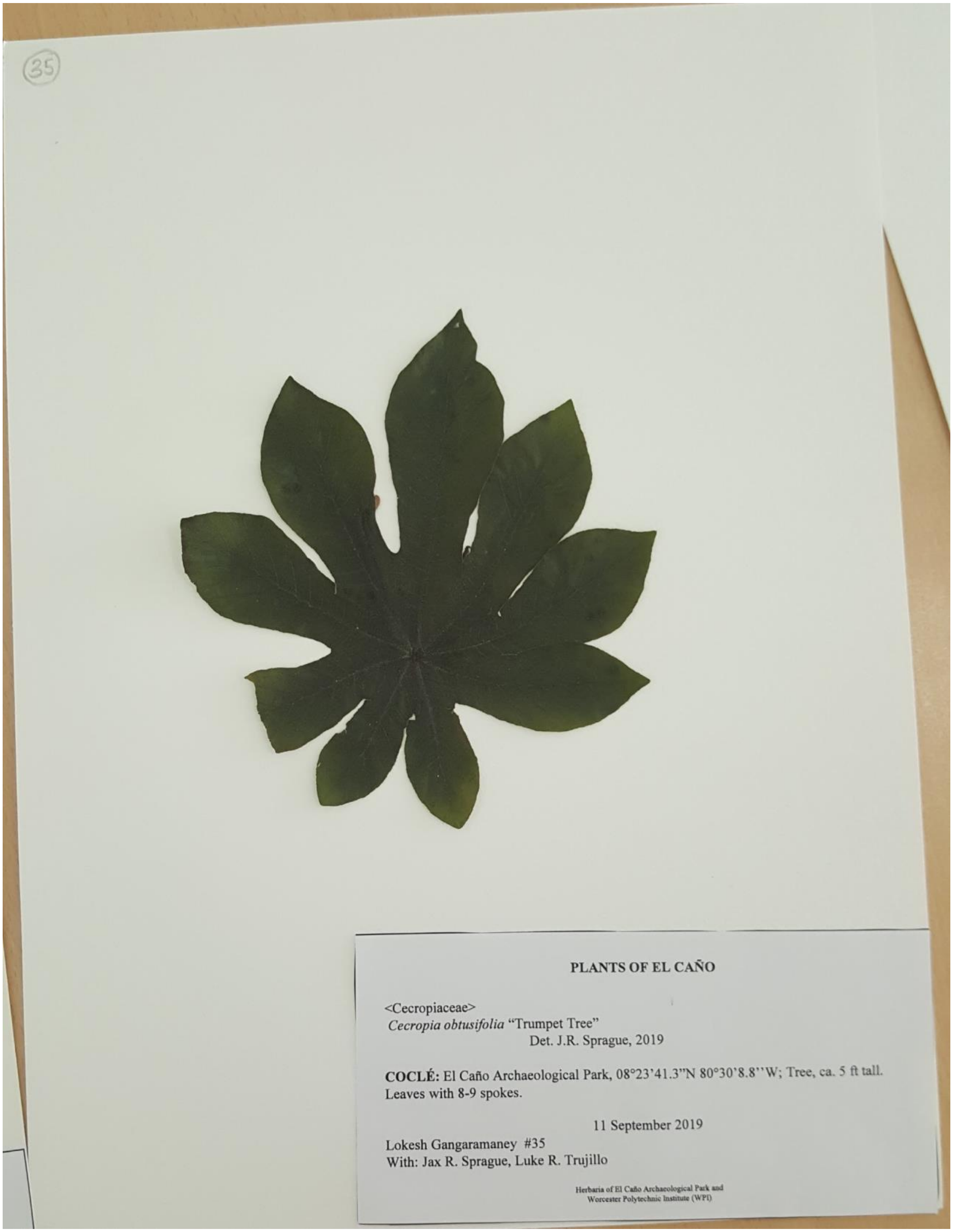
Calathea Latifolis



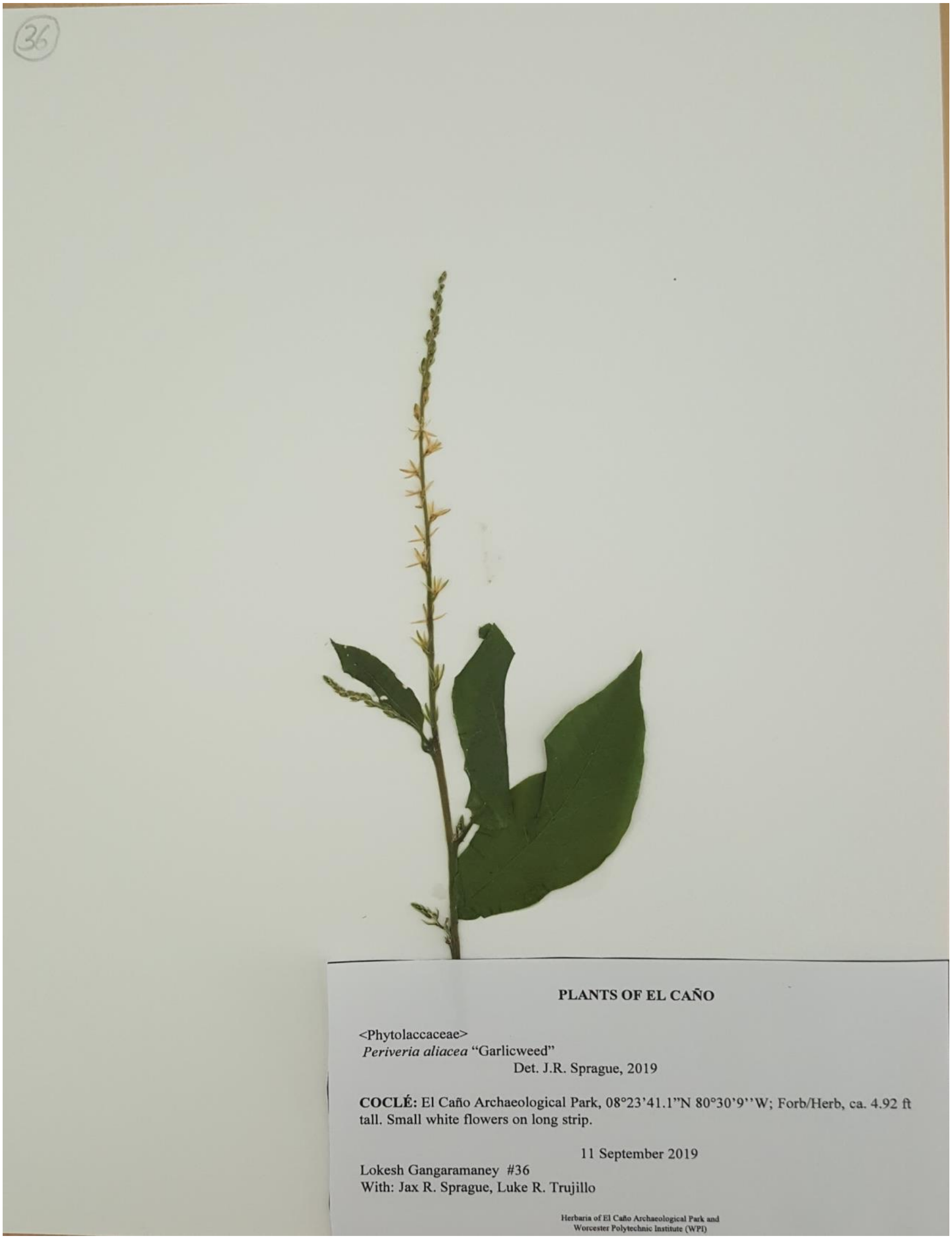
Acalypha Ostryifolia



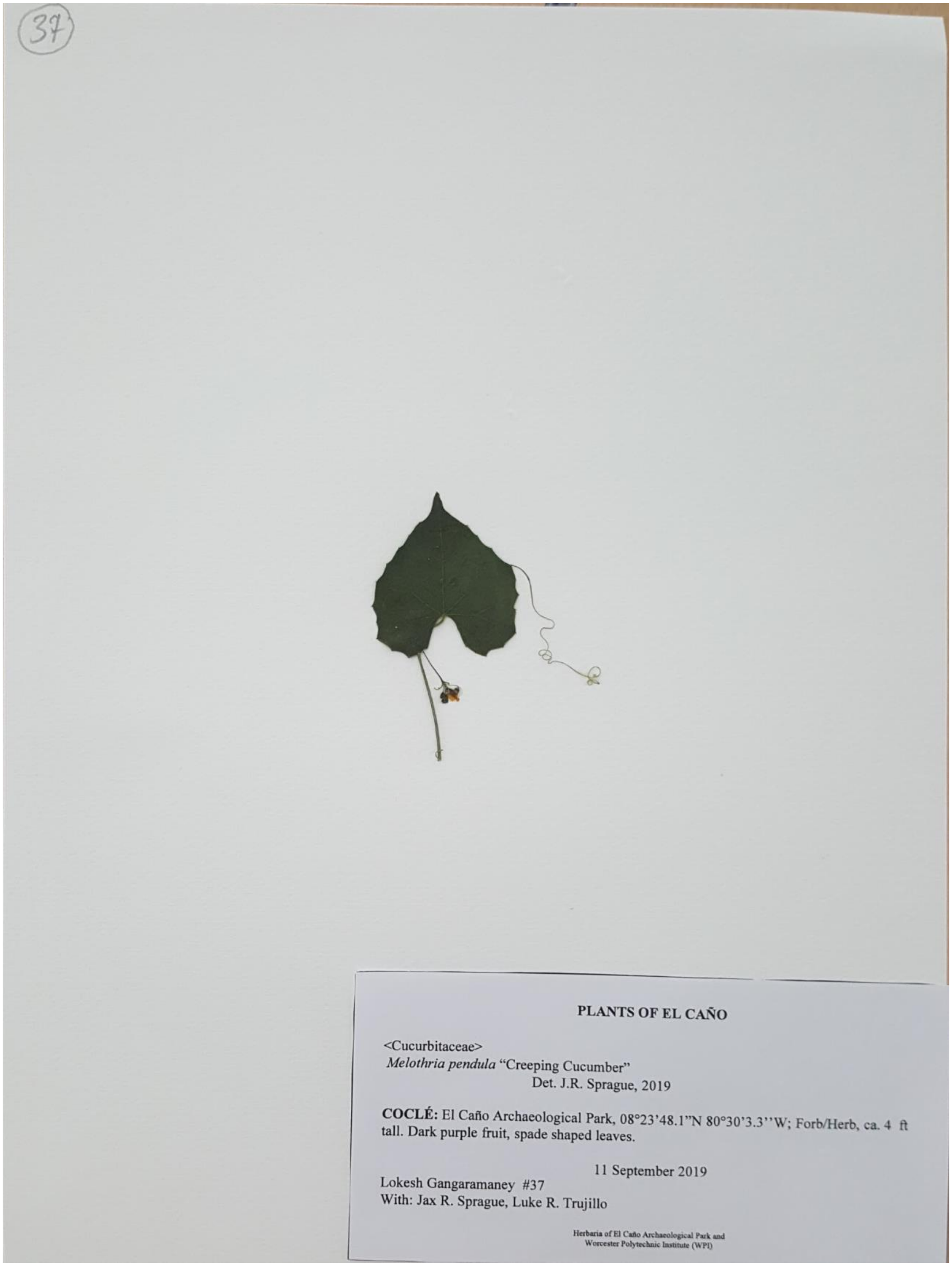
Talinum Paniculatum



Cecropia Obtusfolia

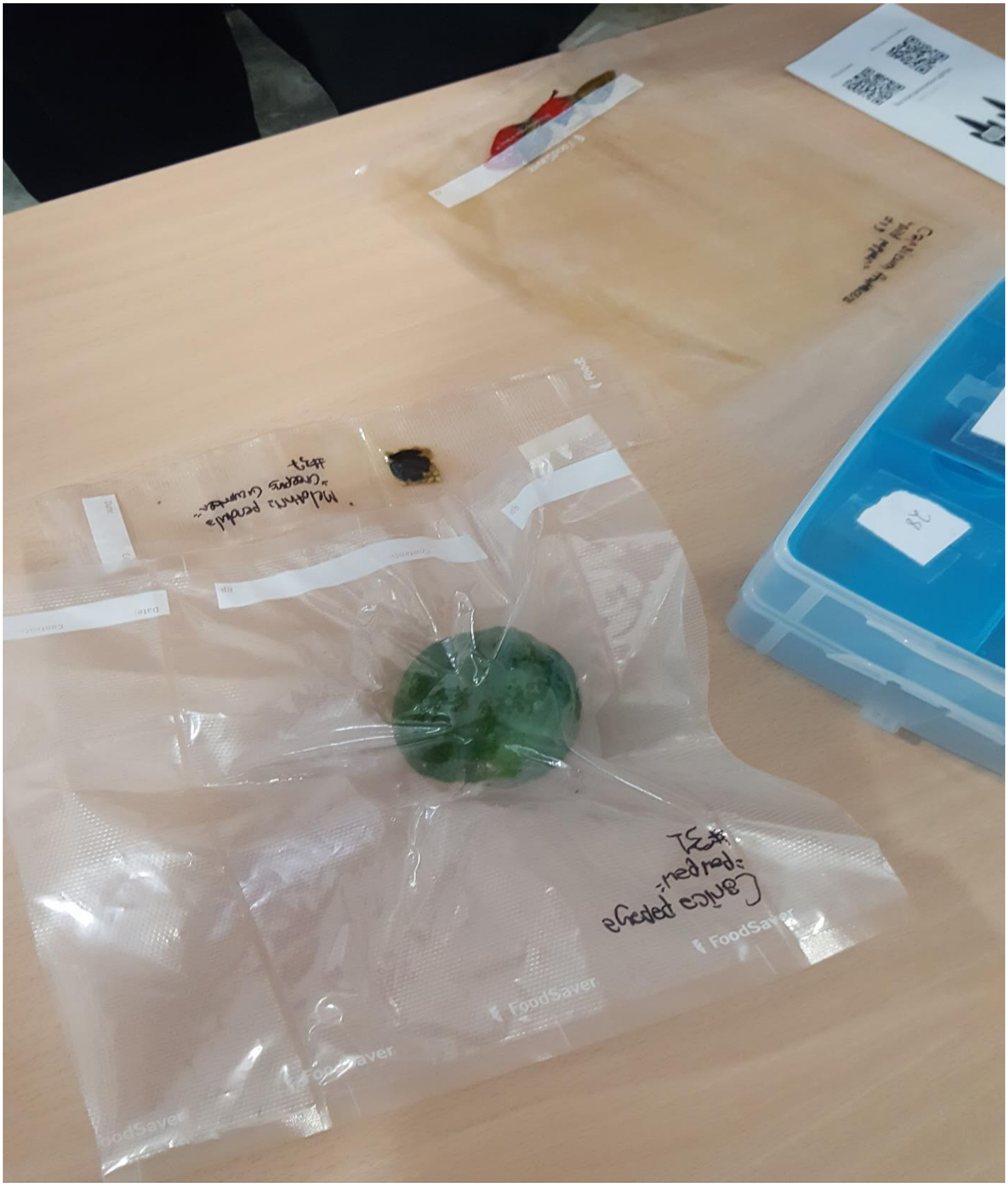


Periveria Aliacea



Melothria Pendula

APPENDIX C: XILOTECA AND VACUUM-SEALED FRUITS


FoodSaver

APPENDIX D: SATELLITE IMAGERY OF EL CAÑO ARCHAEOLOGICAL PARK TO SHOW CHANGES IN ENVIRONMENT OVER TIME


El Caño Archaeological Park
Image taken on March 31, 2014.
Legend
Museo El Caño
Museo El Caño
Google Earth
Image © 2019 CNES / Airbus
600 ft
N


El Caño Archaeological Park
Image taken on January 1, 2017.
Legend
Museo El Caño
Museo El Caño
Google Earth
Image © 2019 CNES / Airbus
N
700 ft


El Caño Archaeological Park
Image taken on April 2, 2018.
Legend
Museo El Caño
Museo El Caño
Google Earth
Image © 2019 CNES / Airbus
600 ft
N

APPENDIX E: PHOTOS OF THE HERBARIUM PRESS MADE BY THE TEAM

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PANAMA Good Times

APPENDIX F: FOLDER FILING SYSTEM EXAMPLE