MEASURING REFORESTATION SUCCESS
IN THE SIERRA GORDA GUANAJUATO
BIOSPHERE RESERVE, MEXICO

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ABSTRACT

MEASURING REFORESTATION SUCCESS IN THE SIERRA GORDA GUANAJUATO BIOSPHERE RESERVE, MEXICO

WANDA BRUHNS

Forest degradation is a serious issue as forest fragments become smaller patches over time. Documentation of degradation patterns and a detailed management plan is needed but severely lacking in many areas. Tree planting is a key strategy for reversing degradation. In this study, the results of tree seed germination are reported. Germination tests focus on four native pine species of central Mexico: *Pinus cembroides, Pinus greggii, Pinus devoniana,* and *Pinus patula.* Of our seed lots, *Pinus cembroides* had most success with 96% reaching germination. *Pinus patula* had the least success out of the four species at 30% germination. There were only minor differences between treatments; seed treatments affected overall germination by a maximum of 6% for *Pinus patula* and a maximum of 3% for all other species. In contrast, the maximum difference in germination between species was 66% for *Pinus cembroides* vs *Pinus patula.* Treatments applied for germination are not recommended because no significant increase of germination time and success are reported in our study.

The second study for this paper focuses on two species for reforestation. Six current reforestation sites within the Sierra Gorda Guanajuato Biosphere Reserve have been monitored for survival. The plots monitored outplantings of *Pinus greggii* and *Pinus devoniana.* Overall survival rates varied by site and species, the highest survival rate reported is 56% and the lowest reported is 3%. Across all sites monitored the overall success of survival is 26%. We recommend the reforestation program to work closely with landowners to establish monitoring plots as outplanting efforts expand. Documenting information such as planting technique, insect infestations, and soil quality could help pinpoint the cause of mortality and help reforestation in this area produce higher survival rates in the future. With these two studies, we hope to provide some groundwork initiatives to promote research to help improve the success rate of native pine reforestation for the Sierra Gorda Guanajuato Biosphere Reserve.

ACKNOWLEDGEMENTS

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1. Introduction

Forests are an invaluable resource to humans and the natural environment. They have important roles in hydrology, climate control, timber production, and biodiversity health. Much of human development depends on forest ecosystems and dynamics. To this day, forests serve as timber sources and house a wide range of biodiversity across the globe. Forest infrastructure has supported the development of great civilizations and housed agricultural farming practices. Throughout history, forest resources worldwide experience pressure from human alteration and demand for forest products. With human population growth on the rise, demands on forest products are increasing. Proper planning and the establishment of priority areas for sustainable management will benefit future generations and the natural environment. For example, bird richness can be enhanced in areas with restoration (MacGregor-Fors et al. 2010). The shortage of economic resources increases the importance of identifying areas that are likely to provide maximum benefits (Myers et al. 2000). Areas with high biodiversity will benefit from proper management, protection, and restoration in the long term.

In Mexico, forests have been used to develop infrastructure and support both urban and rural communities. In many parts of Mexico, rural communities largely rely on forestland and products for sustained livelihood. As forest resources diminish over time, rural communities, large industries, and thus urban areas will experience limited resources. In 2000-2001 the National Forest Inventory reports that 32.75% of Mexican territory covered by woods and forests, corresponding to 63.6 million hectares (Bray et al. 2007). Another study reports that in 2002, 26% of the original tropical dry forests cover remained intact with varying degrees of human disturbance (Challenger and Dirzo 2009). Mexico's forests remain important, they are the largest pine-oak compilation in the world, the diverse communities of *Pinus sp.* and *Quercus sp.* span throughout mountain slopes in the central Mexico region (Bray et al. 2007). These temperate forests cover the Sierra Madre Occidental and the Sierra Madre Oriental mountain ranges and are linked by Central Volcanic Belt in central Mexico (Bray et al. 2007).

These regions contain important biological diversity and reserves have been established to protect these areas. In some reserves, including the reforestation area studied for our project face ecological challenges. Community level based programs encourage ground level incentives to improve and protect remnant forests. Established in 2001, the National Forestry Commission (CONAFOR) has contributed with assisting communities and private land owners in developing management plans to restore degraded areas through reforestation or related projects, encourage the use of non-timber products, and protect ecosystem services (World Bank 2012). Involving local rural communities to participate in these programs is important for success of any project implemented in these areas. Upon recognition of forest degradation, the government began to help the communities manage their forest resources via community-based incentives and advisory programs in the 1990s (World Bank 2012). As of 2012, the World Bank reports an estimated 2,380 communities using forest management plans in Mexico (World Bank Report 2012). Mexico's strategy of forestry approach is becoming increasingly recognized as a global reference (World Bank 2012). The community forestry approach is important for projects such as reforestation, mitigation, restoration, and climate change. Community involvement is important at this level and will likely serve as a foundation for Mexico's strategy of important projects namely Reducing Emissions from Deforestation and Degradation (REDD+) (World Bank 2012).

For this report we created two projects to supplement the community level based reforestation project in the central Mexico region. To assist with the establishment of crucial baseline data about reforestation success of native species, we initiated a study to measure germination rates and outplanting survival focusing on four native species found within the central Mexico region. The development of this database will provide details and data to expand and improve reforestation for the RBSGG. Our objectives for these two studies were to determine the germination success, monitor survival of outplantings between years 2011 and 2012, and provide recommendations for current practices by establishing the first baseline data for the project. We worked with *Pinus cembroides* (Gord.)*, P. greggii* (Engelm. ex Parl.)*, P. devoniana* (Lindl.) (syn. *P. michoacana),* and *Pinus patula* (Schltdl. & Cham.) (International Plant Names Index 2013).

Since many of our research sites experienced heavy deforestation, some of the remnant trees consist primarily of oak (*Quercus sp.*) in some areas. We selected the pine species for the germination tests based on their presence in deforested areas in the RBSGG and their potential to improve reforestation practices within the reserve. The second study presented in this paper reflects outplanting survival during the years of 2011 and 2012. We have developed the first monitoring plots and baseline data to supplement ongoing reforestation efforts in the RBSGG. We selected two species chosen for the reforestation *P. greggii* and *P. devoniana,* occur throughout our monitoring plots.

The study area, the Sierra Gorda Guanajuato Biosphere Reserve, (Reserva de la Biosfera Sierra Gorda Guanajuato, RBSGG; (Figure 1) faces forest degradation through deforestation. Under the delegation of the National Commission of Natural Protected Areas (Comisión Nacional de Areas Naturales Protegidas, CONANP), the RBSGG was the basis of the two studies reported for this paper. CONANP supported our projects discussed in this study by providing background information, history, and site locations of the reforestation attempts. From these data provided, we were able to determine which data were missing and contribute our experience to help accordingly. Through a conjoined program with the Peace Corps and Northern Arizona University we focused on CONANP's reforestation project. The Small Project Assistance (SPA) Grant provided funding for this project from USAID. We noticed an active reforestation project in place, but this project lacked a monitoring plan. Outplantings of tree species were already planted, however there were no data on survival. To assist this project, we developed a monitoring plan to determine an overall survival percentage of the outplantings. Our data will be an additional resource for the managers of the reserve to utilize when working with the reforestation in the future.

The RBSGG is part of the Sierra Gorda, a range located within the northeastern region of the state of Guanajuato, in central Mexico. The Sierra Gorda is part of the Sierra Madre Oriental, which runs from northeastern to central-eastern Mexico, from the states of Chohuila, Nuevo León, San Luis Potosí, Hidalgo, Guanjuato, and Querétaro (Sierra Gorda Ecological Group 2010). The Sierra Gorda spans two states, Guanajuato and Querétaro, and two biosphere reserves have been establish to conserve its natural heritage: Reserva de la Biosfera Sierra Gorda (in the state of Querétaro) and Reserva de la Biosfera Guanajuato (in the state of Guanajuato).

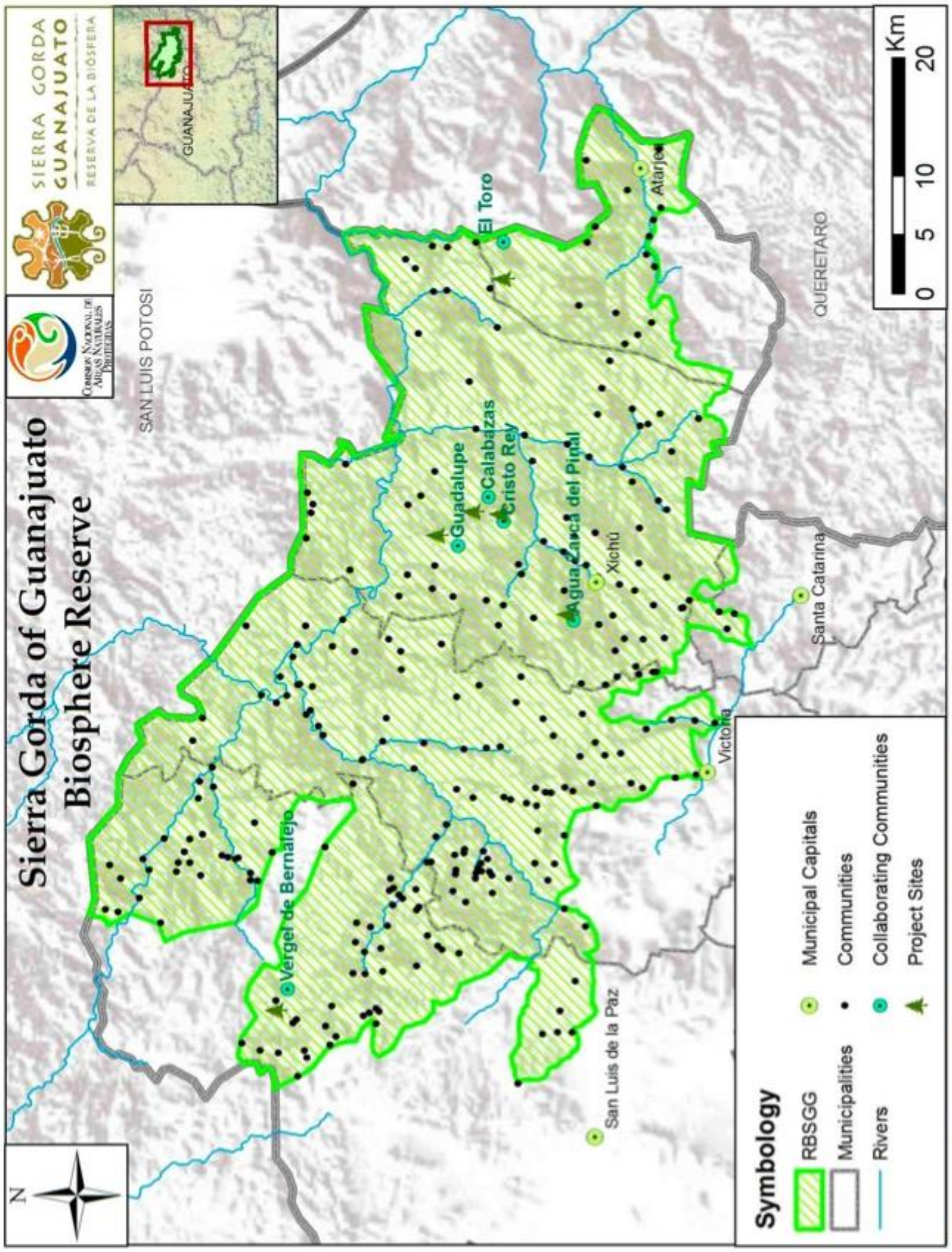


Figure 1. Map of the RBSGG. Courtesy of Ryan Jensen returned Peace Corps volunteer

The RBSGG was officially established as a protected area on February 2, 2007 (CONANP 2013). Human population in the reserve is estimated at more than 20,000 people in more than 200 communities occupying almost the entire 236,882 hectares of the reserve (CONANP 2013). Approximately half of the reserve is part of ejido land and the other half is in private lands. The central management strategy is to work with the communities to promote conservation activities and sustainable development while aiming to benefit the livelihoods of the people. Collaboration and support between private landowners, community members, and CONANP is the key to success when initiating any project.

The reserve contains an extraordinary amount of biodiversity and is considered a biodiversity hotspot (Myers et al. 2000). The ecosystems of the RBSGG provide important habitat for many species of plants and animals. Rare species such as jaguarundi (Charre-Medellin et al. 2012) margay, and ocelot (Iglesias et al. 2008) are reported to occur there. This fragmented biodiversity hotspot remains important, and it is important to protect this natural resource for the future. Different types of ecological communities are found in the reserve, including tropical deciduous forest, semi-tropical deciduous low forest, evergreen rainforest, semi-arid scrub, mixed conifer forest, oak forest, pine-oak mixed forest, cloud forests, as well as riparian and aquatic vegetation.

Many parts of Mexico and Central America experience forest degradation due to land use (Griscom and Ashton 2011). The RBSGG experienced heavy mining during the 1950s and as a result, heavy deforestation took place during this time. Communities of the RBSGG were paid by large mining companies to cut entire forests for mining practices. These areas have been slow or completely unable to recover from these impacts due to the continuous demand on natural resources and the limited productivity of the natural systems. Most of the communities within the reserve are highly marginalized and impoverished, so the people depend largely on the natural environment for survival. The majority of the families within these communities are unemployed however remain self-sustained by growing their own food and extracting resources from forests to establish housing. Historical and present human activities have impacted forest dynamics, such as livestock grazing, swidden agriculture, and unsustainable logging and fuel wood harvesting. As a result of these environmental impacts, severe erosion is visibly present and is a problem throughout large areas of the reserve. In addition to human impacts, natural threats include wildfires, invasive species, forest diseases, and bark beetle outbreaks.

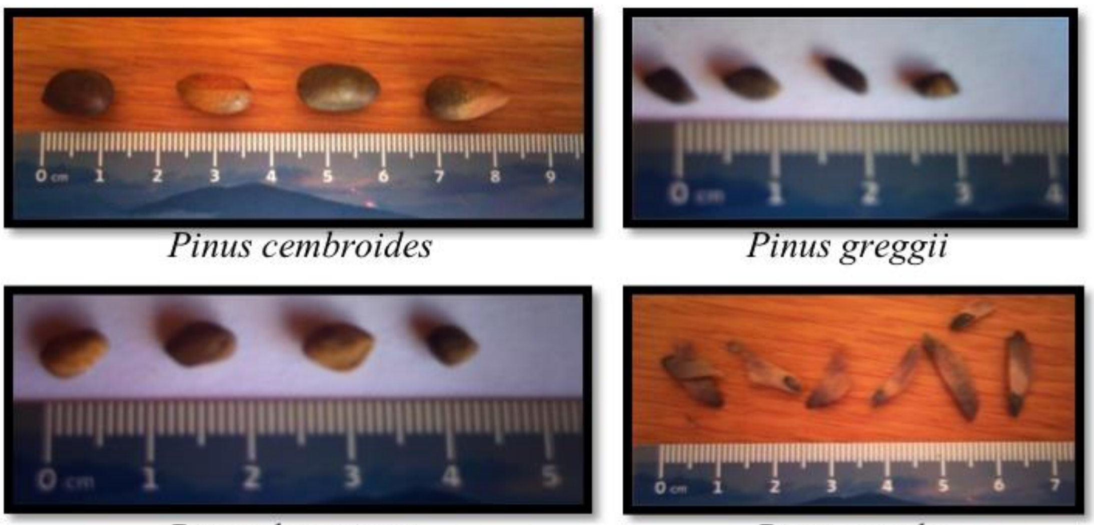
Through funding and management by CONANP, active reforestation had already begun and is currently taking place. We established our monitoring plots for the reforestation study within six communities that host reforestation sites: Agua Zarca, Calabazas, Cristo Rey, El Toro, Rancho de Guadalupe, and Vergel de

Bernalejo (Figure 1). These communities are inside or near deforested areas and were selected as study sites by CONANP. Communities that were not interested were not reforested. CONANP provided funding for interested communities to reforest by purchasing trees and hired community members to plant them. We established our study plots within the reforestation sites of the six communities listed above and based our study on the ongoing reforestation by CONANP.

2. Methods

Seed Germination Study

Our seed germination experiment focused on four species native to the Sierra Gorda Guanajuato region: *P. cembroides, P. greggii, P. devoniana,* and *P. patula* (Figure 2). The San Vicente Nusery in Irapuato, Guanajuato provided the seeds for our study. We created two treatments and one control to test our seed lots. Germination success was recorded for each treatment and control for each of the four species.



Pinus cembroides | *Pinus greggii* | *Pinus devoniana* | *Pinus patula*

Figure 2. Pictures of the seeds for each species

For the four species, 300 seeds were used per species. The experiment was designed for a total of 1,200 seeds. Each seed set included 100 seeds: 100 for the control (no treatment), 100 were soaked in warm water for 24 hours, and the remaining 100 seeds were soaked for 24 hours and then lightly scored with a scalpel. Seeds were placed in a plastic petri dish with a moist paper towel in sets of five. For each treatment, including the control, there were a total of 20 petri dishes for each, making a total of 60 petri dishes for each species (Table 1).

Table 1. Number of seeds for each treatment

Species	Control	Soaked	Soaked & Scored
P. cembroides	100	100	100
P. greggii	100	100	100
P. devoniana	100	100	100
P. patula	100	100	100
Total number of seeds			**1200**

One hundred seeds per treatment allowed for calculations while still providing an adequate sample size of 300 seeds per species. We covered each petri dish with the lid to keep the environment moist. We ran the experiment in a well-lit room at ambient temperature away from direct sunlight. Each petri dish was checked every 24 hours for the 70 day test period. Petri dishes were stacked according to species and rotated daily. They were marked with a number and a code for treatment and species: PICE-1…PICE-20 for the controls; PICE-S1…PICE-S2 for soaked seeds; and PICE-SS1…PICE-SS20 for soaked and scored seeds (Figure 3).

Figure 3. ***Pinus cembroides*** **seed lot**

Seeds were allowed to germinate for a few days before being removed. Seeds were documented as successful germination if the root was clearly visible, and in many cases the first leaves were present. Each species varied slightly, but all species began germination between 4 to 7 days (Figure 5). Seeds with mold growth were also removed to minimize contamination. Paper towels were re-moistened with a spray bottle whenever dry. The experiment was set to run for 10 weeks (70 days), or until all seeds had germinated or been removed due to mold growth. All remaining seeds that contained no mold growth and did not germinate were reported as dead.

Reforestation Monitoring

This study was designed to document survival of outplantings during the years of 2011 and 2012. Two species, *P. devoniana* and *P. gregii* were reported in our findings and our data were collected after the rainy season during the months of September. The San Vicente Nursery in Irapuato, Guanajuato provided the outplantings for the reforestation project. Community members planted the seedlings within and around their communities. Our plots were established for monitoring purposes to supplement the reforestation project implemented by CONANP. Bare-root seedlings were planted for the majority of the reforestation within the RBSGG however other sources included ball and burlap or potted seedlings. The goal of our study was to establish baseline data for monitoring the reforestation efforts in the RBSGG and to provide suggestions for improvement. We applied the guidelines for establishing our monitoring plots from Lee et al. (2008). We chose to follow these techniques because they provided a thorough process for documenting vegetation. The goals of our study were consistent with the technique described. We were able to use their tested process for our research of the reforested areas in the RBSGG.

To monitor survival, we placed plots within each site. The size for each of our plots was 100 m^2. We placed a total of 15 plots throughout six sites for our study (Table 2). The number of plots varied by site and depended on the actual size of the reforestation area. Some areas were larger, therefore we were able to place more plots. Other sites were limited to only one plot. The largest site contained four, Vergel de Bernalejo. All plots were 10 x 10 m (100 m^2) with the exception of Plot 3 for Rancho de Guadalupe (Figure 4). Due to the limited space this plot became 10 x 9 m (90 m^2).

Plot locations were chosen to represent the surrounding environment. Plots were measured and squared by taking the diagonal (hypotenuse) measurement. Each corner of the plots was marked with steel conduit driven into the ground with only a small amount exposed for relocation. Only the steel conduit was left at the plot corners within our sites.

Individual planted tree data were recorded for each plot with the species code and X and Y coordinates relative to the plot origin. Height in centimeters, vigor, and any additional notes were also recorded on the data sheets. Vigor Code Definitions shown in Table 4 were based on the CVS-EEP Guidelines (Lee et al. 2008).

For our sites, we recorded data for each plot. These data included: soil drainage, elevation, azimuth of the plot x-axis, slope %, and aspect in degrees, and plot location (Table 3). Vegetation cover and canopy cover were estimated. The plot diagram was accompanied by drawings to help relocate the plot in subsequent years. Photos were taken of each plot (Figure 4) and the azimuth of the photo was recorded. Additional notes were taken of the layout, plot location, and plot rationale.

Table 2. Reforestation sites, number of plots, and species present

Name of Site	Number of Plots	*P. greggii*	*P. devoniana*
Agua Zarca	3		X
Calabazas	1		X
Cristo Rey	3	X	
El Toro	1		X
Rancho de Guadalupe	3	X	X
Vergel de Bernalejo	4		X

Table 3. Site Data

Site Name	Plot #	Soil Drainage*	Elevation (meters)	Slope (%)	Aspect (degrees)	Canopy cover (Table 4)	Veg cover (Table 4)
Agua Zarca	1	Excessively	2034	19	240	2	4
Agua Zarca	2	Well	2007	15	132	8	8
Agua Zarca	3	Somewhat Excessively	1995	47	72.5	6	7
Calabazas	1	Well	1975	70	280	7	9
Calabazas	2	Somewhat Excessively	1692	45	110	7	9
Calabazas	3	Somewhat Excessively	1569	58	330	7	9
Cristo Rey	1	Well	2169	16	340	1	8
El Toro	1	Well	2008	38	354	8	6
Rancho de Guadalupe	1	Well	1568	19	290	4	9
Rancho de Guadalupe	2	Well	1861	32	302	7	8
Rancho de Guadalupe	3	Somewhat Excessively	1861	33	70	4	8
Vergel de Bernalejo	1	Excessively	1800	23	180	1	6
Vergel de Bernalejo	2	Somewhat Excessively	1856	53	220	2	6
Vergel de Bernalejo	3	Excessively	1812	33	200	7	6
Vergel de Bernalejo	4	Excessively	1800	45	148	5	5

*Definitions of soil drainage as reported in the CVS EEP Protocol: Excessively Drained: coarse textured soils on very steep slopes; Somewhat Excessively Drained: The soil moisture content seldom exceeds field capacity; Well Drained: The soil moisture content does not normally exceed field capacity for a significant part of the year.


Agua Zarca Plot 1


Agua Zarca Plot 2


Agua Zarca Plot 3


Calabazas Plot 1


Calabazas Plot 2


Calabazas Plot 3


Rancho de Guadalupe Plot 1


Rancho de Guadalupe Plot 2

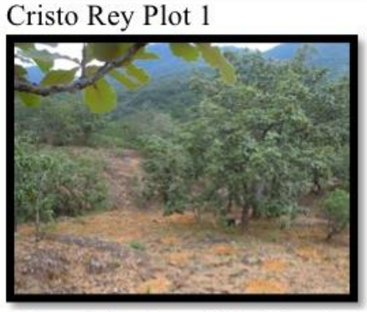

Rancho de Guadalupe Plot 3


El Toro Plot 1


Cristo Rey Plot 1


Vergel de Bernalejo Plot 1


Vergel de Bernalejo Plot 2


Vergel de Bernalejo Plot 3


Vergel de Bernalejo Plot 4

Figure 4. Pictures of the plots at their sites

Table 4. Vigor Codes (Lee et al. 2008)

Vigor Code Definitions	
4) Excellent	No more than minor tissue damage to leafy material exists and a generally normal amount of foliage is present.
3) Good	Minor damage to both leaf material and bark tissue exists or moderately less than a normal amount of foliage is present.
2) Fair	More than minor damage to leaf material and/or bark tissue exists.
1) Unlikely to survive year	Significant damage to leave and/or bark tissue that is likely to lead to mortality or resprout.
0) Dead	The entire plant appears to be dead.
M) Missing	Neither the living plant nor any remains could be found.

Table 5. Aerial Cover Classes for canopy and vegetation cover (Lee et al. 2008).

Cover Class	% cover
1	Trace (<0.1%)
2	0-1%
3	1-2%
4	2-5%
5	5-10%
6	10-25%
7	25-50%
8	50-75%
9	75-95%
10	95-100%

3. Results

Germination Results

The treatments were of 100 seeds therefore the number of germinating seeds is equivalent to the germination percentage (Table 6). Treated samples showed slightly faster germination times than those of the control (Figure 5). The germination times for each seed set varied only by a few days from the untreated samples for each species. *P. cembroides* had the highest germination success out of all species, with an overall average germination survival of 96% (Table 6). *P. greggii* also showed high germination success, with an overall 90% germination survival (Table 6). *P. devoniana* had equal seed germination percentages for both of the treated samples (soaked, soaked & scored) at 70%, the control seed set had most success, 73% (Table 6). *P. patula* showed highest germination success in the controlled set also, but had the lowest overall germination success (Table 6). *P.*

cembroides showed final germination on the 33rd day. *P. greggii* showed final germination on the 41st day. *P. devoniana* showed final germination on the 30th day. *P. patula* showed final germination on the 26th day. Across all species, germination began between days 4 and 7 (Figure 5).

Table 6. Total seed germination (%) over 70 days.

Species	Control	Soaked	Soaked & Scored	Germination Survival
P. cembroides	95%	95%	98%	96%
P. greggii	89%	90%	92%	90%
P. devoniana	73%	70%	70%	71%
P. patula	32%	33%	26%	30%

Table 7. Non-surviving seeds over 70 days.

Species	Moldy	Dead	Total non-surviving	% non-surviving
P. cembroides	9	3	12	4%
P. greggii	21	8	29	10%
P. devoniana	77	10	87	29%
P. patula	5	204	209	70%

For all species the soaked and soaked & scored treatments showed a slightly faster initial germination time than their controls (Figure 5). In the cases of the *P. cembroides* and *P. greggii* the soaked & scored treatments showed the highest amount of germination (Table 6). *P. devoniana* had equal germination success for both soaked and soaked & scored treatments (Table 6). *P. patula* was the only species where the soaked & scored treatments showed least germination success when compared to the control and the soaked treatment (Table 6 and Figure 5). Table 7 shows the majority of seed mortality containing mold. For this reason, the high mortality rate of the seeds could have been caused by mold due to excess moisture.

The differences between treatments were minor (maximum 6% for *Pinus patula,* maximum 3% for all other species) compared to the differences between species (maximum average difference was 66% for *Pinus cembroides* vs *Pinus patula*).

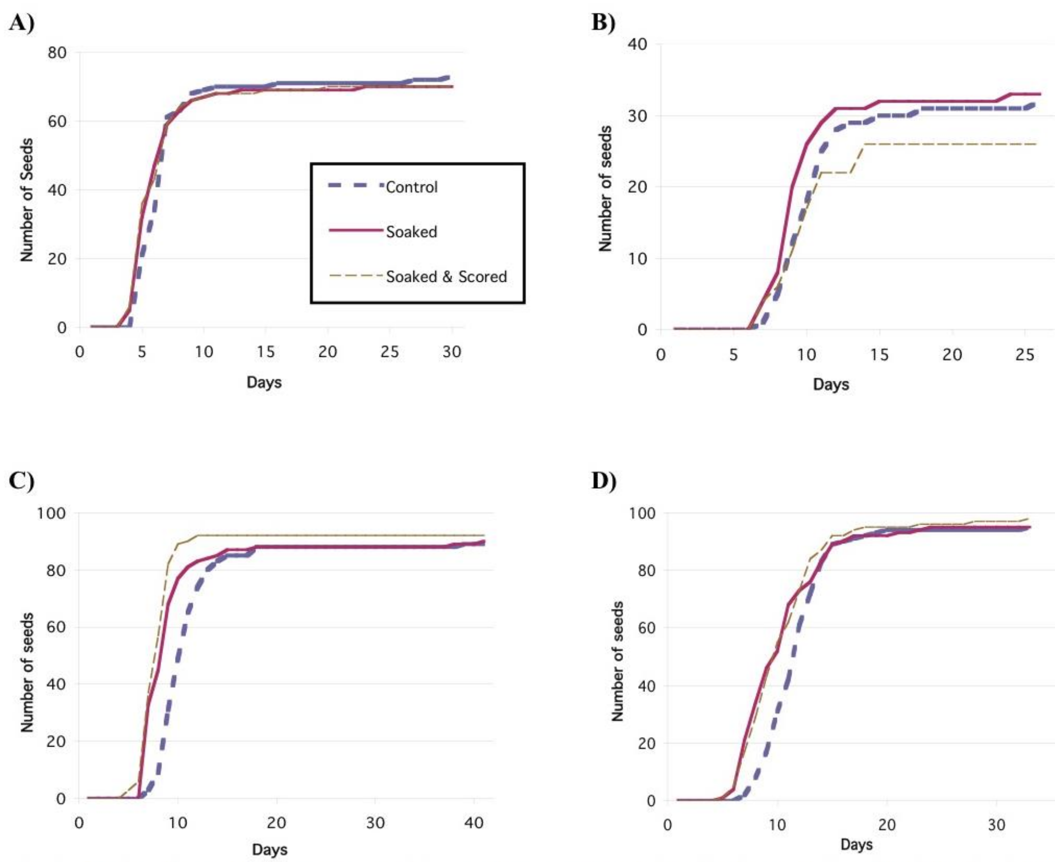


Figure 5: Number of seeds germinated over time. A) *P. devoniana* began germination day 4; final germination on day 30 B) *P. patula* began germination day 7; final germination on day 26 C) *P. greggii* began germination day 5; final germination on day 41 D) *P. cembroides* began germination day 5; final germination on day 33

Tree survival from 2011 to 2012

Survival rate varied by site (Table 9) and our findings report an overall survival rate of 26% across all of the sites we visited. *P. greggii* and *P. devoniana* were the species chosen for the outplantings and reported within our results. Both tree species were planted randomly and were not based on any type of methodological planting strategy. For this reason, not all of the plots had the same number of trees originally planted within them. Some sites already contained planted trees that were dead. The dead trees were noted but not included in our calculations.

Agua Zarca had the highest survival average at 56% while Calabazas showed near-total mortality with an overall survival average of 3%. Rancho de Guadalupe showed a 10% survival rate and Vergel de Bernalejo had a similar survival rate of 11%. El Toro showed 17% survival and Cristo Rey 29% (Table 9).

Table 8. Survival for each year by species and by site

Site	Plot #	PIGR 2011	PIMI 2011	PIGR 2012	PIMI 2012	PIGR Survival (%)	PIMI Survival (%)	Total Survival (%)
Agua Zarca	1	n/a	10	n/a	10	n/a	100%	100%
Agua Zarca	2	n/a	14	n/a	9	n/a	64%	64%
Agua Zarca	3	n/a	15	n/a	3	n/a	20%	20%
Calabazas	1	n/a	15	n/a	0	n/a	0%	0%
Calabazas	2	n/a	11	n/a	0	n/a	0%	0%
Calabazas	3	n/a	7	n/a	1	n/a	14%	14%
Cristo Rey	1	14	n/a	4	n/a	29 %	n/a	29%
El Toro	1	n/a	11	n/a	2	n/a	18%	18%
Rancho de Guadalupe	1	n/a	10	n/a	0	n/a	0%	0%
Rancho de Guadalupe	2	10	n/a	3	n/a	30%	n/a	30%
Rancho de Guadalupe	3	n/a	10	n/a	0	n/a	0%	0%
Vergel de Bernalejo	1	n/a	21	n/a	0	n/a	0%	0%
Vergel de Bernalejo	2	n/a	19	n/a	0	n/a	0%	0%
Vergel de Bernalejo	3	n/a	15	n/a	6	n/a	40%	40%
Vergel de Bernalejo	4	n/a	18	n/a	13	n/a	72%	72%

Table 9. Survival (%) by species and total survival (all trees)

Site	Survived PIGR (%)	Survived PIMI (%)	Total Survival (%) *both species/all trees
Agua Zarca	n/a	56%	56%
Calabazas	n/a	3%	3%
Cristo Rey	29%	n/a	29%
El Toro	n/a	18%	18%
Rancho de Guadalupe	30%	0%	10%
Vergel de Bernajelo	n/a	26%	26%

4. Discussion

Seed Germination

Germination treatments did not show a significant difference between time and percentage. Therefore we do not recommend treating the seed lots with our two treatment methods. Our germination treatments were not necessary because our results depicted a small variation of survival percentage and there was no significant difference between the first days of germination. Excess moisture caused mold growth and this became the cause of death for many of the seeds in our seed lots. Reducing moisture or limiting the amount of water to remoisten paper towels could offset mold. A species similar to *P. devoniana,* specifically *P. montezumae* was reported as being susceptible to damping-off, thus applying a fungicide is recommended (Galván and Martínez 1985 in Aldrete 2002).

Some species may require more seeds to produce the same number of germinants. According to our results *P. patula* would require up to three times as much seed to produce the same germination percent as the other species tested. Without any cold stratification *P. patula* seeds will germinate between 7 to 10 days after placement in germination chambers (Dvorak 2002). Our findings for the seed germination test of *P. patula* are consistent with this report. Although we saw slight increases in germination after 10 days, the majority of seeds germinated within the 7 to 10 day bracket (Figure 5). Techniques including cold stratification, soaking seeds in water, or soaking seeds in 1 percent hydrogen peroxide have been shown to increase germination percentages in other studies (Dvorak 2002). Our results only showed a 1 percent difference between the control and soaked tests. If we tripled the number of seeds in the seed lot, we may see a larger increase of seed germination for the soaked samples. Consequently the soaked & scored sample may have experienced damage from the scalping from the razor, which resulted in the low survival percentage. As mentioned above using 1 percent hydrogen peroxide should yield better results.

Another study reported natural stands of *P. greggii* showing variation in seed production throughout different geographical locations in Mexico, and seed efficiency for this species as higher when compared to other pine species (Lopez-Upton and Donahue 1995). Although our study was not in a natural environment, the overall seed survival between species showed similar results. We found that germination survival was 90% for *P. greggii* and this was higher than the overall germination survival for *P. devoniana* and *P. patula*. When compared to *P. greggii, P. cembroides* was the only species that showed a slightly higher germination survival percentage by 6%. Seeds collected from natural *P. greggii* stands in Mexico showed a 30 to 70 percent germination rate (Dvorak 2002). Our germination percentage rate was slightly higher because our indoor tests excluded natural disturbances such as insect attacks and extremes in precipitation.

Different types of seed tests could have been useful to compare with the germination results. For example, a tetrazolium test for vigor and viability can provide faster results of seed viability. Different types of tests can produce results faster than the standard germination tests we conducted. It can be useful for land managers and researchers to compare the results of vigor and viability between these different types of tests to ensure accuracy. In another study, a quick test for vigor of *P. patula* seeds was assessed by the use of leachate conductivity (Demelash et al. 2004). Different tests on seed lots have been able to produce results for viability and vigor without running the standard long germination tests. These types of tests would also eliminate the percentage killed by mold growth. Seed collection and seed lot storage could have affected the results of our study. Storage conditions affect seeds and deteriorate physiological and biochemical perturbations (Demelash et al. 2004). Therefore, proper storage and different types of vigor and viability tests in conjunction with the typical long germination study will provide more information and precise data. Other factors affect germination rates and will likely show different results in a natural or outdoor setting. Correlations between seed germination and light conditions tend to be oversimplified and a conceptual framework incorporating demography and forest patch dynamics is needed to better understand forest population, dynamics and life history strategies. (Martinez-Ramos and Cristiän 1997).

Reforestation

Agua Zarca had higher survival rates in two of the three plots. Overall, Agua Zarca depicts the highest survival rate at 56% (Table 9). Plot 3 of Agua Zarca had the highest slope (Table 2). Plot 2 and 3 had darker loamy soil compared to Plot 1, which had hard, rocky red soil. We speculate that the mortality for this site could be related to slope steepness and dry southerly aspect. This could have been a factor of tree mortality due to soil drainage type causing high water runoff. Many other factors could have affected survival that we were unable to measure such as tree planting techniques or effects from livestock grazing.

The overall survival rate at Calabazas was the lowest at 3% (Table 9). Local community members mentioned the issue of drought on numerous occasions and failed reforestation attempts from other agencies. All three plots from Calabazas were on hillsides and had some soil erosion. This site has healthy visible evidence of natural re-growth. However it remains unclear as to why previous reforestation attempts were reported as having failed by the community members. Placing monitoring plots in areas where other agencies have reforested will be useful to determine the survival of older trees. Through comparisons between reforestation attempts, managers can apply the strategies that produce the best survival percentage.

Cristo Rey had moderate survival at 29%, but only one plot was established at this site (Table 7 and Table 9). The reforestation project at this site covers a small area of land, so placing more than one plot was not a viable option. Soil at this site was dark and moist. As the project expands, it will be useful to place more monitoring plots for this site, and hopefully we will see an increased survival rate. The local community informed us of pest outbreaks, although it remains unclear of which types of pests they had found. By addressing this issue and working with community members to eliminate pests, reforestation at Cristo Rey could potentially improve.

El Toro was another small area for reforestation and only consisted of one plot. This site showed a low overall survival rate of 17% (Table 9). Similar to Cristo Rey, soil texture was dark and loamy, but El Toro had a steeper slope of 38 % (Table 3). Our plot may have experienced high water runoff with the soil drainage type due to slope. El Toro had some natural regeneration of *P. devoniana* within our plot (see appendices). Natural regeneration was recorded, but not represented in our survival rate percentage because we only wanted to focus on measuring the success of outplantings for this study.

Rancho de Guadalupe contained three monitoring plots and showed an overall low survival rate. It is important to note that Rancho de Guadalupe was the only site that contained both of the species, *P. devoniana* and *P. greggii*. None of the plots within our study had both species present within the same 100 m. The overall survival rate of *P. greggii* was 30% while *P. devoniana* had 0% survival (Table 8). Nonetheless, the final survival rate between the three plots was 10% survival (Table 9). Since we saw no survival of *P. devoniana* at this site, other species may be better candidate species for reforesting this area. Once a candidate species is established and successfully being reforested, managers can incorporate additional species to supplement the effort.

Vergel de Bernalejo was the only site that contained four plots. Overall the survival was low at 11% (Table 9), but plot 4 showed a higher survival rate (Table 7). The majority of this reforestation site occupied a steep hillside with hard rocky red soil and had visible signs of erosion. Our plot placements at this site where chosen to represent the overall conditions of the outplanting area. The slopes varied at each plot, and we do not correlate the slope percentages and the survival rates (Table 3).

The potential causes for mortality likely contain multiple factors. Soil type, quality, soil water retention, current forest structure, current land use practices, climate change, misplanting, and individual tree health could all contribute to outplanting failure. The impact of drought and climate will also affect tree survival and health. With proper planning, reforestation has the potential to mitigate effects of forest degradation, protect biodiversity, and improve the resources of forest goods and services (Orsi and Geneletti 2010). Techniques vary throughout different parts of Mexico. Reforestation priority was determined in Chiapas by identifying locations where biodiversity should be protected and where reforestation is likely to succeed (Orsi and Geneletti 2010).

Misplanting is the cause for seedling mortality in many cases (Londo and Dicke 2006). Bareroot seedlings require a hole that is equal to the taproot, approximately 6-8 inches (Londo and Dicke 2006). If the planted hole is not sufficient in depth, the roots are forced close to the soil surface and decrease the chance of survival (Londo and Dicke 2006). Natural causes also inflict lower chances of survival for individual planted trees. As reported from the community of Cristo Rey, there have been occurrences of pest outbreaks that could have affected survival rates. Drought was mentioned numerous times within three sites, Calabazas, El Toro, and Vergel de Bernalejo. Although lack of water can affect survivability of young trees, slope and runoff potential need to be considered as well. Most of the trees in Vergel de Bernalejo and Calabazas were planted on hillsides with very steep terrain close to cliff edges. Steep terrain and erosion problems could contribute to water loss for this area.

Finally, we established our plots in order to develop the foundation of baseline data. By providing the overall survival rate of each site, we hope these data can contribute to the management plan for the RBSGG. A general inventory of plant biodiversity and health is still needed for each site. We hope our studies can contribute to improved reforestation techniques for this region and future management strategies. As managers and landowners plant in new areas it would be useful to create monitoring plots from the beginning. Well-documented data and pictures, along with testing multiple species at each location will help establish a stronger database. The performance of different species can be compared and future plantings can be more efficient by selecting the best species.

Recommendations

We highly recommend continuing to build the database of tree survival. As the reforestation project expands, more monitoring plots should be established. The establishment of plots to document heath and survival could help reduce mortality rates and further help determine the areas in which survival would be most successful. A small amount of funding and research to establish more plots could potentially save time, money, and resources. As the RBSGG develops a detailed management plan, land use history, rainfall data, bark beetle control, and soil type will be important to ensure success of reforestation efforts. A clear understanding of historical land conversion is important for native-species reforestation (Griscom and Ashton 2011). A detailed analysis of forest structure and composition can also help refine goals for the future. Site assessments prior to planting will allow managers to actively decide what species will be best to plant under given conditions. We suggest the RBSGG to include native non-conifer or broad-leafed species when replanting. Including additional species allows sites to develop more like natural forests rather than mono-culture plantations. Mixing planting species at appropriate sites could boost habitat value for wildlife, provide hard wood for better products, and add beauty. Certain species are also less flammable than pine species and can provide resilience to forest structure. Based on the early stage of the life-cycle of trees the transition stage between seed and seedlings species are classified into pioneers and climax species, therefore it is important to establish a better data set on the demography of forest trees (Martinez-Ramos and Cristiän 1997). Identifying suitable pioneer species for to each site can help strengthen reforestation attempts from early on.

Incorporating *P. cembroides* as a candidate for outplanting efforts may be useful in some areas of the RBSGG, as it is known to tolerate dry, poor, alkaline soils (Gilman and Watson 1994) and as a drought tolerant species associated with xeric environments (Romero-Manzanares et al. 2012). This species has a wide distribution (Romero-Manzanares et al. 2012) and could be a pioneer species in some forests of in some forests of the RBSGG. Species found in the understory of *P. cembroides* can be used as indicators of ecosystem health (Romero-Manzanares et al. 2012). Active management is important and research has shown on sites with a long history of land clearance to have missing functional groups and low species diversity (Griscom and Ashton 2011). In terms of conservation, *P. cembroides* is declared as the most important species in the *cembroides* complex, (Romero-Manzanares et al. 2012) and could help promote the natural functions of forest dynamics in reforested areas.

Using different reforestation practices can be helpful to aid restoration efforts in RBSGG. Instance, establishing plantations can be an option in some sites, especially in areas where the original forest structure has changed drastically over time by having lost their native forest cover. The ideal density of a plantation should be made individually, based on management objectives and requirements as well as costs (Londo and Dicke 2006).

Vergel de Bernalejo could benefit from a plantation-based strategy to prevent further soil degradation, as there is severe soil erosion throughout this site. Plantation style reforestation can increase forest productivity and protect watersheds (Pausas et al. 2004). At this site, *Quercus sp.* is establishing naturally but there were no strong visible observations of pine regeneration. Plantations have contributed to providing employment for rural areas (Pausas et al. 2004) and if applied to the RBSGG, plantation forestry could help increase income for the local communities. According to experimental studies, cleared lands have the ability to grow back to forests (Griscom and Ashton 2011). Extremely degraded lands with older plantations, have developed into functional pine forests (Pausas et al. 2004). Applying a plantation style reforestation approach with an enrichment planting approach using pine species may help improve survival at Vergel de Bernalejo. As pioneer species establish, different species can be incorporated into the reforestation process to work toward improving biodiversity.

As this reforestation project continues to grow, CONANP hopes to fund more communities and develop new sites. Developing community nurseries within the RBSGG is a new goal to expand reforestation attempts and can be incorporated as a new objective in a management plan. It is also extremely important to establish clear incentives as to why some areas are being reforested. Is the reforestation for wildlife habitat, restoration, timber production, soil improvement, aesthetic purposes, or for other reasons? This study hopes to provide some groundwork to assist with the development of baseline data for monitoring planted trees and inspire specific goals desired for the RBSGG. With these data we can fill in some of the information gaps and we hope this information will be used improve success for reforestation of native species in the RBSGG.

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Appendices:

A1. Plot UTM coordinates at each bottom left corner of all 10 x 10 m plots.

Site	Plot	Latitude (Northing)	Longitude (Easting)
Agua Zarca	1	0387409	2358019
Agua Zarca	2	0387565	2357844
Agua Zarca	3	0387626	2357864
Calabazas	1	0396095	2366113
Calabazas	2	0395775	2366229
Calabazas	3	0396350	2365875
Cristo Rey	1	0395896	2363784
El Toro	1	0415864	2363522
Rancho de Guadalupe	1	0394097	2369166
Rancho de Guadalupe	2	0393906	2369156
Rancho de Guadalupe	3	0394198	2369125
Vergel de Bernalejo	1	0353759	2382867
Vergel de Bernalejo	2	0353871	2382997
Vergel de Bernalejo	3	0353809	2382871
Vergel de Bernajelo	4	0353553	2382925

A2. Individual Tree data with X and Y coordinates of location within plot.

Site Name	Plot #	Species Code	X	Y	Height (cm) 2011	Vigor (table 3) 2011	Heigh t (cm) 2012	Vigor (table 3) 2012	Notes
Agua Zarca	1	PIMI	186	156	5.5	4	11	4	
Agua Zarca	1	PIMI	667	108	6.5	4	4	4	Buried at the base when revisited
Agua Zarca	1	PIMI	866	55	5.5	4	5	4	Buried at the base 2012
Agua Zarca	1	PIMI	190	412	3.5	3	6	4	
Agua Zarca	1	PIMI	459	364	5	3	12	4	
Agua Zarca	1	PIMI	728	444	5	4	6	4	
Agua Zarca	1	PIMI	474	611	9	3	14	4	
Agua Zarca	1	PIMI	770	711	1	4	13	4	
Agua Zarca	1	PIMI	838	525	10	4	12	4	Large root visible
Agua Zarca	1	PIMI	789	989	10.5	3	16	4	
Agua Zarca	2	PIMI	50	22	8	4	10	4	
Agua Zarca	2	PIMI	486	200	13	4	n/a	M	missing
Agua Zarca	2	PIMI	41	353	4	4	n/a	D	dead
Agua Zarca	2	PIMI	720	231	5	4	9	4	
Agua Zarca	2	PIMI	1000	338	5	4	15	4	
Agua Zarca	2	PIMI	540	381	13	4	31	4	
Agua Zarca	2	PIMI	714	511	11	3	n/a	D	
Agua Zarca	2	PIMI	980	603	1	4	12	4	
Agua Zarca	2	PIMI	980	902	9	4	17	4	

Site Name	Plot #	Species Code	X	Y	Height (cm) 2011	Vigor (table 3) 2011	Height (cm) 2012	Vigor (table 3) 2012	Notes
Agua Zarca	2	PIMI	739	800	1	4	13	4	
Agua Zarca	2	PIMI	520	643	6	4	6	4	Buried at the base 2012
Agua Zarca	2	PIMI	461	829	1	4	n/a	M	Missing
Agua Zarca	2	PIMI	38	971	2	4	n/a	D	Dead
Agua Zarca	2	PIMI	43	670	9	4	11	4	Somewhat buried at the base 2012
Agua Zarca	3	PIMI	38	75	7	4	n/a	D	Dead
Agua Zarca	3	PIMI	383	73	6	4	n/a	D	Dead
Agua Zarca	3	PIMI	604	110	3	4	n/a	D	Dead
Agua Zarca	3	PIMI	962	149	6	4	n/a	D	Dead
Agua Zarca	3	PIMI	870	400	10	4	n/a	D	Dead
Agua Zarca	3	PIMI	525	363	11.5	3	n/a	D	Dead
Agua Zarca	3	PIMI	285	355	9	3	n/a	D	Dead
Agua Zarca	3	PIMI	34	363	6	4	n/a	D	Dead
Agua Zarca	3	PIMI	58	670	6	4	n/a	D	Dead
Agua Zarca	3	PIMI	353	615	5	4	22	4	
Agua Zarca	3	PIMI	602	652	9	4	26	4	
Agua Zarca	3	PIMI	860	673	4.5	3	n/a	M	Missing
Agua Zarca	3	PIMI	643	925	6	3	n/a	D	Dead
Agua Zarca	3	PIMI	393	876	7	4	18	4	
Agua Zarca	3	PIMI	33	967	9	4	n/a	M	Missing (hole present)
Calabazas	1	PIMI	69	30	4	4	n/a	D	Dead
Calabazas	1	PIMI	253	65	2	3	n/a	D	Dead
Calabazas	1	PIMI	616	35	13	4	n/a	D	Dead
Calabazas	1	PIMI	824	37	10	4	10	1	
Calabazas	1	PIMI	830	313	10	4	n/a	D	Dead
Calabazas	1	PIMI	645	349	9	4	n/a	D	Dead
Calabazas	1	PIMI	471	304	8	4	n/a	D	Dead
Calabazas	1	PIMI	160	292	8	1	n/a	D	Dead
Calabazas	1	PIMI	70	572	9	4	n/a	D	Dead
Calabazas	1	PIMI	321	575	10	4	n/a	D	Dead
Calabazas	1	PIMI	500	610	6	4	n/a	D	Dead
Calabazas	1	PIMI	725	590	6	4	n/a	D	Dead
Calabazas	1	PIMI	653	120	5	4	n/a	D	Dead
Calabazas	1	PIMI	455	137	2	4	n/a	D	Dead
Calabazas	1	PIMI	223	762	4	4	n/a	D	Dead
Calabazas	2	PIMI	801	885	6	4	n/a	D	Dead
Calabazas	2	PIMI	196	879	3	4	n/a	D	Dead
Calabazas	2	PIMI	528	690	3	4	n/a	D	Dead
Calabazas	2	PIMI	935	677	4	3	n/a	D	Dead
Calabazas	2	PIMI	898	448	5	4	n/a	D	Dead
Calabazas	2	PIMI	630	406	4	4	n/a	D	Dead
Calabazas	2	PIMI	70	340	5	4	n/a	D	Dead
Calabazas	2	PIMI	59	25	4	4	n/a	D	Dead
Calabazas	2	PIMI	318	45	3	4	n/a	D	Dead
Calabazas	2	PIMI	565	25	0	2	n/a	D	Dead
Calabazas	2	PIMI	835	38	3	3	n/a	D	Dead
Calabazas	3	PIMI	158	825	8	4	n/a	D	Dead
Calabazas	3	PIMI	403	790	3	4	n/a	D	Dead
Calabazas	3	PIMI	732	820	n/a	D	n/a	D	Dead
Calabazas	3	PIMI	865	420	6	4	n/a	D	Dead
Calabazas	3	PIMI	611	422	7	4	8	1	Almost Dead
Calabazas	3	PIMI	331	410	n/a	1	n/a	D	Dead
Calabazas	3	PIMI	77	435	4	1	n/a	D	Dead
Calabazas	3	PIMI	50	73	n/a	D	n/a	D	Dead
Calabazas	3	PIMI	329	12	4	4	n/a	D	Dead

Site Name	Plot #	Species Code	X	Y	Height (cm) 2011	Vigor (table 3) 2011	Heigh t (cm) 2012	Vigor (table 3) 2012	Notes
Calabazas	3	PIMI	578	75	n/a	D	n/a	D	Dead
Calabazas	3	PIMI	786	55	3	4	n/a	D	Dead
Cristo Rey	1	PIGR	68	43	14	4	10	2	Two stems, taller stem is brown
Cristo Rey	1	PIGR	343	58	25	4	26	3	Dead
Cristo Rey	1	PIGR	563	56	21	4	n/a	D	Dead
Cristo Rey	1	PIGR	960	13	19	4	31	4	Dead
Cristo Rey	1	PIGR	819	296	21	4	n/a	D	Dead
Cristo Rey	1	PIGR	453	308	13	4	n/a	D	Dead
Cristo Rey	1	PIGR	157	452	22	4	27	2	Dead
Cristo Rey	1	PIGR	63	630	21	4	n/a	D	Dead
Cristo Rey	1	PIGR	12	888	17	4	n/a	D	Dead
Cristo Rey	1	PIGR	300	978	18	4	n/a	D	Dead
Cristo Rey	1	PIGR	580	880	18	4	n/a	D	Dead
Cristo Rey	1	PIGR	939	785	13	4	n/a	D	Dead
Cristo Rey	1	PIGR	691	583	22	4	n/a	D	Dead
Cristo Rey	1	PIGR	347	665	14	4	n/a	D	Dead
El Toro	1	PIMI	43	38	1	4	n/a	M	Missing
El Toro	1	PIMI	339	9	1	4	n/a	M	Missing
El Toro	1	PIMI	670	7	4	4	12	4	
El Toro	1	PIMI	946	29	1	4	n/a	M	Missing
El Toro	1	PIMI	970	92	46	4	49	4	Natural
El Toro	1	PIMI	185	440	1	4	n/a	D	Dead
El Toro	1	PIMI	260	466	156	4	167	4	Natural
El Toro	1	PIMI	467	404	1	3	n/a	D	Dead
El Toro	1	PIMI	777	504	1	4	n/a	M	Missing
El Toro	1	PIMI	160	87	4.5	4	n/a	M	Missing
El Toro	1	PIMI	374	978	32	4	40	4	Natural
El Toro	1	PIMI	424	910	2	4	n/a	D	Dead
El Toro	1	PIMI	710	950	2	4	10.5	4	
El Toro	1	PIMI	991	971	8	4	n/a	D	Dead
El Toro	1	PIMI	848	628	56	4	76	4	Natural
Rancho de Guadalupe	1	PIMI	38	30	2	4	n/a	M	Missing
Rancho de Guadalupe	1	PIMI	450	25	5	4	n/a	D	Dead
Rancho de Guadalupe	1	PIMI	712	57	4	4	n/a	D	Dead
Rancho de Guadalupe	1	PIMI	987	17	3	4	n/a	M	Missing
Rancho de Guadalupe	1	PIMI	816	391	10	4	n/a	M	Missing
Rancho de Guadalupe	1	PIMI	542	357	2	3	n/a	M	Missing
Rancho de Guadalupe	1	PIMI	244	383	5	3	n/a	M	Missing
Rancho de Guadalupe	1	PIMI	72	770	3	2	n/a	M	Missing
Rancho de Guadalupe	1	PIMI	767	488	3	4	n/a	M	Missing
Rancho de Guadalupe	1	PIMI	742	730	3	3	n/a	M	Missing
Rancho de Guadalupe	2	PIGR	24	35	7	3	n/a	M	Missing
Rancho de Guadalupe	2	PIGR	322	49	12	4	n/a	D	Dead
Rancho de	2	PIGR	495	133	7	4	8	4	

Site Name	Plot #	Species Code	X	Y	Height (cm) 2011	Vigor (table 3) 2011	Heigh t (cm) 2012	Vigor (table 3) 2012	Notes
Guadalupe									
Rancho de Guadalupe	2	PIGR	390	330	11	3	11.5	4	
Rancho de Guadalupe	2	PIGR	35	460	11	4	n/a	M	Missing
Rancho de Guadalupe	2	PIGR	229	610	12	3	n/a	M	Missing
Rancho de Guadalupe	2	PIGR	662	647	8	3	10	3	
Rancho de Guadalupe	2	PIGR	495	770	8	3	n/a	M	Missing
Rancho de Guadalupe	2	PIGR	272	925	15	3	n/a	M	Missing
Rancho de Guadalupe	2	PIGR	21	830	12	4	n/a	M	Missing
Rancho de Guadalupe	3	PIMI	942	13	4	4	n/a	D	Dead
Rancho de Guadalupe	3	PIMI	581	52	5	4	n/a	M	Missing
Rancho de Guadalupe	3	PIMI	127	138	6	3	n/a	M	Missing
Rancho de Guadalupe	3	PIMI	45	523	7	4	n/a	M	Missing
Rancho de Guadalupe	3	PIMI	266	475	1	3	n/a	M	Missing
Rancho de Guadalupe	3	PIMI	567	426	16	4	n/a	M	Missing
Rancho de Guadalupe	3	PIMI	895	477	7	4	n/a	M	Missing
Rancho de Guadalupe	3	PIMI	775	725	5	4	n/a	M	Missing
Rancho de Guadalupe	3	PIMI	480	820	4	4	n/a	D	Dead
Rancho de Guadalupe	3	PIMI	205	875	7	4	n/a	M	Missing
Vergel de Bernalejo	1	PIMI	188	64	15	4	n/a	D	Dead
Vergel de Bernalejo	1	PIMI	400	90	1	4	n/a	D	Dead
Vergel de Bernalejo	1	PIMI	905	60	12	4	n/a	D	Dead
Vergel de Bernalejo	1	PIMI	623	144	9	4	n/a	M	
Vergel de Bernalejo	1	PIMI	764	127	7	3	n/a	D	Dead
Vergel de Bernalejo	1	PIMI	558	294	6	4	n/a	M	
Vergel de Bernalejo	1	PIMI	709	349	5	4	n/a	D	Dead
Vergel de Bernalejo	1	PIMI	324	345	7	4	n/a	M	
Vergel de Bernalejo	1	PIMI	36	357	3	4	n/a	D	Dead
Vergel de Bernalejo	1	PIMI	20	510	8	4	n/a	D	Dead
Vergel de Bernalejo	1	PIMI	367	432	2	4	n/a	D	Dead
Vergel de	1	PIMI	578	465	8	4	n/a	D	Dead

Site Name	Plot #	Species Code	X	Y	Height (cm) 2011	Vigor (table 3) 2011	Heigh t (cm) 2012	Vigor (table 3) 2012	Notes
Bernalejo									
Vergel de Bernalejo	1	PIMI	932	411	n/a	D	n/a	M	Dead/Missing
Vergel de Bernalejo	1	PIMI	937	598	6	3	n/a	M	Missing
Vergel de Bernalejo	1	PIMI	830	568	7	4	n/a	D	Dead
Vergel de Bernalejo	1	PIMI	618	486	8	4	n/a	D	Dead
Vergel de Bernalejo	1	PIMI	728	448	9	4	n/a	M	Missing
Vergel de Bernalejo	1	PIMI	948	228	7	4	n/a	M	Missing
Vergel de Bernalejo	1	PIMI	813	604	11	4	n/a	D	Dead
Vergel de Bernalejo	1	PIMI	940	707	6	4	n/a	M	Missing
Vergel de Bernalejo	1	PIMI	968	905	7	4	n/a	M	Missing
Vergel de Bernalejo	1	PIMI	982	771	3	4	n/a	M	Missing
Vergel de Bernalejo	2	PIMI	39	989	9	4	n/a	M	Missing
Vergel de Bernalejo	2	PIMI	243	902	8	4	n/a	M	Missing
Vergel de Bernalejo	2	PIMI	432	905	13	4	n/a	M	Missing
Vergel de Bernalejo	2	PIMI	665	860	2	4	n/a	M	Missing
Vergel de Bernalejo	2	PIMI	900	163	7	4	n/a	D	Dead
Vergel de Bernalejo	2	PIMI	904	361	16	4	n/a	D	Dead
Vergel de Bernalejo	2	PIMI	668	421	3	4	n/a	M	Missing
Vergel de Bernalejo	2	PIMI	428	385	8	4	n/a	M	Missing
Vergel de Bernalejo	2	PIMI	232	370	10	4	n/a	M	Missing
Vergel de Bernalejo	2	PIMI	328	505	12	4	n/a	D	Dead
Vergel de Bernalejo	2	PIMI	290	832	8	4	n/a	D	Dead
Vergel de Bernalejo	2	PIMI	93	883	9	4	n/a	M	Missing
Vergel de Bernalejo	2	PIMI	65	970	3	4	n/a	D	Dead
Vergel de Bernalejo	2	PIMI	281	985	7	4	n/a	M	Missing
Vergel de Bernalejo	2	PIMI	477	775	8	4	n/a	M	Missing
Vergel de Bernalejo	2	PIMI	484	560	6	3	n/a	M	Missing
Vergel de Bernalejo	2	PIMI	765	610	14	4	n/a	M	Missing
Vergel de Bernalejo	2	PIMI	700	812	6	4	n/a	D	Dead
Vergel de	2	PIMI	888	857	10	4	n/a	M	Missing

Site Name	Plot #	Species Code	X	Y	Height (cm) 2011	Vigor (table 3) 2011	Heigh t (cm) 2012	Vigor (table 3) 2012	Notes
Bernalejo									
Vergel de Bernalejo	3	PIMI	540	176	3.5	4	n/a	M	Missing
Vergel de Bernalejo	3	PIMI	664	232	n/a	D	n/a	M	Missing
Vergel de Bernalejo	3	PIMI	929	48	5	4	n/a	M	Missing
Vergel de Bernalejo	3	PIMI	932	282	6	4	n/a	M	Missing
Vergel de Bernalejo	3	PIMI	770	362	13	4	n/a	D	Dead
Vergel de Bernalejo	3	PIMI	408	349	6	4	9	4	
Vergel de Bernalejo	3	PIMI	566	500	5	4	n/a	M	Missing
Vergel de Bernalejo	3	PIMI	930	486	7	4	n/a	M	Missing
Vergel de Bernalejo	3	PIMI	754	598	3	4	n/a	D	Dead
Vergel de Bernalejo	3	PIMI	646	885	2	4	2	2	Buried under soil and leaves
Vergel de Bernalejo	3	PIMI	767	754	1	4	2	2	Buried under soil and leaves
Vergel de Bernalejo	3	PIMI	565	663	2	4	n/a	D	Dead
Vergel de Bernalejo	3	PIMI	582	824	1	4	1	4	Partially buried in soil
Vergel de Bernalejo	3	PIMI	446	812	7	4	4	2	
Vergel de Bernalejo	3	PIMI	287	935	12	4	10	4	
Vergel de Bernalejo	3	PIMI	33	905	1	4	n/a	D	Dead
Vergel de Bernalejo	4	PIMI	48	27	8	2	9	4	
Vergel de Bernalejo	4	PIMI	220	78	6	4	9	4	
Vergel de Bernalejo	4	PIMI	383	188	7	3	9	4	
Vergel de Bernalejo	4	PIMI	665	15	3	4	4	4	
Vergel de Bernalejo	4	PIMI	665	238	3	4	3	4	
Vergel de Bernalejo	4	PIMI	1000	0	10	4	n/a	M	Missing
Vergel de Bernalejo	4	PIMI	876	360	4	4	4	4	
Vergel de Bernalejo	4	PIMI	788	617	1	4	n/a	M	Missing
Vergel de Bernalejo	4	PIMI	918	844	9.5	4	10	4	
Vergel de Bernalejo	4	PIMI	99	467	12	4	n/a	D	Dead
Vergel de Bernalejo	4	PIMI	29	650	8	4	9	4	
Vergel de Bernalejo	4	PIMI	198	878	4	4	n/a	D	Dead
Vergel de	4	PIMI	436	603	12	4	12	4	

Site Name	Plot #	Species Code	X	Y	Height (cm) 2011	Vigor (table 3) 2011	Heigh t (cm) 2012	Vigor (table 3) 2012	Notes
Bernalejo									
Vergel de Bernalejo	4	PIMI	434	403	8	4	7	4	
Vergel de Bernalejo	4	PIMI	268	527	5	4	7	4	
Vergel de Bernalejo	4	PIMI	595	514	2	4	5	4	
Vergel de Bernalejo	4	PIMI	819	113	1	4	n/a	M	Missing
Vergel de Bernalejo	4	PIMI	654	747	n/a	D	n/a	M	Missing
Vergel de Bernalejo	4	PIMI	13	722	7	4	8	4	