

# GROWING AGAVES FOR BATS

## A GUIDE FROM SEED TO FLOWER



*Borderlands Restoration Network*  
2021

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## ***Growing Agaves For Bats: A Guide from Seed to Flower***

was developed with funding from Bat Conservation International and Mountain Rose Herbs. Thank you for supporting this work!

The work of Borderlands Restoration Network is focused primarily in southeastern Arizona and northern Sonora, on the unceded, ancestral lands of the Tohono O'odham, Opata, Yoeme, Comca'ac, and Apache people. Additionally, we acknowledge that the regions discussed in this booklet extend across numerous territories and encompass the homelands stewarded by native communities throughout what is commonly called the United States and Mexico.

Thank you to Rezipiral for publishing the original “guia vivero” (nursery guide) book that this booklet is based on - *Amigos del Maguey y la Biodiversidad*.

Thank you to the following partners for their contributions and consultations – *Dr. Kristen Lear, Dr. Emma Gómez-Ruiz, Socorro González Elizondo, Martha González Elizondo, David Suro, Wendy Hodgson, Robert Villa, and Dr. Gary Nabhan*.

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Back Cover - Photo by *Kayla Lewis Photography*

[*Agave palmeri* in monsoon rain, Southeastern Arizona]

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First edition - 50 copies printed at *Abalone Mountain Press* in Phoenix, AZ



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## HELLO - WE'RE VERY GLAD YOU'VE PICKED UP THIS BOOKLET!



*Agave palmeri* in a monsoon rain, Southeastern Arizona [p.c. - Kayla Lewis Photography]

This is a first edition. It has been developed with help from our extraordinary colleagues in the overlapping networks of agave nerds & bat groupies, but the priorities, methods and errors set forth are ultimately our own, a reflection of our current understanding of a complex and extensive field. Certain details have been left out for brevity's sake, but we welcome any feedback that might inform a second edition. Nothing here is definitive, except our commitment to growing agaves, restoring bat habitat in the process & supporting folks like you who want to come along for the ride.

-The Native Plant Materials Team  
Borderlands Restoration Network [BRN]  
Patagonia, Arizona USA  
May 2021

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## WHY GROW AGAVES?

Agaves are an ecologically and economically important drought tolerant plant native to Mexico and the southwestern United States. Although considered perennials, these native succulents are more accurately described as monocarpic, meaning they will live decades but the vast majority of the species in the genus die after a single flowering. Ecologically, this monocarpic life-cycle means agaves spend their entire lives storing sugars in preparation for flowering, at which point their nectar will provide food for bats and hundreds of other pollinators. These same pollinators play a pivotal role for agaves as well though, as their flight from flower to flower ensures cross-pollination - the transfer of pollen from one plant to another - which allows the plant to produce seeds! As we will discuss later, agaves reproducing from seed makes for greater genetic diversity which, in turn, increases the resilience of agave populations to environmental stressors such as freezes, diseases and drought. It's important to understand however that seeds are not the only way that agaves reproduce: most agaves also send out "pups" from the mother plant. These genetically identical clones offer both advantages and disadvantages when used in agriculture and restoration - also discussed later.

Although agaves may be processed into many different food, drink and fiber products, the same stored sugars that make them such a vital food source for pollinators are at the heart of their economic importance as the raw material for fermentation and distillation into agave spirits. In recent years, the harvesting of wild agave to meet the ever-increasing demand for tequila, mezcal, bacanora, raicilla and pulque from Mexico, paired with high mortality from climate events, as well as habitat loss from overgrazing and development are reducing populations of wild agaves. Fewer agaves means less nectar is available in the landscape, stressing nectar-feeding bats and other pollinators along their migratory routes.



**FIG 1:** Anatomy of a Paniculate Agave [p.c. - Colectivo Sonora Silvestre]

## WHY AGAVE FOR BATS?

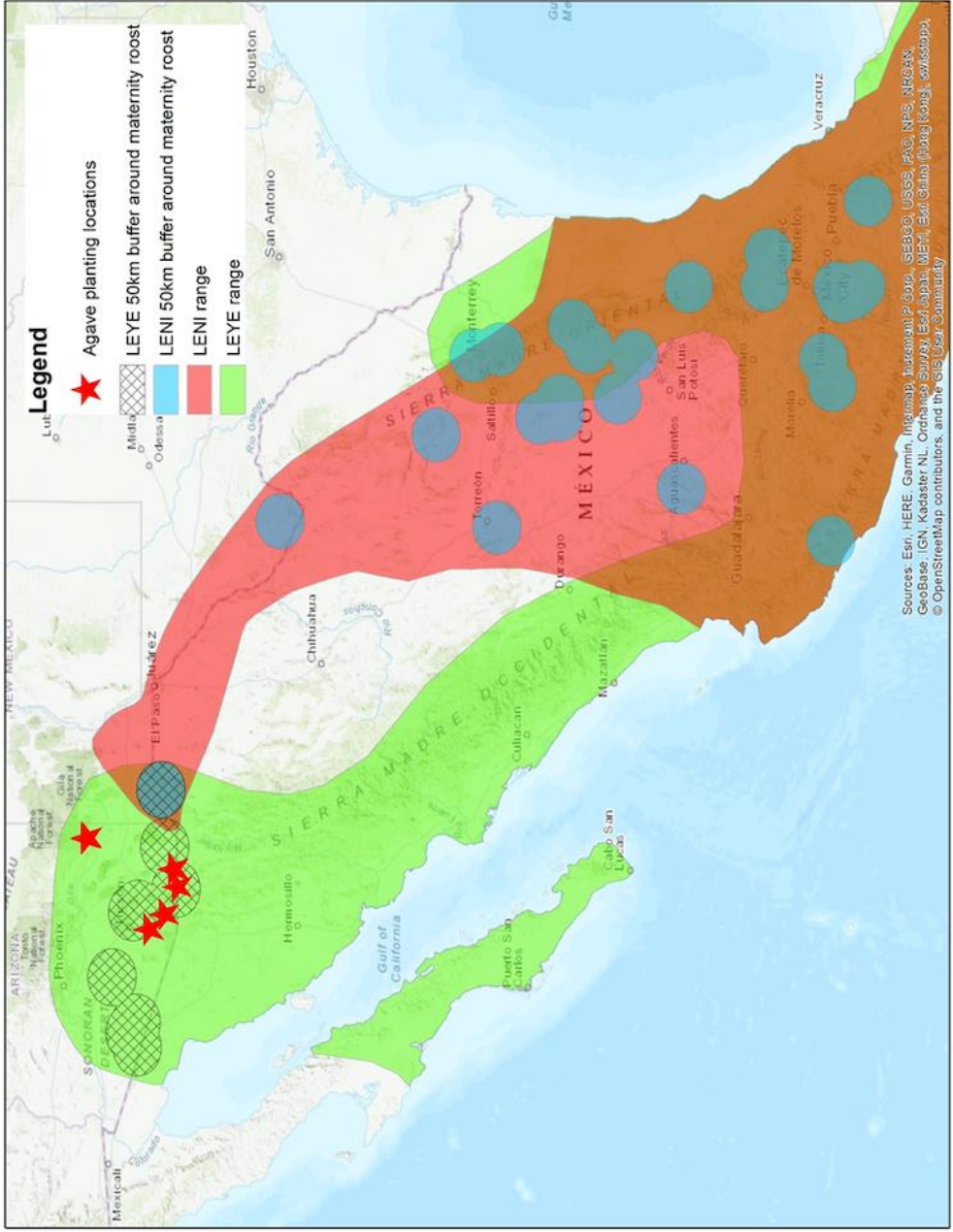
Nectar-feeding bats rely heavily on flowering wild agaves for sustenance in the US-Mexico borderlands. There are only three species of these bats that migrate to northern Mexico and the southwestern US, including the lesser long-nosed bat (*Leptonycteris yerbabuenae*), the greater long-nosed bat (*Leptonycteris nivalis*), and the Mexican long-tongued bat (*Choeronycteris mexicana*). While the greater long-nosed bat has been listed as endangered in the US since 1988, the US Fish & Wildlife Service delisted the lesser long-nosed bat in 2018. Regardless of endangered listing status though, all three nectar-feeding bat species are contending with food and habitat precarity that needs sustained scientific support through research and monitoring, policy support through wild harvesting regulation, and community support - through people such as yourself who want to grow agaves for bats!



A clonal patch of flowering  
*Agave parryi* var. *huachucensis*.  
[p.c. - BRN]



Greater long-nosed bat feeding on the  
nectar of nocturnal agave flowers while  
spreading pollen. [p.c. - David Suro]



**FIG 2: Migratory Route Map of Nectar-Feeding Bats [p.c. - Bat Conservation International]**  
**LEGEND:** LEYE - *Leptonycteris yerbabuena*, lesser long-nosed bat // LENI - *Leptonycteris nivalis*, greater long-nosed bat

## **AGAVE SPIRIT PRODUCTION IN THE US-MEXICO BORDERLANDS: CURRENT URGENCY & HISTORICAL CONTEXT**

Communities all over present-day Mexico have long-standing relationships to agave plants as a source of drink, food & fiber. Long before the introduction of distillation methods, agave plants provided food as the hearts and leaves were roasted for a sweet snack, and drink in the form of pulque, which is derived from the fermented sap. Agaves have also provided the raw material for various fiber needs from textiles and clothing, to building materials, paper, and cordage (Buchanon, 2020). Additionally, agaves hold religious and cultural significance for people from the southwestern United States all the way to southern Mexico (Dreiss and Brown, 2014). Many of the traditional uses of agave continue today, but none has created as large a splash globally as distilled agave spirits have.

The skyrocketing global demand (particularly from the US, Europe & China) for tequila, mezcal and agave distillates more generally has put unprecedented pressure on the industry to increase output. This change in scale - the volume of mezcal exported from Mexico quadrupled between 2014 and 2019 (Mendoza, 2020) - presents an economic opportunity for historically low-wage producers, but also a threat to wild agave populations as more and more are harvested to supplement crops cultivated for distillation. Additionally, trans-national spirits companies often take advantage of these kinds of industry booms and, as seen with tequila, exploit producers by tying them into contracts with fixed yearly production quotas and limited authorship over the final product as well (Tetreault et al., 2021). This undermines the relationship between plants and the producers who have tended to them, often for multiple generations, allowing the market to dictate the product rather than the availability of raw material, which depends on shifting environmental conditions. Often this results in ecological degradation as well as the exploitation of a cultural practice - in which producers see very little of the increased profits.



## SONORA-ARIZONA BORDERLANDS: "TODO EL BACANORA ES DE SONORA"

The term bacanora has referred to the regional mezcal of Sonora since agave distillation techniques spread into the area in the 17<sup>th</sup> and 18<sup>th</sup> century. In 2006, a Denomination of Origin (DO) was adopted for the protection and regulation of the spirit's production - with support for agricultural cultivation of agaves, and permits issued for wild harvest. Historically though, bacanora production has not been so favorably looked upon: in 1912, the government of Sonora outlawed the production of bacanora and for 80 years it was bootlegged throughout the state until its decriminalization in 1992 (Gutierrez-Coronado, 2007). Even during its prohibition, a time when production was much smaller-scale than it is today, there was concern that the poaching of wild agaves was depleting agave populations. Today, the threats to these populations are greater than ever as the spirit gains popularity in the region (on both the US and Mexican sides of the border) before sustainable agricultural production can keep up (Gutierrez-Coronado, 2007; Burwell, 1995; Trejo-Salazar, 2016).

The sole agave species officially recognized by the DO for bacanora production is *Agave angustifolia*, sometimes referred to as *Agave pacifica* (González Elizondo, 2021); accordingly, producers are increasingly cultivating it in agricultural settings, reducing the strain on wild populations. *Agave palmeri* however - the most common wild agave in Northern Sonora/Southern Arizona - has not been so fortunate: there are no economic incentives to cultivate it (as the species falls outside of the DO regulation) yet it is still harvested along with other agave species for a bootlegged distillate, often referred to as *lechugilla*. Incidentally *Agave palmeri*, a slow growing and cold tolerant species that can survive both the low temperatures and dry periods of the Arizona-Sonora borderlands, is an incredible pollinator plant when flowering as its flowers produce 713  $\mu$ l of nectar in a single night on average (higher than any other species in northern Mexico) (Trejo-Salazar, 2016).



Mural in Bacanora, Sonora of a bacanora producer removing an agave's leaves before roasting the heart. [p.c. - BRN]

## TEXAS/NEW MEXICO, NUEVO LEÓN, COAHUILA, AND TAMAULIPAS

Every year in the fall, the greater long-nosed bat (*Leptonycteris nivalis*) migrates through southwestern New Mexico and Texas, then southward through northeast Mexico along the Sierra Madre Oriental. Due to the lack of columnar cacti and other suitable nectar sources for this endangered bat species along its migratory route, the Mexican states of Coahuila, Nuevo León, and Tamaulipas have been identified by bat biologists as regions in critical need of agave restoration. Only Tamaulipas lies within the Denomination of Origin for mezcal and tequila, but this large area boasts numerous regional agave distillates as well - which, in all likelihood, will be codified as DOs in coming years.

At best, the dynamic cycle of growth and regulation of the agave spirit industry presents an extraordinary opportunity to both restore wild agave populations and protect the genetic diversity of cultivated populations by allowing a proportion of plants to flower and produce seed. Such strides will secure the nectar landscape for the same pollinators whose presence ensures the resilience and longevity of the raw material producers depend upon. At worst, should growth outpace sustainable wild harvesting and production, healthy agave populations will shrink, further stressing migrating pollinators and, in the long run, threatening producers' livelihoods. As lucky consumers of the varied, delicious spirits distilled from agaves, we all have a role to play in this tension: it begins with educating ourselves about the cultural history of this extraordinary plant and then advocating for the environmentally and socially sustainable growth of the industry, no matter how far removed we are from the farmed fields and wild hillsides dotted with magnificent agave blooms.



*Agave palmeri* at sunset in the Madrean Archipelago ecoregion of southeastern Arizona. [D.C. - BRN]

## THE IMPORTANCE OF LOCAL SEED

When it comes to effective ecological restoration, it is most useful to grow plants from seeds sourced as locally as possible to the intended restoration site. For instance, a rancher seeking to plant agaves on their ranch in northeastern Sonora would prioritize sowing seed collected from many individual plants on their own hillsides and then from their nearest public lands (with proper permitting of course) over seed sourced from central Arizona, several hundred miles away. The reason for this is that using the most locally-adapted seed (i.e. seed from individual plants with very similar rainfall, elevation and ecosystem conditions) will maximize the transmission of the favorable genetics that those existing plants rely on to survive in that particular environment.

### **PUPS VS. SEEDS: WHAT'S THE DIFFERENCE?**

In addition to sexual reproduction (wherein the agave's flowers are pollinated by a bat, say) most agaves also can reproduce asexually by means of clonal offshoots called pups. Pups are small plantlets attached to the mother plant by an underground root stock called a rhizome. They are genetically identical to the mother plant and can replace it when it dies after flowering. The primary propagation method used in agricultural agave cultivation is to transplant clonal pups to quickly expand plant stock and thus yield. This is much faster than growing agaves from seeds, but also leaves crops vulnerable to massive failure if a disease or weather event affects all of the clonally produced plants with equal severity due to their identical genetic vulnerabilities. The inherent adaptive genetic variability in agaves grown from seeds makes the entire population or crop more resilient, versus a crop that has been cultivated only from pups. A combination of production from pup and from seed can be insurance for the security of the crops and livelihood of the producers.

However, there is currently an overall lack in availability of locally collected seed in the Arizona/Sonora borderlands even with widespread evidence for its importance for successful restoration (Leimu and Fischer 2008; Alberto et al. 2013). Consequently, seed from distant or unknown provenances is often introduced during restoration which, unfortunately, brings with it an array of unintended, potentially negative effects that reduce population fitness (Lesica and Allendorf 1999; Hufford and Mazer 2003; McKay et al. 2005). Furthermore, there is also growing recognition that climate change resilience in both wild and cultivated settings depends heavily on the genetic diversity that using locally adapted seed provides. In other words, using locally sourced seed ensures the plant will be able to establish and thrive in that given environment and also have the genetic resources to adapt to changing climatic conditions (Davis and Shaw 2001; Jump and Peñuelas 2005). Ethically conducted wild seed collection and seed banking (i.e. seed storage programs, large and small) is at the heart of restoring the regions we call home - and you can help make that happen! In fact, we discuss methods, permitting and best practices for agave seed collection later in this booklet (p.19).



*Agave parryi* var. *huachucensis* patch covered in snow in southeastern Arizona. [p.c. - BRN]

## THE POLLINATOR HEDGEROW MODEL

In any agricultural agave production setting, producers should leave a percentage of agaves to flower in order to provide food for pollinators and increase genetic diversity. In a pollinator hedgerow model, producers can plant agaves that provide nectar for pollinators as a living fence, a natural barrier to cattle and a windbreak that protects their crop. Pups produced from the agaves in the hedgerow can be harvested for transplanting into production fields, with one pup always remaining to replace the mother plant when it dies. Additionally, allowing some seed-grown agaves to flower and go to seed in a cultivated setting will provide mezcaleros an easily accessible seed source for future plantings.



Example of a "living fence" or hedgerow for keeping cattle out [p.c. - Colectivo Sonora Silvestre]

## SPECIES LISTS

In the tables on pages 20 and 21, we have listed what are, in our estimation, the most important agave species to plant for nectar-feeding bats in the regions found on either side of the Sierra Madre: Arizona/Sonora/Chihuahua, and Texas/New Mexico/Nuevo León/Coahuila/Tamaulipas. We have chosen these species specifically because they:

1. flower nocturnally (when nectar-feeding bats primarily seek food);
2. are *paniculate* (i.e. they have branching flowering stalks conducive to bat pollination);
3. are found within the migratory routes or near maternity roosts of the lesser long-nosed bat (Arizona and northwestern Mexico) or the greater long-nosed bat (Texas and northeastern Mexico).

It is important to note, the following tables do not contain exhaustive lists, and all agave species in these regions are important for the pollinators they support. For a more extensive regional species list that is evolving with input from bat biologists and agave experts alike, visit the resources page on our website: <http://www.borderlandsplants.org/resources>

For a very thorough and systematic account of all Agave species in North America, see *Agaves of Continental North America* by Howard Scott Gentry. (University of Arizona Press, 1982)

# COLLECTING AND STORING SEED

## PREPARING TO COLLECT

- 1. Identify agaves ready for collection:** Keep an eye out - in your neighborhood, on your favorite hiking trails, on your family's land - for agaves beginning to send up their flower stalks. Using the species table below, the knowledge of plant-lovers in your entourage or some good old-fashioned internet research, do your best to determine the species of agave in question.
- 2. Get permission to collect:** It is necessary to receive permission from the landowner whose land you wish to collect on. In the case of federally or state-owned lands, you will likely have to apply annually for a paper permit from the managing agency and carry said permit on-site for reference. Informal written permission or a verbal agreement will likely suffice in the case of private landowners, neighbors, or collectively owned ejido lands.



*Agave parryi* var. *huachucensis* with a fully grown flowering stalk and flowers in full bloom. [p.c. - BRN]

SPECIES	COMMON NAME(S)	APPROXIMATE ELEVATION RANGE	HABITAT	A Z	S O N	C H I H	FLOWERING SEASON	PRIMARY REPRODUCTIVE STRATEGY
<i>Agave angustifolia</i>	Narrow-leaf Agave, Bacanora	0-4950' (0-1500m)	Sonoran thornscrub, tropical-deciduous forest	x	x	x	Early winter (all year)	Seeds, Pups
<i>Agave colorata</i>	Mescal Ceniza	0-2000' (0-610m)	Sonoran desert scrub, foothills and coast, Sonoran thornscrub		x		December-March	Seeds
<i>Agave palmeri</i>	Palmer's agave, palmer's century plant, lechuguilla	3000'-6000' (930-1850m)	Sonoran/Chihuahuan desert grasslands into Madrean oak woodlands	x	x	x	June-August	Seeds
<i>Agave parryi</i> var. <i>huachuensis</i>	Huachuca agave, artichoke agave, agave de huachuca, mezcál, magüey	5000'-7000' (1550-2150m)	High Sonoran desert grasslands into Madrean oak woodlands	x	x		May-July	Pups
<i>Agave simplex</i> *	amul, lechuguilla, mezcál, desert agave	1000-4000' (405-1524m)	Low Sonoran desert scrub, coastal areas near the top of the Sea of Cortez	x	x		May-July	Seeds, Pups
<i>Agave shrevei</i>	lechuguilla	3000'-6000' (930-1850m)	Sonoran/Chihuahuan desert grasslands into Madrean oak woodlands in the Sierra Madre Occidental		x	x	June-September	Seeds, Pups

**TABLE 1:** Priority Species for Restoration in Arizona and Northwestern Mexico in the Regions Along the Migratory Route for the Lesser Long-Nosed Bat.

\**Agave simplex* is a species formerly known as *Agave deserti* subsp. *simplex*. *Agave deserti* grows in similar conditions but is an important species for California near the US/Mexico border and Baja California.

SPECIES	COMMON NAME(S)	APPROXIMATE ELEVATION RANGE	HABITAT	T X / N M	C H I H	N L	C O A H	T A M P S	FLOWERING SEASON
<i>Agave americana</i>	Maguay de castilla cenizo; Maguay blanco de Castilla; Maguay cenizo; El Manso; Maguay manso; Cenizo forrajero	Variable	Both cultivated and native varieties present in variable habitat types; Disturbed areas in desert scrubland and semi-desert grassland	x		x	x	x	Summer
<i>Agave salmiana</i>	Maguay de castilla verde; Castilla verde	3935-7870' (1200-2400m)	Semi-arid rocky uplands, high desert plains			x	x	x	Spring-Summer
<i>Agave gentryi</i>	Maguay verde; Maguay verde del monte; Maguay verde del campo	8690-11975' (2650-3650m)	Oak woodland and pine-oak forests at higher mountain elevations			x	x	x	Summer
<i>Agave asperima</i>	Charchín; Cenizo del monte; Maguay Rasposo; Rough agave	2460-7875' (750-2400m)	Desert scrubland, Coahuilan desert mountains	x		x	x	x	Spring-Summer
<i>Agave montana</i>	Maguay chino	9840-12140' (3000-3700m)	Oak woodland and pine-oak forests at higher mountain elevations			x	x	x	Spring-Summer
<i>Agave parryi subsp. neomexicana</i>	Maguay Mezcal, New Mexico Century Plant, New Mexico Agave	4920-8200' (1500-2500m)	Semi-desert grassland and shrubland, oak woodland, pine and oak forests	x			x		Summer
<i>Agave havardiana</i>	Maguay Norñoño, Harvard's Agave	4590-6562' (1400-2000m)	Rocky grassland slopes, desert scrubland into oak woodland	x			x		Summer-early Fall

**TABLE 2:** Priority Species for Restoration in Texas/New Mexico and Northeastern Mexico in the Regions Along the Migratory Route for the Greater Long-Nosed Bat

3. **Get your timing right:** When planning to collect seed from any plant, it is important to consider the life cycle of the plant. For agaves, you must observe when the plant sends up its flowering stalk; how long it flowers for; when the fruits develop and begin to set seed; and when the plant naturally disperses its seed. When you understand these cycles, you can plan to collect the seed when it is fully developed and viable, but before it rots or is eaten by insects. Also, keep in mind that it is easiest to collect the seeds on a day that isn't too windy!

As an example, mature *Agave palmeri* plants in southern Arizona and northern Sonora begin to grow their flowering stalks in the early summer months through the summer rainy season. The plants flower at the end of the rainy season, then finish flowering and begin setting seed as the season dries out and begins to cool off. The seeds are ready for collection between the time the fruits begin to change from green to



Watch the flowering phenology of the plant you wish to collect seed from! Here is the growth of an agave flowering stalk in stages. [p.c. - BRN]

brown, and the time they have completely lost their green color, appear very dry, and the pods have opened at the tops and along the seams (October-December). If you are uncertain if the seeds are mature and ready to be collected, you can always remove one cluster of fruits, cut them open with a knife and check. The seeds should appear fairly dry and completely black.

4. **Get a few simple tools:** For effectively collecting agave seeds, a few simple tools suffice. You'll need a long stick with a hook or paint roller tool mounted on the end (without the brush!), a tarp and some buckets. Grab some garden snips for trimming away excess plant material & line up some friends who want to help!



Some useful tools for collecting seed from agaves: 5 gallon bucket, paper bags, pen/marker for recording location information, gloves, garden snips, and a paint roller for attaching to an extended pole. [p.c. - BRN]

5. **Collect respectfully/responsibly:** Never collect more than 50% of seed that is available on one plant, and no more than 20% of the seed available in the population (the total number of plants in an immediate area), so as to not significantly interrupt the population's sexual reproduction.



Agave seeds being removed from their seed pods [p.c. - Bat Conservation International]

## HOW TO COLLECT AGAVE SEEDS

First, wrap the tarp around the base of the flowering stalk and extend it as far out from the plant as possible, covering the leaves. Then use the hooked stick to hit the flower stalk, knocking seeds out of the pods and onto the tarp. Funnel the seeds from the tarp into the buckets. You can also use the paint roller tool to hook onto one of the branches and pull it down to remove it from the central stalk. If using this method, be sure to leave at least 50% of the branches on the plant. You can trim the branches down to just the seed pods for easier transportation from the site. The pods will be broken open later and the seeds removed.



Agave seed collection in action! [p.c.- BRN]

Be careful to never transport the seeds from the place of collection in a closed plastic bag for long periods of time, as this can trap the moisture of the organic material before the seeds have been cleaned and dried, which can lead to rot. Never forget the seeds in your car, which can act as an oven and bake the seeds on a hot day, and is also an easy place to forget about the seeds!

## HOW TO STORE SEED & RECORD PROVENANCE

If you are not going to sow the seeds immediately after collection, it is very important to separate the seeds from the other plant material (seed husks/heads, bits of flower branches etc.) and store them in a cool, dark, and dry place. In addition to the black seeds, there will also be what appears to be under-developed, papery white seeds. These are not viable seed, but will not hurt the collection, and it is ok if these are not completely removed.



Example of an airtight tupperware container for keeping seed collections stored in paper in the refrigerator without letting too much moisture in. [p.c.- BRN]

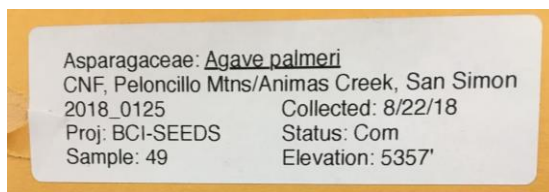
After laying the seeds out to dry for a couple of days, it is absolutely imperative that you remove any remaining insects and organic material that can decompose and rot. Store the completely dried seeds in a paper or plastic bag. It is ideal to keep the bag in an air-tight tupperware container to protect the seeds from changes in humidity and from insects or rodents. Store the collection in the refrigerator, freezer, or in a cool, dark pantry or cabinet.

Collection Information	
Family	Asparagaceae
Scientific Name	<i>Agave palmeri</i>
Common Name	Palmer's century plant
Collection Locality	Peloncillo Mountains
Country	USA
State	NM
County	Hidalgo
Collection Type	Wild
Commercial Status	Commercial
Accession Number	2018_0125
Alternate Collection #	
Sent to:	<input type="checkbox"/> SWSP <input type="checkbox"/> SOS <input type="checkbox"/> SWEPM <input type="checkbox"/> USFS
SOS Collection ID	
Associated Project	BCI-SEEDS

Habitat Information	
Biotic Community	Semidesert Grassland/Shrubland,
Mountain Range	Chiricahua Mountains
Watershed	Animas?
Collector	AM, PM, D. Taylor, A. Arnold, A. Navarette,
Date Collected	11/28/2018
Landowner	USFS
Specimen Collected	<input type="checkbox"/> Yes <input type="checkbox"/> No
Specimen Dated	
Photo Checklist	<input type="checkbox"/> Habitat <input type="checkbox"/> Plant <input type="checkbox"/> Seed Pod
Directions to Location	On Geronimo Trail Road on south facing slopes
UTM Zone #	
UTM E	3486805
UTM N	12R 685454
Lat (Decimal Degrees)	
Lon (Decimal Degrees)	
Elevation	5357'
Datum	NAD1983
Est Seed Count	10000-
Cuttings	
Live Plants	
Population Size	500
# Plants Sampled	48
# Acquired	
Population Density	Scattered
Cutting Type	
Phenology	
Dominant Species	JUNDEP
Six Associated Species	JUNDEP, QUEARI, NOLMIC, ERALEH, BOUHIR, BOTBAR
Habitat & Modifying Factors	Grazed Semidesert grassland/shrubland on south facing, rocky, dry slopes. Sunny, open, windy
Soil Color	
Soil Texture	Sandy gravel
Soil Moisture	Dry
Rock Type	Granite
Area Sampled (Acres)	10
Light Exposure	Sun
Slope °	0-40+
Aspect Direction	S, SW
Location Hazards	Slippery slopes/loose rocks
Notes	

Sample collection data form with provenance information. [p.c.- BRN]



Example of a label on a seed collection container. Note that the number corresponds to a data record with more provenance information (the full record is pictured above). [p.c.- BRN]



Examples of various seed storage containers including food-grade heat sealed plastic, glass jar, paper bag, and manila envelopes. [p.c.- BRN]

At the very least, some basic information should be written down, even just on the paper bags that the seeds are collected in, such as the date, the name of the species collected, and where the collection was done. From there, depending on the scale of your project, it can be useful to record more detailed provenance information. Large seed banks often record the biotic community type where the collection was done (e.g. is it low Sonoran desert scrub, semi-desert grassland, or Madrean oak woodland?); associated species; GPS coordinates; elevation; nearest mountain range; local watershed (this can be the closest small creek or arroyo, or nearest river); aspect direction; and sun exposure. A simple form can be made and printed out for recording data in the field, or this information can be kept in a digital table. For organizational purposes, if doing data entry once the seed is dry, each seed collection can be given an accession number on its packaging that corresponds to the provenance data record, so that the recorded information doesn't get separated from the seeds.

## GREENHOUSE CONSTRUCTION

Agaves can be grown with low-tech infrastructure, on a very limited budget. Some options that work well include shaded areas on tables, in protected beds in the ground, or in a simple greenhouse. Whichever option is used, the basic requirements are as follows: irrigation, ample drainage, protection from predation, and protection from excessive sun exposure and hard freezes.

Propagating agaves in a greenhouse is ideal because it protects seedlings from predation, cools them in the summer, and warms them in the winter for the quickest growth to a plantable size. Greenhouses also don't have to be high tech or expensive to achieve success, because native agave species are adapted to the local climate already. A simple greenhouse consists of a frame, shade cloth, plastic film covering for winter months, and irrigation. If budgets allow, you can include other components such as an overhead irrigation system set on a timer, ground covering for rodent control and prevention of weed proliferation (using weed cloth, stone, or both), tables/benches, heat mats, fans/breeze frames etc.

Elevated surfaces - called benches in the nursery trade - are useful for keeping plants off the ground and away from rodents, and can be as simple as placing pallets on top of concrete blocks in long rows. A consideration with this method also involves reducing areas that may provide rodent nesting habitat. Another great method to protect agaves from predation is to build wood-frame tables with aluminum flashing along the legs to keep rodents from climbing, with heavy duty expanded sheet metal on top for proper drainage. Keeping agaves out of stagnant water is also important for preventing disease, pathogens and rot.



Greenhouse with permanent shade cloth and a soft plastic layer that is added or removed seasonally. First photo shows plastic on, second is with plastic off. [p.c.- BRN]

Since most agave species grow in warmer climates, building a greenhouse using a removable film covering makes the most sense for cooling them through the summer. It's very expensive to cool a structure during the hot season using fans, and more cost-effective and better for the plants to receive rainwater throughout the summer anyway. This is why we recommend using a seasonal plastic film covering that can be affixed over the structure in the fall to protect the plants from freezing temperatures, and then removed in the spring when temperatures warm again. With this method, the shade cloth over the structure is permanent and allows rainwater to permeate through during the summer, and the plastic film is seasonal on the structure and goes over the shade cloth for the winter. For the shade cloth we recommend using 25-50% shade, and for the top covering one should use heavy duty poly film, 6 mil or higher, and wiggle wire (sometimes called spring or zig-zag wire) secured in U-channels for easy installation and removal.

When planning greenhouse construction it's helpful to know how many plants you can fit into a given structure. To calculate growing space for agaves, walkways between benches should be factored and eliminated. For example, if you have a structure that is 48' long by 26' wide, you could have four 4' wide benches running the length of your greenhouse, one on each side and two down the middle, and two 5' wide aisles between middle and side benches. This would leave you with 16' of bench width by 48' long, equaling a total of

768 sq ft total of growing space in this size greenhouse. At the Borderlands Restoration Network nursery, we like to up-pot our agave seedlings to 4"x10" pots. Using this example, we could therefore fit about 10 pots wide by 140 pots long, equaling 1,400 total per bench. So with four benches, this example would provide space for 5,600 mature agaves.



Greenhouse construction in action!  
[p.c.- BRN]

Sourcing materials in a small town can be difficult, which is why we recommend sourcing things online, and as locally as possible. Sometimes you can find supplies from a city just a few hours away and save several hundred dollars on shipping. Ordering all of your materials together helps to reduce shipping costs as well.

Important factors for greenhouse construction:

1. Benches or pallets to keep plants off the ground and away from standing water and rodents
2. Adequate air flow from doors, fans and/or breeze frames on both ends of the structure
3. Heating mats if germinating during winter
4. Rodent-proofing the structure
5. Weed or ground cloth

Here's a rough budget when planning to build your greenhouse -- of course, the smaller the structure, the cheaper it will be!

**TABLE 3:** Sample Greenhouse Construction Budget

<b>ITEM</b>	<b>COST</b>
Structure (48x26ft)	\$3,000
Plastic	\$1,000
Weed cloth	\$500
Irrigation	\$350
Shade cloth	\$1,000
End pieces (framing, doors, breeze frames)	\$1,500
Labor	\$3,000
Heat mats	\$250
Pallets, hanging trays, extra costs	\$1000
<b>TOTAL</b>	<b>\$12,500</b>

## HOW TO GROW AGAVES FROM SEED

Growing agaves from seed is very straight-forward and low-tech. To germinate any seed (cause it to sprout leaves), there are three requirements: warmth, water, and light. Most agave species do not have any seed dormancy, meaning that if the quality of the seed is good (i.e. the seeds are fully developed, have been stored well, and are not damaged by rot or insect predation), they are suitable for immediate sowing, and should germinate readily within 30 days. Agave seeds should be sown into containers that have a depth of at least 4" and have holes on the bottom for water to drain out. Some container options include conventional plastic plant pots, tray pots with multiple small cells, or an easily constructed wooden tray/box with newspaper lining the bottom. The container of choice should then be filled with soil. Agaves can also be sown directly into the ground or in raised beds, so long as the beds can have a little bit of shade and are protected from rodents and other predators with fencing.



Sowing agave seeds in plug-trays that have small separated cells and holes in the bottom for drainage. [p.c.- BRN]



An example of a wooden box lined with newspaper that can be used to sow agave seeds. [p.c.- BRN]

Agaves can be grown in a variety of soil types, but they need ample drainage and some nutrients, so a soil mix that contains up to 50% sand or perlite and cinder sand in addition to some composted organic material is a good choice. Too much drainage, on the other hand, can cause the plants to dry out too much

and can wash away important soil nutrients. Before sowing, the soil mix should be wet down until it is moist throughout, but not over-saturated, and then used to fill the container. Agave seeds should be sown at a depth that is twice the diameter of the seed, and spaced about 3” apart to avoid overcrowding. A good way to do this is to use your finger or a pen to make a depression in the soil of the appropriate depth; drop 1 to 2 seeds in the hole; sprinkle the hole with soil and lightly tamp it down. If direct sowing into beds or wooden trays, the seeds can be spread across the surface then lightly covered with a layer of soil media, enough to cover the seeds even after watering may wash some of the soil away. With any of these sowing protocols, using an organic fertilizer is optional, but by no means necessary for successful germination.



An example of agaves being grown directly in beds in the ground with amended soil, weed cloth between rows, drip irrigation, and a fenced perimeter to protect from animal predation. Image is of the Vivero Amigos del Maguey y la Biodiversidad facility, a project of Rezpíral. [p.c.- Rezpíral]

Once the seeds are sown and covered with soil, the container or bed should be watered thoroughly. The pots should not be in direct sunlight or else the seedlings may burn. If shade cloth is hard to come by, place the containers in a place where the sunlight is not direct all day long, or where the sunlight is dappled or filtered by overstory tree branches.

The seed pots should be watered daily until the seedlings germinate. When Agaves germinate, a little green tentacle emerges called the cotyledon, with the empty seed held on its tip. Later, “true” leaves will emerge and the plant will begin to look familiar as a tiny version of itself. Once the true leaves emerge, watering can be reduced to every other day, but supplemented when the soil seems excessively dry or temperatures spike. After about 6 months, or

when the seedlings have 3 true leaves and are beginning to crowd each other in the container, the plants can be transplanted individually to larger pots. At this point, it may be helpful to mix an organic fertilizer into the soil media for added vigor but, again, it is not required. To avoid transplant shock, it is always a good idea to give the plants a little extra water in the first month after transplanting them. After that, water them as needed - likely every other day, depending on the season (less in winter/fall, more in spring/summer) - but take care not to overwater! The best indicator for fine-tuning your watering schedule is to stick your fingers in the soil around the base of your plants - if it feels even a little bit damp, you can wait until the following day to water.



Germinating agave seedlings! [p.c.- BRN]

## **CARING FOR YOUNG AGAVES BEFORE OUTPLANTING**

As we discuss in the ‘Diseases, Pests & Predation’ section of this booklet (p.42), agaves are susceptible to certain common diseases and pests whether in the wild or in a nursery setting. These biotic or ‘living’ threats are generally exacerbated when the plant is otherwise weakened by abiotic (or ‘non-living’) factors - such as frost damage, sunburn, poor soil drainage and overwatering. However, with proper attention to growing conditions as they mature in your nursery, your agaves will thrive.

## FROST DAMAGE

When temperatures drop below 32°F for several hours, young agaves will likely show signs of frost damage: the affected leaves will blacken and, after a few weeks, will turn crispy and dry. Many agave species are very sensitive to frost and will easily become damaged or die. Some higher elevation species like *A. palmeri* and *parryi* are able to withstand frosts and, unless the young plants experience a hard freeze (i.e. several hours below 28°F), they'll recover with time. Note that the leaves of agave seedlings often turn pink following frost damage or cold. It is not necessary to cut back the frost-damaged leaves. This is purely cosmetic and they will return to their green color with time.

Frost damage can be easily prevented. When planning your nursery location, consider opportunities for maximizing early sunlight and hilltop/hillside locations out of cold air drainages. If not growing in a greenhouse, another surefire way of protecting from frost is to cover your plants at night. Cloth covering (such as sheets, blankets or towels) is preferred for this purpose but, if using plastic covering, ensure the plastic is not directly touching the agave or else the freezing temperature will transfer to the leaf at the point of contact.

The information above is included to help protect *young* agaves in a nursery setting - agave species are adapted to their local climates and, once mature, will be able to withstand the routine freezes that come with their landscape.

## SUNBURN

Young agaves are especially prone to sun damage and often grow in partial shade provided by a “nurse” plant in the wild (a sumac, an oak, a mesquite). As described in the greenhouse construction section (p.28) some sort of shade structure over the agaves during the long, hot days of summer will help protect them. If your agave's leaves start turning yellow in your nursery, it's probably from too much sun exposure!

## SOIL DRAINAGE & SOIL TYPE

In the nursery, soils with poor drainage (more than 25% clay for instance) will predispose the plants to attack by soil-borne, root-rotting pathogens that may result in the death of the plant. Inversely, soils with too much drainage or with materials that dry out and become hydrophobic should be avoided because they will drain very rapidly and retain little water and nutrients. As mentioned earlier, the ideal soil mix is one that has good drainage and aeration as well as nutrients. For example a good mix could be 25% perlite, 25% cinder sand, 25% compost, and 25% coconut coir. If you don't have access to some of these nursery grade soil supplies, that's ok! In that case we suggest combining 50% well-draining material with larger particles for aeration (e.g. sand with lightweight gravel) and 50% composted materials for nutrients. Fertilizers can be useful for stimulating plant growth but are by no means necessary if the plant is getting enough nutrients from the soil media. If fertilizing, do not use fresh/uncomposted manure as their high salt content will inhibit root growth.



LEFT: Young agave plants in a plug tray after 6+ months of growth. CENTER: Young agave plants with bare roots before being transplanted into larger pots. RIGHT: Maturing agaves in 3 gallon pots, ready for outplanting. [p.c.- BRN]

## OUTPLANTING

Agaves grown from seed are ready to be outplanted when they have 6-8 leaves, usually when they are about one year old. For one month before outplanting, it is good practice to acclimate your agaves to the direct sunlight and water regimen they will experience in the open landscape. This can be achieved by moving plants to a fenced outdoor area with a similar amount of sun exposure to where they will ultimately be planted, and watering only once or twice a week. It is best to plant agaves during the summer rainy season so they can get ample water and be established before the first frost. However, agaves are very hardy and can handle limited watering. The most important part about outplanting agaves into a wild setting, is protecting them from predation, especially from javelininas.



LEFT: Bare-rooted *Agave angustifolia* ready to be outplanted into the field. [p.c. - Colectivo Sonora Silvestre.] RIGHT: Planting agaves is fun! [p.c.- BRN]

Agaves do best on rocky slopes and sometimes in the partial shade provided by the edge of a tree's canopy, such as mesquite. It is helpful to pick a planting site based on where you observe agaves growing naturally in the landscape, noting soil type, topography, associated species, and aspect direction (is the plant on a south facing slope? This is helpful for orienting the plants in relationship to sunlight).

After you pick an appropriate planting site, dig a hole deep enough for the plant's shallow roots to be fully extended downward, avoiding disturbing other established plants. Place the agave in its new home and backfill around the base of the agave with the soil so that the roots are completely covered and the plant is supported to stand up straight. Next, use some medium sized rocks that are loose on the surface of the ground nearby to mulch around the base enough so that it will be difficult for javelinas to move the rocks aside and dig up the plant to eat it from its sugar filled base. Rock mulch also helps maintain soil moisture during very dry periods to minimize transplant shock as the agave adjusts to its new home. You can also use a few pieces of overlapping wire fencing or mesh and some metal ground staples to affix them to the ground around the base of the agave, then put the rocks on top. Another method to prevent predation is to affix a piece of shade cloth or burlap over the plant with some ground staples to create a protective tent. This method works well to deter javelinas and to protect the young plant from sunburn, plus burlap disintegrates over time, so does not need to be removed. Any materials other than rocks and burlap will need to be removed after a year or two, once the agave is established. Water the plant thoroughly after planting, and return once a month to water for the first 6 months if there has been no rainfall.



TOP: Outplanted *Agave palmeri* with rock mulch. MIDDLE: Close-up of protective fence pieces affixed around the base of an outplanted agave with ground staples. BOTTOM: Outplanted *Agave palmeri* with protective fencing pieces stapled into the ground around the base and covered with rock mulch.

[p.c.- BRN]



Densely planted hedgerows of *Agave angustifolia* [p.c.- BRN]

If planting a pollinator hedgerow with agaves in an agricultural setting for mezcal or bacanora production, the agaves can be outplanted when they are a little bit younger, since they will have additional care, such as continued irrigation, which they wouldn't have in a wild landscape. Pups can be harvested from a pollinator hedgerow for transplanting into the cultivated area for production, but at least one pup should be left with each mother plant so that it can replace the mother plant after it flowers and dies.

## MONITORING PROTOCOLS

In monitoring the planting site, it's important to note how successful the planting was so that restoration of agaves can improve over time and there's a record of what works and what doesn't. Monitoring should happen as often as time/budget permits, but ideally in the time span of every few months to a year. Below is an example of the kinds of information to gather. Notes should include watering schedule if any, and type of predation, or fatality.

**TABLE 4:** Agave Restoration Monitoring Form

SITE NAME/#:		ORIGINAL PLANTING DATE:
SPECIES:	# PLANTED:	CAGING OR ROCK MULCH?:
Monitoring Date	# Alive	Predation or fatality notes
Year 1:		
Year 2:		
Year 3:		

Monitoring can also happen through casual, qualitative observation of survivorship after a planting. Anecdotal evidence from monitoring should inform how you adapt the planting and management protocols to improve the success of future plantings. Bat Conservation International takes monitoring of their agave restoration sites to the next level by recording other important observations such as, reason for death (i.e. no evidence of plant left, cold stress, drought stress, predation, etc.), level of health, etc.

The National Phenology Network also has done important monitoring of wild agave populations for the purpose of understanding shifts in phenology, population health and threats. Check them out!

## HOW TO SALVAGE AGAVES

Salvaging agaves that would otherwise be destroyed during construction projects, development, or mowing is a wonderful way to conserve these plants and to keep genetic diversity in a population. Agaves are easily salvaged because of their hardy nature, and basal sugar storage allows them to be transported without soil and remain bare rooted for up to 3 months before being out-planted. When salvaging Agaves, you must have a digging shovel with a long handle and sturdy gloves to protect your hands. It is also useful to have the following items: pick mattock, hand pick, tarp. When salvaging agaves from the wild, always wear long pants, and closed toe shoes to avoid being stabbed by the leaves. The goal is to remove the agave with some of the roots intact and not too damaged, rather than popping off the above-ground part from its anchor. Having at least one root on each plant will make survival and re-establishing in a new site much more successful.

Use the digging shovel to wedge under the base of the agave at a sharp angle in order to maintain some of the roots attached to the plant. You can loosen compacted soil or remove large rocks with the pick mattock or hand pick. Use a levering motion with the shovel to loosen the plant and pull it out. This can be repeated on another side of the plant after the soil has been loosened if it doesn't come out easily. Minimize soil disturbance to avoid colonization by opportunistic invasive species, and avoid digging out too much soil or any near-by plants that may not be killed in the activities that the agaves are being salvaged from. Bare-rooted agaves can be thrown in the back of a pickup truck for transportation, or gathered on the tarp and dragged. If you are not planning on planting the agaves soon after salvaging them, it is best to store them in an area with partial shade to protect them from sunburn. Although nursery-grown agaves can be transplanted directly into the ground from their pots, either with the potting soil or with bare roots, salvaged agaves should be left bare rooted to callous in the shade for a few weeks before outplanting. This will help the plant heal any tissue damage caused by the shovels during salvage so that soil-borne pathogens don't get into open wounds.

## DISEASES, PESTS, & PREDATION

Familiarity with the telltale signs of the common agave diseases and pests in the following table is paramount for the sustained health of your nursery stock & wild or outplanted populations, as well as the selection of plants that are suitable for salvage. You don't want to bring diseased/infected plants into your nursery! Even a low-level infection of a plant in the wild can flourish when brought into the more protected and moist environment of the nursery. In general, the severity of infection related to any of the following blights will be lesser in drier climates and at drier times of year.



Leaf rot caused by agave snout weevil larvae, and the larvae themselves. [p.c.- BRN]

In summary, ensure you are growing agave species suited to the local conditions of your chosen outplanting site (preferably from seed sourced from the site, or a comparable one). This will reduce the risk of serious disease and infestation. Before reusing any plastic pots or placing healthy agaves on surfaces where infected agaves were, be sure to sterilize all surfaces and vessels

by using a bleach and water solution. Additionally, always make sure that plants are kept out of areas where water can collect and pool in order to prevent water-borne diseases from infecting plants. If you notice any pests in the early stages of an infestation, it is possible to try to treat your plants with an organic pesticide or to manually remove and kill pests. However, if you notice a disease or infestation worsening, despite your efforts to maintain pest-free growing conditions, remove the afflicted plant(s) from the population in a garbage bag and dispose of it somewhere it cannot infect other plants, or even burn it.

**Table 5: Agave Diseases, Pests, & Predation**

DISEASE/PEST	SIGNS AND SYMPTOMS	PREVENTION AT EARLY STAGES	TREATMENT AT LATE STAGES
AGAVE SNOOT WEEVIL ( <i>Scyphophorus acupunctatus</i> )	<i>Leaf rot near center of plant, often leads to crown rot (this can be ascertained by tugging on the center leaves), presence of grubs or weevils themselves</i>	<i>*See "Traps for the Agave Snout Weevil" below</i>	<i>Remove diseased plant(s) from greenhouses</i>
MITES	<i>Small insects hopping around between leaves near hear of plant; Pock marks on leaves</i>	<i>Spray infected areas with an organic insecticide, a soap and water spray, neem oil, or lime</i>	<i>Remove diseased plant(s) from greenhouses</i>
CROWN/ROOT ROT	<i>Rot at heart of plant around center leaves (this can be ascertained by tugging on the center leaves)</i>	<i>Decrease irrigation frequency, change soil to a better draining mix</i>	<i>Remove diseased plant(s) from greenhouses</i>
ANTHRACNOSE (Fungal infection of <i>Colletotrichum</i> )	<i>Lesions on leaves and at heart of plant, orange spore masses within lesions, infections likely to occur during cool, wet periods</i>	<i>Eliminate overhead irrigation, decrease irrigation frequency, change soil to a better draining mix, remove plants from standing water</i>	<i>Remove diseased plant(s) from greenhouses</i>
PLANT BUGS ( <i>Caulotops barberi</i> )	<i>Bugs visible on leaves and heart of plant in late summer and early fall, causing a yellow-tan discoloration</i>	<i>Spray infected areas with an organic insecticide, a soap and water spray, neem oil, or lime in the early morning or late evening</i>	<i>Remove diseased plant(s) from greenhouses</i>
SOFT SCALE ( <i>Coccid spp.</i> )	<i>Presence of flattened, plate-shaped scales, 1/8" in size, on leaves. Stressed plants are especially susceptible.</i>	<i>Maintain stress-free plants by keeping healthy growing conditions.</i>	<i>Manually remove scales, spray plants with organic insecticide, lessen plant stress by improving growing conditions, and remove diseased plant(s) from greenhouses if damage is irreparable</i>
MAMMAL PREDATION (javelina, cattle, pack rats, deer)	<i>Broken/bit off flowering stalks, chewed leaves, rodent nests, dug up plants</i>	<i>Fencing around plant/population, fencing with ground staples around base, rock mulch</i>	<i>No treatment if plants are completely eaten, but fencing can always be added later to prevent further damage</i>

[For a more thorough treatment of these diseases & pests, please refer to *Problems and Pests of Agave, Aloe, Cactus and Yucca* (University of Arizona Cooperative Extension, 2008)]



TOP LEFT: Agave with developing flower stalk chewed off, likely by cattle. [p.c.- BRN]  
TOP MIDDLE: Agave parryi var. huachucensis showing signs of crown rot. [p.c.- BRN]  
TOP RIGHT: Agave mite on a leaf, and agave leaves showing pock marks. [p.c. - BRN]  
CENTER: Agave snout weevil up close. [p.c. - FOBADES]  
BOTTOM ROW: Agave palmeri with crown rot caused by agave snout weevil infestation. [p.c. - BRN]

## TRAPS FOR THE AGAVE SNOT WEEVIL

Our colleagues at FOBADES (Fondo del Bacanora para el Desarrollo Sostenible) have developed a baited trap for containing agave snout weevil infestation in agave fields, the design and instructions for which are as follows:

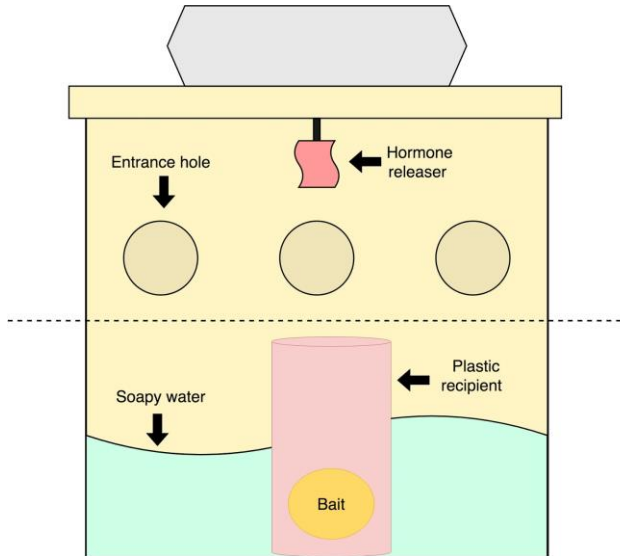


FIG 3: Diagram of an Agave Snout Weevil Trap [p.c. - FOBADES]



The trap before it is placed, and a finished trap, with lid weighted down with a rock.

[p.c. - FOBADES]

1. Traps are placed among diseased or established plants at a rate of one for every five acres of agave field.
2. Traps are dug into the ground at a depth of approximately 6 inches with the entry holes just above ground level.
3. The trap contains a specific pheromone (2-methyl-4-octanone + 2-methyl-4-octanol) that attracts the weevil. The pheromone must be replaced every month during the months of August to November; the rest of the year it may be changed every two months.
4. The trap contains soapy water - thus avoiding the use of insecticides that may affect other organisms that are not the target. The soapy water is changed out every 15 days and, during very hot months, may be changed every 7 days due to evaporation.
5. A bait consisting of approximately 300 grams of agave heart (or, if unavailable, agave leaf or flower stalk) is placed inside a plastic container with holes that allows its release without coming into contact with the soapy water. The bait must be changed every 15 days.

## CONCLUSION

In order to address threats to the habitat of bats and other pollinators, as well as to ensure the sustainability of agave spirit production, agave populations in the US-Mexico borderlands - wild & cultivated - need tending. Whether you're doing this work with your friends and neighbors, your fellow ranchers and mezcaleros, your regional non-profits and government agencies, we hope this booklet has helped you understand the importance of using locally sourced agave seed for your propagation efforts and given you the tools to collect, grow and nurture agaves of your own! If nothing else, remember this: when you use local agave seed you're helping agaves maintain the genetic diversity they need to be resilient in the face of climate change and crop failure, and when you let your agaves flower, you're patching the gaps in the nectar landscape for all of the pollinators traveling through the region you call home. We're thankful for your commitment to this important work and would venture to guess the bats and all of their pollinator companions appreciate it too...

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We look forward to your questions & feedback.

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