Cacti are pretty sick! But so is the earth. And it's probably our fault.

How can individual Lophophora cacti be grown and raised to maturity for ecological restoration in the American Southwest?

Figure 1. Lophophora. *Lophophora williamsii graft,* 2008.

Aki Ang

Cacti are pretty sick! But so is the earth. And it's probably our fault.

A study on the cultivation and preservation of *Lophophora williamsii* and other *Lophophora* Species for the Native American Church (NAC) and Environmental Preservation

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“Everyone should smile. Life really isn't that serious. We make it hard. The sun rises. The sun sets. We just tend to complicate the process.”- Baba Ram Dass

Relevant Course History

HORT4092- Senior Project in Horticulture

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Spring 2024

Notable work: this document

HORT4012- Plant Propagation

Mr. Brian Grubb

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Notable work: n/a

HORT3020- Soil Science & Plant Nutrition

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HORT2012- Agriculture Ecology

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HORT1011- Horticulture Science II

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HORT1011L- Horticulture Chemistry

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Abstract

Methods of cultivating and propagating *L. williamsii* are available on the internet and in academic journals. In particular, five, *L. williamsii* specimens were observed and their growth rates and overall vitality are determined. Furthermore, particular soil mixtures, temperature and humidity control, light, and moisture are crucial for growing individuals from. Variations in grafting stock are present, in particular, *Pereskiopsis, Hylovereus, Tricho, cereus* and *Myrtillocactus*. Among literature review, it was found that *L. williamsii* growth and seeding is dependent extremely dependent on pollinators, temperature, and precipitation in the wild. In terms of yielding *L. williamsii* specimens with the fastest growth rate and highest likelihood of survival in the wild, the graft stock to be used is *Trichocereus* and *Pereskiopsis*.

Keywords

Peyote, *Lophophoroa williamsii, Lophophora,* mescaline, NAC (Native American Church), plant propagation, variety, *Cactaceae* cultivation, *Cactaceae* cloning, in vitro, ex vitro, grafting, *Pereskiopsis, Hylocereus, Trichocereus, Myrtillocactus*, micrografting

Problem Statement

Due to infrastructure development, overharvestation, and its slow growth speed, many species of *Lophophora* and other cactuses which grow alongside them currently have diminishing populations in the American Southwest. How can multiple varieties of *L. williamsii,* along with methods of producing and growing individual plants be analyzed to find

a method at which *Lophophora* can be grown in higher quantities at the fastest rate reasonable.

Figure 2. Mansfield, *Potted Lophophora*, 2018.

Project Justification

This research is important for several reasons, the first being of that many *Lophophora* species are becoming endangered in recent years and this research can assist in reintroducing plants into their natural habitat as well as preserving live specimens. Secondly, it serves the Native American Church (also known as NAC) for the usage of their religious ceremonies with *L. williamsii*, also known as peyote in this context. Finally, the research done on *L. williamsii* can be applied to other species in the family of *Cactaceae* to assist in commercial growth methods as well as production to repopulate a particular species.

User-Client Description

To be clear, this project is directly meant for usage by the Native American Church (NAC). *L. williamsii* and its main psychoactive alkaloid, mescaline, are Schedule I controlled substances in the United States. They are considered to have a high potential for abuse, no

accepted medical use, and unsafe in the eyes of the federal government. Due to this, possession and consumption of *L. williamsii* and mescaline is illegal in the United States. Based on these restrictions, this project cannot intentionally serve anyone else. For the NAC, *L. williamsii* is referred to as peyote. However, this term can be sometimes interchanged with a different species of *Lophophora* called *L. diffusa.* This cactus has psychoactive alkaloids present in its biology as well, carrying pellotine rather than mescaline. The NAC, among many others who have chose to ingest peytote, report a varying range of effects. This can range from to nausea and vomiting shortly after ingesting the cactus, to hallucinations, enhanced perception of music and colors, euphoria, paranoia, suggestibility, and ego dissolution. The most notable characteristic for peyote is the effect of having mystical experiences.

All mystical experience utilized by the NAC for its rituals involving the usage of peyote. Practitioners generally go on a fast for a few days to clear out the body of impurities before ingesting the plant. They are also told to fast from food, nicotine for non-ritual purposes, and from technology in order to focus on the issue and thoughts on their mind that brought them to partake in the ritual. Then after several days, the peyote is ingested under guidance. The practitioner then experiences the effects of the peyote for about eight to twelve hours. This is also known as a Spirit Walk in the Southwest.

Figure 3. Arizona State Government, *The native habitat of L. williamsii, along with other cacti,* 2024.

Major Project Elements

The major project elements consist of tracking the growth and development of *L. williamsii* specimens through the usage of plant propagation and grafting. These are to be the independent variables of this study, as they are the ones being altered by myself. The fresh mass of the *L. williamsii* plant itself is one of the dependent variables, meaning that it is the quality of the *L. williamsii* that is being measured. The other aspect that is to be observed in this study is the quality of the specimen throughout the period at which it is being studied. It is important to note that *L. williamsiil,* and as a matter of fact, most *Lophophora* are known to grow relatively slowly and take around 8 to 10 years to mature in the wild. However, with modern techniques using propagation from seed and grafting onto other species of cactus, this process can be cut down to about 8 months to a year. Due to time constraints however, this experiment could not be done in real life due to slow growing

nature of *Lophophora* cacti. All that is written onto here is theoretical and can and should be tested in real life. What is being documented in this section is based on research found from a wide variety of sources, that of which being: academic journals, online psychonaut forums, cactus enthusiast blog posts, and videos posted on YouTube.

Before any experimentation begins, the *L. willamsii* is to be sown and germinated in a soil mix particular to *Lophophora* cacti. The soil mix for cacti in general differs from plants that grow in traditional soil mixes in that in requires a grainier medium that allows for quick drainage with effective water absorption for the plant. Mixes online for general cacti consist of standard soil mix combined with inorganic grit, such as gravel or coarse sand, pumice, and scoria, two types of organic rock. A mix of half potting mix, one quarter pumice, and one quarter scoria is to be used as the soil mix for both the *L. williamsii* seedlings and the grafting stock.

As for the other conditions the *L. williamsii* specimens to grow on, the germinated seedlings are to be placed in indirect light from a well-lit window. The pots at which the specimens are placed in are to be 4” for the germination stages. The water is to be moistened and dried before adding seeds; none of the specimens need to be watered during the germination stage, as *Lophophora* has evolved to be able to function without water for extended periods at a time, almost up to over a year for some particular varieties.

To summarize this section, the factors of light, soil mix, and water are all standardized among all the *L. williamsii* specimens and their respective graft stock. The elements that are to be primarily analyzed are graft stock for *Lophophora* and its reintegration into soil after degrafting processes.

Process Documentation

To begin the explanation of the process documentation, a brief description of grafting and its application on cactuses is helpful. Grafting is essentially taking one plant and sticking it on top and attaching it to another plant; this causes both plants to fuse and keep each other alive. This can be done with woody plants and cacti primarily, and has been done for hundreds, if not thousands of years. Regarding *Lophophora* species, the notion of grafting has proved to be extremely useful, as it cuts down the time for the plant to reach sexual maturity by a number of years. The reason by which grafting works is because the vascular cambiums of both plants combine and work in conjunction with each other. Proper grafting procedures are crucial because of this; however, it is fairly easy in the case. The plant that is stuck on the top is the scion. For these purposes, the scion is *L. williamsii*. The plant that is on the bottom is called the stock. Because the *L. williamsii* is being transferred from a pot onto the stock cactus at such an early stage, there should not be a much of an issue with the fusion of the vascular systems, especially with stock with large widths.

The stock cacti to be used are *Pereskiopsis spathulata, Hylocereus undatus, Tricocereus pachanoi,* and *Myrtillocactus geometrizans.* The respective common names for these plants are Alfierillo, Dragon Fruit, San Pedro, and Blue Myrtle Cactus. The former species differs significantly from the latter three due to its unique shape, especially as seen in the below figures. Notably, *Pereskiopsis* is unable to support the same kind of weight as the other cacti due to its overall width; however, it is still commonly used as stock to graft a myriad of different cacti. Notably online, *Lophophora* and *Tricocereus* are seen to be a favorite scion to place a top of these skinny succulents. Regarding the Dragon Fruit, San Pedro, and Blue Myrtle as stock, the width of these cacti is noticeably thick. The point for

choosing these particular cacti is based upon recommendations from *Lophophora* enthusiasts on the internet. *Pereskiopsis* is known to be reliable for most cacti in general. Dragon Fruit and Blue Myrtle provide a steady base for the *L. williamsii* scion to securely fuse onto the stock. San Pedro also offers a steady base, and noticeably has an appeal towards many psychonauts online because of its own mescaline production and other psychoactive alkaloids.

Figure 4: Magicacti.com, *Perekiopsis spathula,* 2006.

Figure 5; Plantsam.com, *Hylocerus undatus, 2014.*

Figure 6: Lone Star Nursery, *Trichocereus pachanoi*, 2022.

Figure 7: GDNC Nursery, *Myrtilloactus geometrizans,* 2024.

The steps at which grafting these particular cacti will now be described. For all of the cacti to be used as graft stock, the cut should be made at the spot that is the fattest. Lines are shown in the below figures where the cut would take place. This cut should be made as flat and level to the stock cacti as possible. The next step applies for all the stock cacti to be used except for the *Pereskiopsis*. The sides of the cut stock cacti should be cut diagonally, away from the vascular cambium. It should be done a fashion that would result in the cactus to be somewhat pointed, like a primitive spear. This prevents the sides of the cacti from curling upward during the healing process. Now, the specific steps for the experiment shall be given. It is placed into a list form for ease of readability.

1. L. williamsii seeds are acquired and sowed into five small plastic pots placed in a plastic tub with the soil mix created specifically for Lophophora.
2. Placed near a well lit window, but not in direct sunlight to not fry the seedlings. Temperature must be at 80-110 degrees F during daylight hours, and lower than 80 degrees F during nighttime hours.
3. Seedlings are left to grow under these condition for 7-14 days, or until a visible sprout appears.
4. When sprouts are visible and take a circular green shape, take four of the plastic pots and remove the L. williamsii by cutting with a sterilized knife. The leftover pot is to be used as control.

5. Pereskiopsis spathulata, Hylocereus undatus, Trichoereus pachanoi, and Myrtillocactus geometrizans are acquired and prepared for grafting. L. williamsii scions are placed atop the graft cuts and secured with tape around the pot itself.
6. Grafted cacti are left to grow for 8 months.
7. After this 8 months, L. williamsii scions are cut off of the stock and are weighed for their fresh mass.
8. Following the degrafting process, each one of the plants are set back onto the Lophophora specific soil mix. Individual specimens from graft are then observed to see how well they reintegrate into soil mix over the course of 6 months using visual cues.

Figure 8: Magicacti.com, *Lophophora seedling grafted onto Pereskiopsis,* 2006.

Figure 9: Globalherbswholesale.com, *Mature Lophophora grafted onto Trichocereus,* 2020.

Process Solution

The solution to this process comes from the usage of a digital scale and an understanding of visual cues of *Lophophora* health. Fresh mass is chosen as the main indicator of success for this study because it shows the observer the fresh mass per unit of time. In this case, it will be gram/month. The visual cues for *Lophophora* health are fairly simple. After the period at which the *L. williamsii* scions are fairly simple. The aspects to be be checked are the color and shape. The perceived vitality levels are to be rated on a scale of 1- 10, although this is purely subjective to the researcher doing the experiment itself. Specific to this experiment, the entire specimen is to be taken out of the pot that it was replanted into. The length and width of the taproot is to be measured with a ruler and a tape measurer. Surface area is to be found using the formula for a cone shape. This is to be measured using the formula: **Surface area=** $\pi r(l + r)$. The variable "r" represents radius of the taproot, and the "l" represents slant height of the taproot. The specimen that produces the most fresh mass following degrafting, has the highest perceived vitality rating, and largest taproot surface area.

In addition, the process solution is found in the overall productivity, growth rates, scion health, exhibited by each stock cacti and its relation to the *L. williamsii*. How well each specimen reintegrates into its natural habitat will be taken into account. Due to time constraints and the overall climate of the Cincinnati area, this was not able to be done in real life. Despite these issues, through observation of online cacti enthusiasts documenting their procedures with *Lophophora* and research on the individual cacti used, a solution is found.

For the fastest growth rate and overall productivity, the *Pereskiopsis* and *Trichocereus* cacti are used at different stages of *L. williamsii* development. When seedlings are to be transferred from soil to the stock cacti, the *Pereskiopsis* is used. This is due to its widespread usage with *Lophophora* cacti and with other scion cacti in general. In addition, *Pereskiopsis* notably grows at a much faster rate in comparison to other cactus species. The downfall of this stock cacti is that it can only support the *L. williamsii* scions' weight before it reaches a mature state. Once it reaches a weight that the *Pereskiospis* can no longer support, it is transferred onto the *Trichocereus.* This stock exhibits a fast growth rate as well and can support the weight of a mature *Lophophora* scion. Notable to this cacti species, is how it contains mescaline as well, along with other alkaloids to protect it from predators. Grafting *Lophophora* onto the *Trichocereus* has the potential for the *Lophophora* scion to have a higher mescaline content without severely stressing it. This way, specimens can be reintegrated into their natural habitat in a healthy state.

The process solution also consists of a revision of the specific steps taken for this study. These are drawn out on the board that corresponds with this document. The steps are below.

1. L. williamsii seeds are acquired and sowed into five small plastic pots placed in a plastic tub with the soil mix created specifically for Lophophora.
2. Placed near a well-lit window, but not in direct sunlight to not fry the seedlings. Temperature must be at 80-110 degrees F during daylight hours, and lower than 80 degrees F during nighttime hours.
3. Seedlings are left to grow under these condition for 7-14 days, or until a visible sprout appears.

4. When sprouts are visible and take a circular green shape, take four of the plastic pots and remove the L. williamsii by cutting with a sterilized knife. The leftover pot is to be used as control.
5. Pereskiopsis spathulatae specimens are acquired and prepared for grafting.
6. L. williamsii scions are placed atop the graft cuts along the ridges.
7. Grafted cacti are left to grow until individual specimens are too large for the *Pereskiopsis* to support. They are then moved to an individual *Pereskiopsis* specimen that is able to support the scion weight.
8. *Pereskiopsis* and *L. williamsii* specimens are left to grow. Once *L. williamsii* scions are too large for *Pereskiospis* to support, they are moved to *Trichocereus.*
9. Once scion is transferred to new stock cacti, it is secured with duct tape to ensure their fusion.
10. Once the scion and stock are fused, the tape is removed and is left to grow to maturity.
11. When maturity is reached, it is transferred to a pot with the *Lophophora* soil mix. Root growth solution is added onto the bottom after the scion is cut off.
12. Once roots are formed, the *L. williamsii* specimen is removed from the pot.
13. After being removed from the pot, it is put back into its natural habitat.

Literature Review

Lophophora williamsii is generally covered in anthropological, social, or medical contexts in the majority of existing literature that covers it. The cactus's ecological function is covered to a lesser extent, in general. However, there is literature that does cover these functions, as well as cultivation techniques and experiments and regional differences of

populations. As previously stated, due to overharvesting since the sparks of psychedelic tourism in the late 1960s, infrastructure development, and overall ecological change in the American southwest, *L. williamsii* and other *Lophophora* populations in the area have become threatened. To combat this, efforts have been made to understand cultivation practices, both ex vitro and in vitro, to deepen understanding of *L. williamsii* varieties, and the seed dispersal and pollination processes of *L. williamsii*. The main purpose of this literature review is to find what has been done, and to find gaps in the research that can be further explored.

In terms of cultivation techniques of *L. williamsii*, ex vitro germination and growth processes are generally used. Most individual specimens of this plant are found in their natural habitat growing in clumps. When reproducing in the wild, *L. williamsii* depends primarily on its own seed dispersal and pollinators. In horticultural settings, other methods have been used. In vitro protocol has been tried (Rodríguez) and proved to be highly successful in generation with the usage of agar and sucrose as a medium. In terms of primarily ex vitro, many cultivators gravitate towards using existing cuttings or growth by seed. Grafting an *L. williamsii* cutting onto a cactus of a different species is found to be a particularly useful method (Propogation of *Lophophora*). However, a specific standardized method for outdoor growth or greenhouse growth was not described. It is also worth noting that in-vitro processes are generally a lot more costly than primarily using outdoor methods, raising the question of whether or not it is an affordable option for the Native American Church and peyote practitioners.

Regional differences in *L. williamsii* are quite notable in this study as well. Because of the mountainous regions at which *L. williamsii* and its slow method of repopulation, it is mostly found in patches, separate from other populations. Due to this, the separated populations develop their own characteristics, particularly notable in growth rates and density. The main

reasons for being are primarily dependent on the temperature and precipitation of the area(Hulsey). However, there is not much literature or accepted information about the specific varieties about *L. williamsii* and their physical and chemical properties. Despite this, further research into the different varieties can lead to faster methods of growth to reintroduce into the wild and for usage by the NAC.

Seed pollination and dispersal are integral pieces of information in regard to the conservation of *L. williamsii,* especially for wild specimens. *Lophophora* in general does not self-reproduce particularly well without human intervention, so it generally relies on pollinators for these processes. The pollinators of *Lophophora* are usually small insects; however, insects are also part of the reason for endangered populations due to being eaten by them (Briseño-Sánchez). The literature found on this ultimately shows that pest control and management of a particular region has a profound effect on *Lophophora* populations.

From this literature review, there are a few main points derived. First of all, although in vitro is known and proven to work, it can be costly and the funding for these processes could be an obstacle; however, the usage of grafting onto other *Cactaceae* species can be useful. Regional differences are also important and show that the existing populations of *L. williamsii* are highly dependent on precipitation and temperature. Seed pollination for the *Lophophora* genus is also found to be highly dependent on pollinators.

Case Study Summary

For the study, *Ecology and conservation of peyote in Texas, USA: Comparative survey of Lophophora williamsii populations in Tamaulipan Thornscrub and Chihuahuan Desert*, we are introduced to the ecology of *L. williamsii* and the regional differences among populations. We are shown two populations of *L. williamsii*; one being in the Chihuahuan

Desert and the other being in the Tamaulipan Thronscrub. General linear models were used in the methods of this study to determine the relationship of precipitation and temperature on *L. williamsii* plant density. The findings from this body of work can be used in the monitoring of individual plants and can possibly used in developing soil mixtures or medium formulas if in-vitro methods are used.

Regarding in-vitro growths of *L. williamsii*, this is covered by the study *In vitro germination and growth protocols of the ornamental Lophophora williamsii as a tool for protecting endangered wild populations*. This study goes into depth on the usage of in vitro technology (growing a plant from cutting or seed in an enclosed environment with a growth medium as opposed to soil). Multiple formulas for growth medium were used, focusing on agar and sucrose concentrations. The findings of this study can be used to find information about the specific growth processes of *L. williamsii* and can provide information about the factors that determines growth in media.

In the study *Biotic interactions prior to seed dispersal determine recruitment probability of peyote (Lophophora diffusa, Cactaceae), a threatened species pollinator-dependent,* the seed dispersal and fertilization of *Lophophora diffusa* is analyzed. Although it is not *L. williamsii*, *L. diffusa* is still used by the NAC and is considered peyote despite having different alkaloids. The information from this piece can be used in monitoring reintroduced plants and to help encourage population growth. Furthermore, the information used can be applied to pest management processes outside of this study.

Historical Context

The genus of *Lophophora* consists of small button-shaped, spineless cacti that are generally found throughout Mexico and South Texas. *Lophophora williamsii*, or commonly

known as Peyote, is the most well-known out of these cacti due to its psychoactive effects. These are attributed to mescaline, a naturally occurring molecule which is known to have effects similar to LSD or psilocybin mushrooms. Peyote has been used for thousands of years by indigenous populations in the American Southwest and Mexico, generally to treat physical ailments or to treat mental health concerns. When the Controlled Substances Act was passed in 1970, it placed *L. williamsii* as a Schedule I substance, leading to its subsequent criminalization. Indigenous populations responded to this by forming the Native American Church (NAC) so they could practice their ceremonies with religious freedom. Despite this cactus still being illegal until the legal exception was made for NAC in 1997, peyote was still used in religious ceremonies by the NAC; the main difference was that the ceremonies were generally kept secret in more secluded locations and that Christian iconography and philosophies were added to the rituals.

Since *L. williamsii* has been legal specifically for NAC, specific guidelines for harvesting, cultivation, and usage have been held by the United States government. Ranches that also contain *L. williamsii* within its landscape are also to have permits and give permission to Peyoteros (people who are legally licensed for this process) to harvest plants on their land.

L. williamsii is legal, although "… police makers of DEA were primarily tasked with making peyote difficult to obtain not with ensuring the NAC would be able to obtain enough peyote" (Terry). Currently in South Texas, there is a decrease in number, size, extent and density of peyote populations. A solution to this would to be cultivating and propagating cuttings from existing plants in large quantities. This is already done by cactus collectors and some owners of peyote farms (that unsurprisingly, are not marketed on the internet). However, the NAC generally discourages this practice and is apprehensive towards the

loosening of restrictions due to fears of a lessening of the already diminishing supply of *L. williamsii*.

Project Goals

The main purpose of this study is to assist the Native American Church in cultivating *L. williamsii* and reintegrating it back into its natural habitat. It is unknown what the disappearance of *Lophophora* cacti would do to the ecosystem in the American Southwest, and the species is best to be preserved. Furthermore, this study allows for the NAC to harvest *L. williamsii* in a more sustainable manner due to larger local populations. This research can also assist in terms of decreasing the time to maturity for other slow growing cacti in different areas of the world. As with the one discussed in this study, many cacti have medicinal or cultural value.

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