Final progress report November 2016, Ernesto Sandoval, UC Davis Botanical Conservatory

Title: Aloe Cultivation Evaluation, Testing of Propagation Techniques, Education and Distribution of This Extremely Low Water Adapted Group for Drought Stricken California.

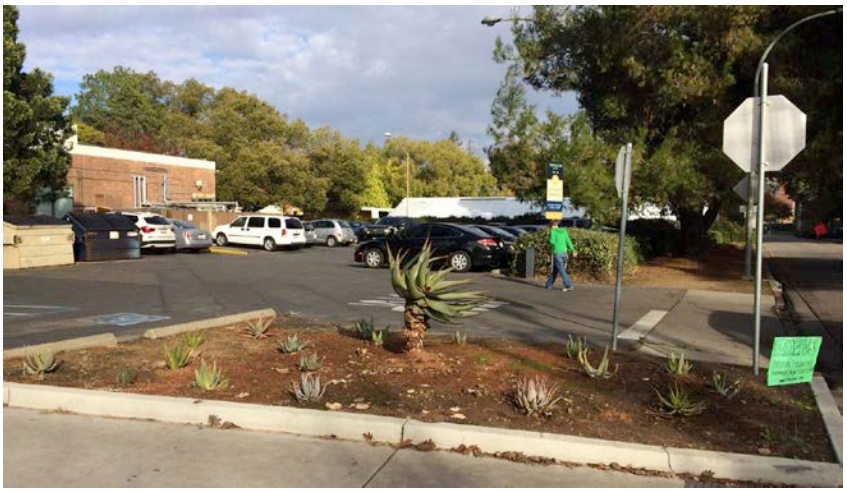
Introduction:
The availability of reliable information on the cultivation of succulents in California and even more so in the central and northern portions of the state is sorely needed. Also, the promotion of succulents as part of the recipe of low water use landscape plants has never been as imperative for the California landscape as our recent drought has proven. Californians are increasingly embracing these plants as low water alternatives.

Aloes, due to their varied growth forms and minimal prickles, compared to those of cacti, agaves and other sizeable succulents, makes them more appealing to a broader audience of gardeners for their landscape potential. Furthermore, Aloes have broader appeal because they flower reliably yearly, feed hummingbirds, and unlike agaves (similar growth form) their leaves are more variable in shape and color and their rosettes do not die upon flowering.

The goal of this project has been to increase the availability of information and plant material itself for increasing the cultivation of at least 45 taxa of Aloes, including some hybrids, in Northern California. A small group of succulent aficionados are cultivating many of these plants on a limited basis throughout the state and Sandoval met with those growers to glean information on the success and challenges of growing these plants in Northern California.

Our goal has been to expand their use as landscape plants by gathering qualitative and quantitative information on their culture as well as propagation techniques and disseminate that information as well as increase the availability of these plant by growing them out for availability. The larger goal of this project is to encourage more water conserving plantings throughout the state and Northern California in particular.

Propagation and Distribution:
The general goals of this project progressed well on several fronts. Over 100 accessions of Aloes were added to the Botanical Conservatory in association with this grant. With the help of several undergraduate students, at least 62 distinct Taxa (See Table 1 below) have been propagated, 40 of those are species and the remainder as known or new and unique hybrids. Over 4,300 propagules have been generated, primarily as seedlings and a few hundred as cuttings, as a direct result of this project and more than half of these have already been distributed! Several thousand more are still growing on their way to being made available through a variety of venues this coming year. Several hundred plants were donated to The Ruth Bancroft Garden and Cal Poly San Luis Obispo as well as towards several plantings on the UC Davis campus at Bainer Hall and along Kleiber Hall Drive.



Aloe plantings, Fall 2016, of new Accessions at Kleiber Hall Drive on the UC Davis campus

In late spring and Summer 2015 seeds of open pollinated Aloes (humming birds and bees) were collected for germination trials and development of seed propagation techniques. Desirable plants for which at least the seed parent was known were further grown out for distribution at plant sales. (See list below). Seed of species Aloes were acquired through several sources but primarily from Silverhill Seeds in South Africa. From Spring to fall 2016, student employee Kevin Horng ran further germination trials and pollinated multiple species of Aloes. Multiple hybrid crosses were also made. See Appendix I for the results of germination trials.

Table 1: Aloes propagated from seed or cuttings 2015-2016

Genus	Specific epithet	Variety/ Cultivar	Common Name	LabelNote
Aloe				(striata x maculata) x ?? (open pollinated)
Aloe				africana x ?? (open pollinated)
Aloe				buhrii x ?? (open pollinated)
Aloe				humilis x ?? (open pollinated)
Aloe				lavranosii x rivae
Aloe				littoralis x ?? (open pollinated)
Aloe			HYBRID STEMLESS ALOE	maculata x striata
Aloe				marlothii x vryheidensis
Aloe				microstigma x ?? (open pollinated)
Aloe				peglerae x ferox white
Aloe				species or hybrid
Aloe				striata x ?? (open pollinated)
Aloe				suprafoliata x arborescens
Aloe				vaotsanda x ?? (open pollinated)
Aloe				x spinosissima) x ?? (open pollinated)
Aloe		'David Verity'		
Aloe		'Kryptonite'		
Aloe		'Tangerine'		form of A. x principis?

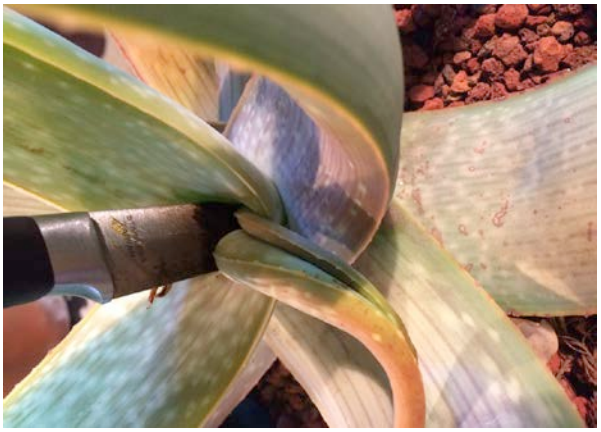
Aloe		hybrid	MADAGASCAR HYBRID ALOE	KG 14
Aloe		x spinosissima		= Aloe arborescens x humilis
Aloe	aculeata		PRICKLY ALOE, NGOPANIE	
Aloe	africana		UITENHAGE ALOE	
Aloe	arborescens		CANDELABRA ALOE	yellow-flowered form
Aloe	arborescens	'Variegata'	VARIEGATED CANDELABRA ALOE	
Aloe	boylei			
Aloe	broomii		MOUNTAIN ALOE	
Aloe	burgersfortensis			
Aloe	camperi			green clone
Aloe	comosa		CLANWILLIAM ALOE	
Aloe	esculenta			
Aloe	ferox		BITTER ALOE	
Aloe	ferox	white flower form	BITTER ALOE, BITTERAALWYN	F-3 white selfed
Aloe	fosteri			
Aloe	glauca		BLUE ALOE	
Aloe	greatheadii	var. davyana		
Aloe	greatheadii	var. graethedii		
Aloe	hereroensis		SANDAALWYN (SAND ALOE)	
Aloe	humilis		SPIDER OR HEDGEHOG ALOE	
Aloe	humilis		SPIDER ALOE, HEDGEHOG ALOE	blue clone
Aloe	krapohliana		KRAPOHL'S ALOE	
Aloe	kraussii			
Aloe	lavranosii			
Aloe	littoralis		COASTAL ALOE	
Aloe	longistyla			
Aloe	marlothii		MOUNTAIN ALOE	
Aloe	melanacantha		BLACK-SPINED ALOE	
Aloe	microstigma		SMALL-SPOTTED ALOE	
Aloe	mitriformis		MITRE ALOE	
Aloe	mitriformis	subsp. distans	GOLD TOOTH ALOE	= A. distans
Aloe	peglerae		RED-HOT POKER, BERGAALWYN	
Aloe	polyphylla		SPIRAL ALOE	
Aloe	pratensis		ROCKY MEADOW ALOE	
Aloe	pretoriensis			
Aloe	reitzii			
Aloe	striata		CORAL ALOE	
Aloe	striata	subsp. karasbergensis		
Aloe	suprafoliata		MUSTACHE PLANT	
Aloe	variegata		PARTRIDGE BREAST ALOE	
Aloe	vogtsii		VOGTS'S ALOE	
Aloe	vryheidensis			
Aloe	zebrina		ZEBRA LEAF ALOE	= A. transvaalensis

Some seeds of these successful pollinations are being distributed to the California Horticultural Society and to the Cactus and Succulent Society of America (fall 2016) to disseminate as part of their annual seed exchange offerings in spring of 2017. Other portions of these seed are being grown out to continue to offer unique and hardy Aloes to California and western state gardeners through various outlets and where climatic conditions are appropriate. Sandoval will continue explore other avenues to donate specimens for trials and general planting at public and non profit institutions.

Propagation techniques:
Where appropriate and plants branch readily, stem cuttings were prepared throughout the year. Standard protocol is to take cuttings, remove lower leaves to expose ½-1" of stem, air dry cuttings upright (for 1-2 months (longer when cool) to allow stem bases to heal and encourage auxins to accumulate at bottom, then plant cuttings in a very coarse material such as ¼" pumice or 3/8" red lava to encourage root growth. Once cuttings are rooted they are then transferred to a succulent mix or planted in the garden.

Preliminary attempts were made using tissue culture (TC) techniques on several taxa of Aloes as a way of vegetatively propagating very desirable clones with limited amount of meristematic tissue. TC Aloe expert Tim Harvey from Southern California was consulted for protocols and media suggestions. TC proved cumbersome and resulted in very limited success. It is our recommendation that much time and staffing is needed to be successful using this technique and should be a project unto itself. If we are to explore TC of Aloes in the future then the material would be sent to a lab with Aloe TC experience rather than attempting in house TC.

Limited trials of meristem splitting were performed on Aloe buhrii and Aloe karasbergenis. We are still waiting on the results from Aloe karasbergensis and were successful with Aloe Africana. This technique will be further explored for particularly appealing clones that do not readily branch.



A sterile stainless steel knife is used to split the meristem of this Aloe buhrii into 4 separate branches that will cause the separated portions of the meristem to proliferate. Spring 2016

Cultivation Information:
Further progress has been made on gathering expanded cultivation information but available sources have been limited. Expanded job duties due to a pending retirement of a senior staff

increased Sandoval's responsibilities including weekend coverage of a class production greenhouse during the first 6 months of this granting cycle limiting his ability to travel. Since March of 2016, Sandoval has settled into his new responsibilities. Sandoval traveled to Southern California in early June and lectured on hardy Aloes for a couple of succulent clubs as well as scheduled meetings with several Aloe growers including Aloe propagator Tim Harvey an several other Aloe experts. The 3 month extension granted by the committee was well appreciated to more thoroughly gather cultivation information as described in the grant. In January 2016 Sandoval attended an informal Aloe summit at the Ruth Bancroft Garden in Walnut Creek where contact was made with several of these Aloe experts.

Sandoval joined Aloe experts and enthusiasts from throughout California to tour Aloe plantings at The Ruth Bancroft Garden in Walnut Creek, California. January 2016.

Through conversations with a number of these Aloe growers in Northern California, it has become obvious to Sandoval that information on the hardiness of Aloes is fairly limited beyond the mild winter climate regions of Southern California and the greater Bay area. Sandoval's discussions yielded limited quantitative data on the hardiness of Aloes in colder regions of California, Sunset Zone 14 and USDA Zone 9b or colder, and is even more limited than Sandoval had expected. Their widespread cultivation in Northern California, beyond institutional plantings and cultivation of Aloe saponaria is a relatively recent trend. With the exception of Brian Kemble at the Ruth Bancroft Garden in Walnut Creek and the UC Davis Botanical Conservatory private growers in this region have limited years of gathered data on Aloe hardiness. Gathering more of this qualitative data from them on drainage, disease and exposure is helping to expand available information. Sandoval visited with multiple growers of Aloes throughout Northern California and inland areas of Southern California during May and June and October of 2016. He gathered qualitative and quantitative data on the cultivation of most of the Aloes in the list **below** as well as acquiring new accessions and information on species and hybrids worthy of the designation of "hardy Aloe". These are taxa tested by those growers for at least 4 years including cold/wet winters. The available information is being added to the Conservatory publication Botanical Notes: the Genus Aloe available at http://greenhouse.ucdavis.edu/files/botnot_01-01.00.pdf The list of hardy Aloes is being expanded to at least 45 from the current of 19 in consultation with Brian Kemble of the Bancroft Garden, several local growers in the Sacramento Region, and a few others in Southern California with Aloe hardiness experience. Duke Benadom from southern California has provided

an expanded list of Medicinal and poisonous Aloes. These significant updates will be concluded by December 2016 and be advertised through Sandoval's upcoming lectures and publications.

Sandoval has already lectured on hardy Aloes to the California Horticultural Society, Sacramento Master Gardeners and a Southern California Succulent & Cactus Club. The talk has been well received and the propagation techniques for better seed germination have encouraged growers and home gardeners to try propagating Aloes using more successful techniques of limited organic matter in the seedling mix. The discussion of using environmental techniques to reduce fungal activity rather than fungicides has been an eye opener to some propagators!

Amended List of Aloes for which horticultural information is being made available as a result of this project:

*aculeata**
africana
brevifolia
buhrii
burgerfortensis
camperi
capitata
ciliaris
comosa
dichotoma
distans
erinacea
excelsa
ferox
framesii
gariepensis
glauca
hereroensis
humilis
karasbergensis
khamiensis
krapohliana
littoralis
*lavranosii**
longistyla
marlothii
melanacantha
microstigma
mitriformis
ortholopa
peglerae
polyphylla
ramosissima
reitzii
reynoldsii
rubroviolacea
saponaria
sinkatana
speciosa
striata
striatula
succotrina
suprafoliata
tomentosa
transvaalensis
variegata
zebrina

*added to list at the suggestion of Aloe expert Brian Kemble.

Seed germinated in sealable bags in 1/8 sifted red lava/scoria seen in stages of transition to open air. Seeds were germinated under indirect light in a greenhouse at 75F daytime temps.

Aloe seedlings of various species just after removal from plastic bags. Early spring 2016

Aloes seedlings approaching size to transplant. Spring 2016

A variety of Aloe species and hybrids sizeable enough to distribute at the UC Davis Arboretum's Spring Plant Sales and Sandoval's horticultural lectures. Spring 2016.

Student employee Kevin Horng is shown pollinating several Aloes including Aloe buhrii. Netting is seen in back left to exclude pollinators. Spring 2016

Appendix I: Aloe Germination Results

To determine the best method for the germination of Aloe seedlings, we conducted a series of germination tests using nursery bought and self-collected Aloe seedlings. Independent variables for consideration include bags to increase humidity, 1/8" red lava media, sifted succulent mix soil media (60% 5/16" red lava, 16.6% uniform coarse Lapis Lustre sand, 16.6% peat moss, 16.6% redwood compost), uniform coarse Lapis Lustre sand, and combinations of these variables. Dependent variables include germination amount, germination rate, and fungi growth. Constants include the fact that all seeds were watered with fertilizer water, pots were individually randomized in flats and placed in the same general area in the greenhouse, germination count occurred when at least the cotyledons were visible, variable comparisons were done at an equal ratio between same Aloe species, and pots with more than 30 individuals were counted based on estimation. There is also variation in Aloe species and the times in which the project overseer, Kevin Horng, was able to come in count germinations, germination dates, etc. Following are 5 treatment comparisons to reveal the best method for Aloe germination:

- In terms of the bagging variable, the experiment revealed that bagged pots ultimately germinated more seedlings at approximately 468 seedlings compared to unbagged pots at 421 seedlings. Bagged pots sometimes germinated sooner than their unbagged counterparts, but the numbers do not seem to be significant. Bagged pots also had a much greater possibility for fungi growth; not a single pot grown without a bag had any presence of fungi.

- The next comparison, indicated in the excel file with a light blue ribbon, was done between purely sifted soil, purely red lava, and a mix of the two with about 75% soil on the bottom and 25% red lava on top. The purely sifted soil treatments germinated the least seedlings at approximately 309 individuals. Pure red lava germinated approximately 436 individuals and the mix 423. Based purely on numbers, pure red lava was the most productive germination medium, though the difference is not very significant.

- The next treatment, indicated on the excel with a red-orange ribbon, was between pure red lava and red lava with a thin layer of sand on top. The idea was that this layer of sand mulch would help lock in moisture. The pure red lava treatment germinated approximately 239 individuals and the mixture 230. The difference is likely insignificant, though the benefit of sand mulch is that it prevents the growth of fungi; every treatment that had the presence of sand mulch showed no indication of fungi growth.

- The fourth comparison, indicated on the excel by a lavender ribbon, was between the red lava and sand mulch combination and a combination of approximately 5% sand mulch on top, 25% red lava in the middle, and 70% sifted soil on the bottom. In terms of germination, there was virtually no difference as the sand and red lava combination germinated approximately 238 individuals while the triple combination germinated 236. The benefit of sifted soil on the bottom may just be cheaper cost and the ease of transplanting later when the Aloes have sent their roots down into the media as this makes it easier to separate the tangled roots.

- The final test, indicated by a light pink ribbon, was between a combination of sifted soil and red lava at the aforementioned ratio and a combination of red lava, sifted soil, and sand also at the aforementioned ratio. Respectively, these treatments yielded approximately 68 and 100 germinated individuals, a significant difference. However, it is likely an aberration occurred in one of the sifted soil and red lava pots, and because there were only two cross-comparisons in this test, there is not a very large pool to conclude a significant difference.

An additional precaution of washing the seeds in soapy water and rinsing and microwaving the red lava and sand prior to planting was also undertaken to avoid the growth of fungi. The cleaned treatments did seem to have less of an occurrence of fungi but also at a minute difference and not worth the trouble of cleaning. Cleaning added approximately 15 minutes of extra work and consumed more resources. A more feasible method of avoiding fungi is to use sand mulch.

Possible experimental errors include non-uniform watering, non-uniform supply of sunlight, variable temperature conditions and human error including miscounting, non-uniform observation intervals, contamination, and the possibility of sand mulch hiding germinations.

We concluded that to generate the highest rate of germination, avoid having to treat for fungal activity, and allow for ease of later transplantation, Aloe seeds should be germinated in a pot inside of a clean bag with, by volume, layers of approximately 5% uniform coarse #12 mesh Lapis Lustre sand mulch on top of the seed deposited on approx. 25% 1/8" sifted red lava in the middle, and 70% sifted succulent mix soil in the bottom. A close alternative is to omit the sifted soil and use purely red lava instead.

Relative proportion of sand, 1/8" red lava, and succulent mix

BAG VS NO BAG

330	285
61	52
5	7
72	77
= 468	421

Bags increase number of germinations. Germination date doesn't really seem affected, perhaps bags speed up germination a tiny bit

SIFTED SOIL VS. SIFTED SOIL, LAVA VS. RED LAVA (blue)

140	240	235
18	13	20
80	88	84
71	82	97
= 309	423	436

Not much of difference between sifted soil and lava. Based on pure numbers, having only lava is best for germination.

RED LAVA VS. RED LAVA, SAND MULCH (red-orange)

6	4
24	21
23	20
13	3
21	19
5	6
11	12
18	21
25	24
22	30
25	27
46	43
= 239	230

not much of a difference.

RED LAVA, SAND MULCH VS. RED LAVA, SOIL, SAND MULCH (lavendar)

28	33
27	25
100	100
4	1
4	3
35	37
40	37
= 238	236

not much of a difference

SOIL, RED LAVA VS. SOIL, RED LAVA, SAND MULCH (light pink)

50	50
18	50
68	100

Soil, red lava, sand mulch seems to be better but there was only two tests on this, may not be indicative of actual results

FUNGI (surface):
No fungi at all when there was no bag

Within bags:
No visible fungi grew when there was sand mulch

Washed seeds, washed/microwaved sand and red lava helped stop some fungi from growing but not really worth the trouble.