The Plant Press

THE ARIZONA NATIVE PLANT SOCIETY

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The Arizona Native Plant Society

In this Issue

A collage of Arizona's Most Unwanted. From top right, invasions of tamarisk (*photo courtesy Diane Drobka*), stinknet, buffelgrass, and fountain grass (*photos courtesy John Scheuring*).

Invasive Plants

This year's Arizona Botany Symposium celebrated our amazing native plant life and the precious habitats that plants provide for the critters and creatures of Arizona. But our native plants are under increasing pressure from invasive plant species that are quickly spreading along our roadways, seeping into our urban areas, and working their way into our "untouched" riparian waterways, bajadas, and mountainsides. This issue of *The Plant Press* is dedicated entirely to the understanding of the invasiveness of plant species. The authors take us beyond the simplistic distinction between weeds vs. natives or exotics vs. natives. You will learn that even native plants can be weedy or toxic but never invasive. You will be introduced to the concept of noxious weeds and our regulated Arizona Noxious Weed List. You will read the stories of two Arizona noxious weed introductions and their paths to destructive invasiveness. Finally, you will learn about some key exotic plants and their invasiveness in Sonora, our neighbor to the south. We hope these articles expand your understanding of invasive plants and that they will inform your decision-making regarding them in your own neighborhoods and throughout Arizona. Grow native!

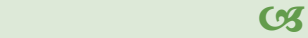
President's Note *by Douglas Ripley* jdougripley@gmail.com

I extend to all members of the Arizona Native Plant Society best wishes for the holiday season and the New Year, along with a fervent hope that 2021 proves to be a far better one than 2020. As the COVID-19 pandemic drastically curtailed so many activities that we all previously took for granted, extreme heat and drought conditions continued in many regions of Arizona and the West resulting in unprecedented wildfires, and billions of people throughout the world suffered drastically from the far-reaching negative economic impacts of the pandemic. Providing a fitting coda to such a lousy year was the recent sad loss of two longtime and enormously active AZNPS members, Richard Felger and Frank Rose, both of whom are memorialized in this issue. Despite all these travails, there has been some not-insignificant comfort afforded to people such as us, thanks to our interest, love, and appreciation for our beautiful natural world.

While the AZNPS had to cancel all its in-person activities starting in March, I'm very pleased to report that our Society has managed to replace many of those activities with remote events. Those have included monthly chapter meetings and even our annual Botany Symposium which was held over three evenings in October and was a great success. With a theme of "Celebrating Arizona's Native Flora," the symposium featured individual speakers describing with beautiful illustrations the special floristic features of many of the unique natural areas of the state. Over three hundred participants attended the symposium, including two individuals each from Australia and Canada! Historically our in-person conferences would attract about 125 participants. So, until the restrictions imposed by the pandemic ease, we will continue to provide and improve remote events wherever possible. We have resumed the publication of our quarterly newsletter *Happenings* after suspending the summer issue due to the cancellation of most of our meetings and events. It, along with Mailchimp notices sent out periodically, our expanded and updated website, and individual chapter Facebook pages, are great sources of information on the activities one can now attend remotely.

This issue of *The Plant Press* focuses on invasive species, their very serious impact on our native flora, and strategies for their control and hopeful eventual eradication. John Scheuring, Chairman of the State AZNPS Conservation Committee, has for many years been the driving force behind AZNPS' efforts to address invasive species issues, as well as land and habitat restoration projects generally. John conceived the idea of this issue and was instrumental in developing its format and recruiting the individual paper authors. We hope you will find this issue very informative and a useful reference or guide for future personal participation in restoration and invasive species control projects.

I extend my sincere thanks to all AZNPS members for their support and enthusiastic participation in our programs this past year. Let's hope that the New Year marks a return to normal times!



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Weeds: Invasives *vs.* Noxious *vs.* Weedy Natives

by John H. Brock[1]

Introduction

The introduction of exotic plant species to the floras of the lands within the United States has been going on for more than 200 years. Many of these introductions were intentional and others were unintentional. Many of these exotic plant species turned out to become weeds in native plant ecosystems, in agronomic lands, and in urbanized areas. Terminology of these weedy plants includes the use of both *exotic* and/or *alien* to describe species. In Arizona, Tellman (2002) listed about 240 exotic naturalized plant species in the Sonoran Desert region. Most of these species were not spreading beyond localized areas. Many of these introduced plants adhere to the "Rule of 10" concerning plant introductions (Jeschke and Pysek 2018). Basically this "rule" states that one out of 10 imported species appear in the wild, and of those, one out of 10 becomes established in the environment. While this plant invasion "rule" is helpful, Jeschke and Pysek (2018) state that it has limitations. However, I find it helpful in understanding the degree of success in plant invasions. Plant invasions occur in four stages: (1) Introduction, (2) Establishment, (3) Spread, and (4) Invasive plant transformation of ecosystems, like downy brome (*Bromus tectorum*) in the Great Basin of the western United States.

Before humans began migrating from their origin(s), they probably dealt with plants they considered undesirable. When humans migrated from those sources, they may well have brought with them propagules of plants they deemed desirable and planted them in their new locations. Chambers and Hawkins (2020) stated "A weed is an unwanted plant, and people have lived with and combated unwanted plants since the dawn of agriculture and perhaps even earlier." With the advent of sedentary agriculture, some plant species clearly became problems in land where desirable plants were being cultivated, including some of those brought by human migrants. With the colonization of North America, European peoples brought with them plant species that were exotic to the local floras and some of those became invasive. Early examples of these plants are found as seed and plant parts in adobe used in building by Spanish colonizers in Mexico and southern California. Other Europeans brought crops and plant materials (as in bedding and forages) to the eastern parts of North America. Some of the plants were intentional introductions and others were "hitchhikers" or "stowaways" within the desirable seeds, and some became weeds to the new land managers.

Definitions

> Weed: *A plant out of place* (Popular usage). *A plant that interferes with management objectives for a given land area at a given point in time* (Torell 2002). *An alien species whose introduction does or is likely to cause economic or environmental harm and harm to human health* (Executive Order 13112. 1999).

Executive Order 13112 was signed by President Bill Clinton in 1999. Among other things, Order 13112 established the Federal Interagency Committee for the Management of Noxious and Exotic Weeds (FICMNEW). Pre-dating the 1999 Executive Order dealing with exotic plants was Executive Order 11987 signed by President Jimmy Carter on May 24, 1977. It requires Federal agencies, to the extent permitted by law, to restrict the introduction of exotic species into the natural ecosystems on lands and waters owned or leased by the United States, states, local governments, and private citizens. These executive orders helped focus land managers to recognize the role of harmful plant introductions.

> Noxious: *A noxious weed is a plant considered to be harmful to the environment or animals, especially if it is one which may be the subject of regulations governing attempts to control it.*

In the United States, noxious weeds are listed per the Federal Noxious Weeds Act of 1970 and they are also defined and listed by state governments. The Arizona noxious weed list was recently updated and is maintained by the Arizona Department of Agriculture. The website for Arizona noxious weeds is found at: **https://agriculture.az.gov/pestspest-control/agriculture-pests/noxious-weeds**. Noxious weeds on federal and state lists are placed there for regulatory reasons. In most cases, weeds of this category, like field bindweed (*Convolvulus arvensis*), are often associated with agronomic lands and are to be removed from the landscape. Unwanted plants and weeds not on the list may be recommended for control by persons doing habitat management. Good examples of these are those that could contribute fuel for wildfires, such as red bromegrass (*Bromus rubens*) and a

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Weeds: Invasives vs. Noxious vs. Weedy Natives *continued*

somewhat recent invader, stinknet (*Oncosiphon piluliferum*). Both of these species contributed to wildfires in June 2020 in the northern part of Phoenix.

Invasion of Exotic Species

Paraphrasing from Brock (2013), biological invasion is considered to be one of the symptoms of global environmental change. Invasive species can displace native species when introduced to habitats where they did not evolve as a part of the functioning plant community. Their success is often linked to the lack of natural enemies from their original ecosystem(s) — not present in the new locations — to keep them in check. There is mounting evidence that increased CO_2 and nitrogen in the atmosphere, warming temperatures, and nitrogen as a water pollutant enable some of the alien invasive species. The ecological traits of invasive plants that make them competitive are largely physiological and reproductive rather than morphological. For example, some invasive species, such as annual brome grasses, capture nitrogen from the soil nutrient pool earlier in the season than do native plants, giving them a competitive advantage. In some cases, aggressive invasive species literally transform the invaded habitat, changing its ecological structure and function. These plants are called **transformer** species since they alter the plant community by changing productivity, forage composition for wildlife species, and watershed and soil erosion processes. In warm deserts, red brome grass and buffelgrass (*Cenchrus ciliaris*) provide fine fire fuel, where such fuel is rare in the native flora. After a fire in invaded sites, these exotic grasses play a role in transforming the Sonoran Desert from a community dominated by shrubs and cacti to one largely devoid of those growth forms.

Lag times

Lag times can hinder or alter the prioritization of managing invasive species because an invasive that was not originally being managed can suddenly become a high priority for management and control within a particular area. It is very hard to identify a potential invasive species as being in its lag period and it is often not until after its population becomes established and spreads that the lag time is detected.

Recalling the Rule of 10, introduced species most commonly do not immediately become invasive. Introduced alien species that become naturalized, i.e., growing without the continued support of humans, may escape almost immediately or may not display their invasive nature for some time. These species display a "**lag time**" during which they are adapting to their new home. Some species become invasive almost immediately, and two invasive riparian trees in southwestern North America fit this scenario. Those species are salt cedar (*Tamarix ramosissima*) and Russian olive (*Elaeagnus angustifolia*). Buffelgrass and stinknet both seem to fit a short lag time condition as well. Lag times for many woody and perennial herbaceous invaders may consist of periods up to 50 years. During this time, the species may be adapting to local conditions or their seeds may lie dormant, especially in plants that produce hard seeds. An example of such an invasive plant with a long lag time is sweet resin bush (*Pentzia incana*), an alien perennial plant native to South Africa. In the mid 1930s, it was introduced to at least three Arizona sites as part of plantings to evaluate non-native plants for erosion control. In the early 1990s, it was observed to be spreading from one of its planting sites near Mount Graham on the Coronado National Forest, which was about 50 years from its

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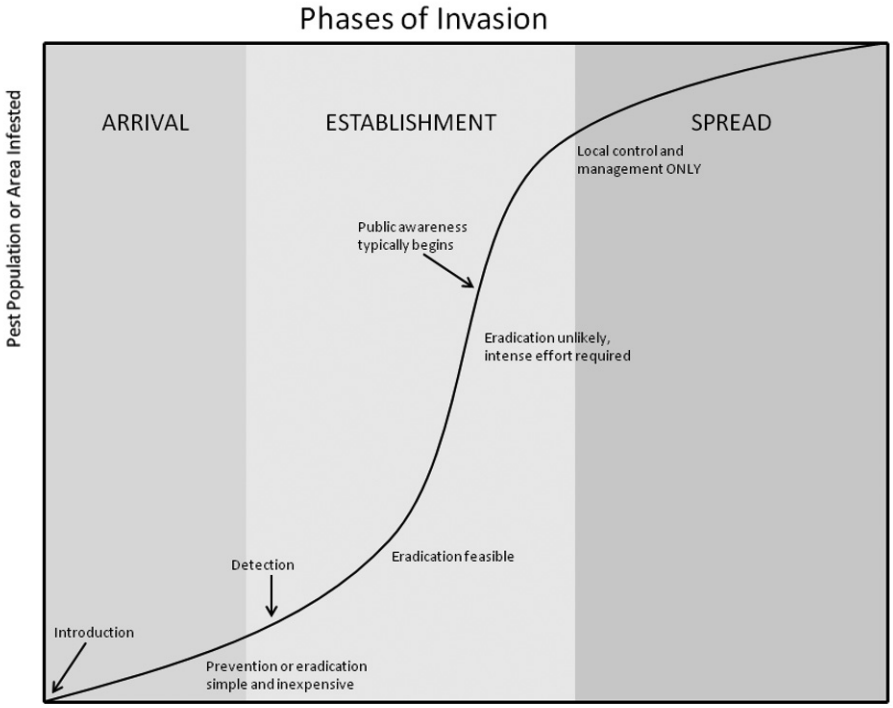

Figure 1. Sigmoidal curve of invasive species (plants) dynamics, as related to spread and effort for management (Alvarez 2016).

Weeds: Invasives vs. Noxious vs. Weedy Natives *continued*

introduction. It was also planted near the town of Miami on the Tonto National Forest and on the Prescott National Forest. Thus, it had a lag time of at least 50 years before its invasive nature was exhibited. Two alien perennial grasses have also displayed a lag time since introduction. These grasses are yellow bluestem (*Bothriochloa ischaemum*) and Lehmann's lovegrass (*Eragrostis lehmannia*)**.** Both species were introduced to the southwestern United States after the 1940s for erosion control and forage. Yellow bluestem (Hickman et al. 2018) and Lehmann lovegrass (Texas Invasives Plant Data Base, 2020) stayed in place after initial planting, and in the case of Lehmann lovegrass, disappeared from many planting sites, except those with calcareous soils. The lag time for these species to become considered invasive was about 40 years. In both cases, these grasses are very competitive to native vegetation and can contribute to a fine fuel load (Figure 1).

Native Weedy Plants

There are several Arizona native plants considered to be weedy to land managers. These species historically were few in number on southwestern landscapes before European colonization. The introduction of domestic livestock, the practice of putting out wildfires, and a major drought, led to native plant expansion on landscapes (Wildeman and Brock 2000). Livestock grazing before 1900 was largely uncontrolled, wildfires were suppressed, and in the late 1880s, southwestern North America experienced a major drought. As a result, many bare areas developed on the landscape and several native plant species took advantage of these areas to colonize the bare soils. Those species included: several junipers (*Juniperus monosperma, J. utahensis* and *J. depenna*), woody legumes such as velvet mesquite (*Prosopis velutina*) and catclaw acacia (*Acacia greggii*), and several species of prickly pear or cholla cactus. In the warmer deserts, plants like creosote bush (*Larrea tridentata*) took advantage of the openings in the community. In addition to the woody species, long-lived perennial herbaceous plants, such as broom snakeweed (*Gutierrezia sarothrae*) and other members of the Asteraceae became more common in the flora. With the advent of rangeland improvement practices over the past 70 years or so, many of these plants have been targeted as "native weeds." However, in Arizona we have never seen weedy native species encroach on or displace other natives outside of disturbed areas.

Conclusion

Hundreds of exotic plant species have already become commonplace in Arizona wildlands, roadsides, and urban areas. Additional new exotic species are constantly being introduced via roadways from adjacent states and Mexico and via the commercial landscape trade. With the extreme weather events brought with climate change, we anticipate an increasing number of introduced exotic species to threaten and displace native flora as noxious weeds. We need to track the occurrence and prevalence of exotic species and identify those species that need to be controlled before they get out of hand. Timely updates of the Arizona Noxious Plant List and the full support of the Arizona Department of Agriculture are vital. Effective control of emergent noxious weed threats will increasingly necessitate the full cooperation between federal, state, municipal and private land managers.

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Note on Scientific Nomenclature for Buffelgrass

The scientific nomenclature for Buffelgrass is a little complicated. Some sources refer to it as *Pennisetum cilare* while others identify it as *Cenchrus cilaris*. Both scientific names are used in this issue.

Figures 1 and 2. Fountain Grass. *Photos courtesy Patti Fenner*

Arizona's Noxious Weed List *by Patti Fenner*[1]

Of the large number of exotic plants growing "feral" in Arizona, only a few have caused significant levels of disturbance. Those species are considered to be "noxious weeds," a term defined by the Weed Science Society of America as any plant designated by federal, state or local government officials as injurious to public health, agriculture, recreation, wildlife or property. (WSSA 2016)

Like all other U.S. states, the state of Arizona has established and periodically updates an official State Noxious Weed List. Until recently that list largely focused on agricultural crop weeds. But with the sudden upsurge in aggressiveness of new weeds with impacts to both urban and wildland landscapes, noxious weeds are taking a front page in the news. In 2020, Arizona's list was in great need of revision, as the last modification to the list was in 2005, with the addition of *Cenchrus ciliaris* (syn. *Pennisetum ciliare*), or buffelgrass. After many delays, the list was finally updated in January 2020 (AAC 2020). In addition to the updating of species, the classification of noxious weeds was redefined to be consistent with noxious weed lists of adjacent states.

Classifications:

Class A Noxious Weed: *A plant species that is not known to exist or is of limited distribution in the state and is a high priority pest for quarantine, control, or mitigation.*

Class B Noxious Weed: *A plant species that is known to occur, but is of limited distribution in the state and may be a high priority pest for quarantine, control or mitigation if a significant threat to a crop, commodity, or habitat is known to exist.*

Class C Noxious Weed: *A plant species that is widespread but may be recommended for active control based on risk assessment.*

Plants of the Arizona noxious weed list:

Cannot be sold or imported into the state

Should be addressed in environmental clearances

Qualify for federal and state funding for control

Can serve as the basis for municipal codes and Home Owners' Association (HOA) do-not-plant lists

The January 2020 revision included:

Addition of 19 species (Table 1)

Removal of 11 species (Table 2)

Notable weeds newly designated for Arizona:

Fountain Grass (*Pennisetum setaceum*) — Native to Africa and the Middle East, Fountain grass (Figures 1 and 2) has been introduced to many parts of the world as an ornamental grass. It is popular in many countries as an ornamental plant and has dispersed into wildlands across Arizona, California, Florida, Hawaii, Fiji, South Africa, and Australia thanks to

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Figure 3. Tree of Heaven. *Photo courtesy Patti Fenner*

Arizona's Noxious Weed List

continued

sales in nurseries. Fountain grass is apomictic, which means it can reproduce either sexually from fertilized seeds or asexually from unfertilized seeds! This perennial grass is a highly aggressive, fire-adapted colonizer that readily out-competes native plants and rapidly reestablishes after burning. Fountain grass raises fuel loads, which increases the intensity and spread of a fire, and results in severe damage to native desert species including all species of cactus.

Tree of Heaven (*Ailanthus altissima*) — A common tree in urban areas where it causes damage to sewer systems and structures, *Ailanthus* (Figure 3) also poses a threat to agriculture and natural ecosystems. It is a vigorous root-sprouter and seed producer that establishes dense stands which push out natives. Tree of heaven contains chemicals that have been found to be strongly allelopathic which enables it to inhibit the growth of surrounding competing plants and thus more easily establish and spread.

Natal Grass (*Melinis repens*) — Natal grass (Figure 4) is moving north from Sonora, Mexico, and is becoming common along highways, riparian areas, and even entire slopes in southern Arizona. In Mexico, this tall grass

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Table 1. Revised Arizona State Weed Rule Noxious Weed List (November 2019) — Species Added to State List in red

Common name	*Scientific name*
Class A Noxious Weeds	
African rue	*Peganum harmala*
Canada thistle	*Cirsium arvense*
Dudaim melon	*Cucumis melo* v. Dudaim Naudin
Dyer's woad	*Isatis tinctoria*
Floating water hyacinth	*Eichhornia crassipes*
Giant salvinia	*Salvinia molesta*
Globe-podded hoary cress	*Cardaria draba*
Hydrilla	*Hydrilla verticillata*
Leafy spurge	*Euphorbia esula*
Plumeless thistle	*Carduus acanthoides*
Purple loosestrife	*Lythrum salicaria*
Purple starthistle	*Centaurea calcitrapa*
Quackgrass	*Elymus repens* (*Elytrigia repens*)
Rush skeletonweed	*Chondrilla juncea*
Southern sandbur	*Cenchrus echinatus*
Spotted knapweed	*Centaurea stoebe* ssp. *micranthos*
Sweet resinbush	*Euryops subcarnosus*
Ward's weed	*Carrichtera annua*
Wild mustard	*Sinapis arvensis*
Class B Noxious Weeds	
Black mustard	*Brassica nigra*
Branched broomrape	*Orobanche ramosa*
Bull thistle	*Cirsium vulgare*
Camelthorn	*Alhagi maurorum* (*A. pseudalhagi*)
Dalmatian toadflax	*Linaria dalmatica* (*L. genistifolia* v. *dalmatica*)
Diffuse knapweed	*Centaurea diffusa*
Field sandbur	*Cenchrus spinifex* (synonym: *C. incertus*)
Giant reed	*Arundo donax*
Halogeton	*Halogeton glomeratus*
Jointed goatgrass	*Aegilops cylindrica*
Malta starthistle	*Centaurea melitensis*
Musk thistle	*Carduus nutans*
Natal grass	*Melinis repens*
Onionweed	*Asphodelus fistulosus*
Russian knapweed	*Acroptilon repens*
Russian olive	*Elaeagnus angustifolia*
Saharan mustard	*Brassica tournefortii*
Scotch thistle	*Onopordum acanthium*
Stinknet/Globe chamomile	*Oncosiphon piluliferum*
Yellow bluestem	*Bothriochloa ischaemum*
Yellow starthistle	*Centaurea solstitialis*
Class C Noxious Weeds	
Buffelgrass	*Pennisetum ciliare*
Field bindweed	*Convolvulus arvensis*
Fountain grass	*Pennisetum setaceum*
Garden or common morning glory	*Ipomoea purpurea*
Grannyvine	*Ipomoea tricolor*
Ivy-leaf morning glory	*Ipomoea hederacea*
Johnsongrass	*Sorghum halepense*
Kochia	*Kochia scoparia*
Morning glory	*Ipomoea triloba*
Morning glory	*Ipomoea* x *leucantha*
Puncturevine	*Tribulus terrestris*
Saltcedar	*Tamarix ramosissima*
Tree of heaven	*Ailanthus altissima*

Figure 4. Natal Grass. *Photo courtesy Sue Carnahan*

Figure 5. Giant Reed. *Photo courtesy Sue Carnahan*

Arizona's Noxious Weed List *continued*

carries recurrent wildfire along highways, changing ecosystem structure and function. By creating a cycle of regular wildfire in the desert, this plant has a competitive advantage over native vegetation.

Giant Reed (*Arundo donax*) — Giant reed (Figure 5) is native to India and was introduced into the United States in the early 1800s for ornamental purposes. Giant reed invades wetlands such as stream banks and lake shores. It competes for water, nutrients and sunlight, suppresses and excludes native vegetation which degrades wildlife habitat, and increases fire risks.

Stinknet (*Oncosiphon piluliferum*) — Stinknet (Figures 6 and 7), a winter annual plant from South Africa, was first noticed in 1981 in California where it has spread from urban areas to extensive coverage of undisturbed slopes in wildlands (Wilen 2018). It began to be noticed in central Arizona around 2005. Since that time it has spread rapidly to vacant lots, yards, roadsides, and public lands throughout central Arizona, and it has now been documented in the Tucson area where it has the capability to spread in the same manner. Its invasive potential is higher than that of any plant this author has ever observed.

Sahara Mustard (*Brassica tournefortii*) — Sahara mustard (Figures 8 and 9) grows very fast, out-competing native herbaceous plants and shrubs for light and soil moisture. In wet years, this weed can form a dense ground cover, and can carry fire when it dries in early spring. Even the Mohave hyper-arid desert, including sand dunes, can burn because of this weed. There have been documented fires in the dunes of the Cabeza Prieta National Wildlife Refuge and in Yuma and Pima Counties, where Sahara mustard was observed growing in stands five feet tall and too dense to walk through.

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Figure 6 and 7. Stinknet. *Photos courtesy Tom Van Devender and Max Licher*

Table 2. Revised Arizona State Weed Rule Noxious Weed List (November 2019) — Species Dropped.

Common	*Scientific name*	Reason for dropping
Alligator weed	*Alternanthera philoxeroides*	A few in L.A. area, mostly SE US east of TX.
Carolina horsenettle	*Solanum carolinense*	Looks like *S. elaeagnifolium*, which is very common. Only one documented *S. carolinense* in AZ, in Phoenix in 1955. Very common throughout eastern US.
Common purslane	*Portulaca oleracea*	Very common in AZ. Possibly a native species.
Dodder	*Cuscuta* spp.	All 16 species in AZ are native
Morning glory	*Ipomoea* spp.	There are many native *Ipomoeas* that are not problem plants, and are, in fact, rare plants that are protected by state regulations. Only those species that are problem plants are now specifically listed on Arizona's noxious weed list.
Perennial sowthistle	*Sonchus arvensis*	Documented only in Four Corners area, but probably much more widespread and common. An agricultural weed.
Puna grass	*Achnatherum brachychaetum* (*Stipa brachychaeta*)	Documented only in CA, W side of state, mostly N of Los Angeles.
Serrated tussock	*Nassella trichotoma*	Documented only in Australia and Argentina.
Tansy ragwort	*Senecio jacobaea*	Nearest documented specimen is in San Jose, CA, near the ocean.
Torpedo grass	*Panicum repens*	Documented only in SE US, NY, HI, Australia, Taiwan, and Guatemala.
Tropical soda apple	*Solanum viarum*	Documented only in LA and SE US E of Louisiana and a few in S. America.
Water chestnut	*Trapa natans*	Documented only in NE US and one site in Austria.
Witchweed	*Striga* spp.	Documented only in one site in San Francisco, and uncommon in FL and NC.

Arizona's Noxious Weed List *continued*

Malta Starthistle (*Centaurea melitensis*) — Malta starthistle (Figure 10) was introduced to the southwestern U.S. from Europe as a seed contaminant. It is similar to yellow starthistle in appearance. Like yellow starthistle, it has been implicated in case reports of chewing disease of horses. Toxicity effects are cumulative and irreversible. In most cases, poisoning occurs where horses had little or no other palatable feed available to them. Dense infestations of Malta starthistle displace native plants and animals, threatening natural ecosystems.

Salt Cedar (*Tamarix ramosissima*) — Salt cedar (Figures 11 and 12) is a fire-adapted species that grows long tap roots that allow it to intercept deep water tables and interfere with natural aquatic systems. It disrupts the structure and stability of native plant communities and degrades native wildlife habitat by out-competing and replacing native plant species, monopolizing limited moisture, and increasing the frequency, intensity and effect of fires. This tree increases the risk of fire

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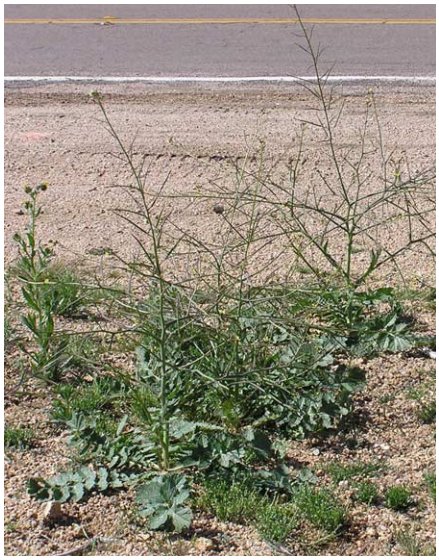

Figures 8 and 9. Sahara Mustard. *Photos courtesy April Fletcher and Max Licher*

Figure 10 . Malta Starthistle. *Photo courtesy Max Licher*

Figures 11 and 12. Salt Cedar. *Photos courtesy Patti Fenner and Liz Makings*

Arizona's Noxious Weed List *continued*

in riparian ecosystems through deposition of flammable fuels. Salt cedar carries an extremely hot fast fire in riparian areas, which are not adapted to fire. Salt cedar fires have become frequent events in sites along the Gila River. The foliage of tamarisk can add salt deposits to the soil, inhibiting growth of other species. Although it provides some shelter, the foliage and flowers of salt cedar provide little food value for native wildlife species.

Russian Olive (*Elaeagnus angustifolia*) — Russian olive (Figure 13) was introduced from Europe in the early 1800s as a desirable ornamental shade tree. This fast-growing tree is now invasive in 17 western states. It is especially invasive in riparian woodlands, taking advantage of scouring events to replace cottonwood and willow trees. It has nitrogen-fixing roots, which enable it to grow on bare mineral substrates and dominate riparian vegetation where overstory cottonwoods have died. It can survive drought conditions, so is adapted to ephemeral riparian drainages that are common in Arizona. Dense thickets of Russian olive increase the occurrence of catastrophic wildfires in riparian areas, due to their heavy fuel-loading.

Figure 13. Russian Olive. *Photo courtesy Max Licher*

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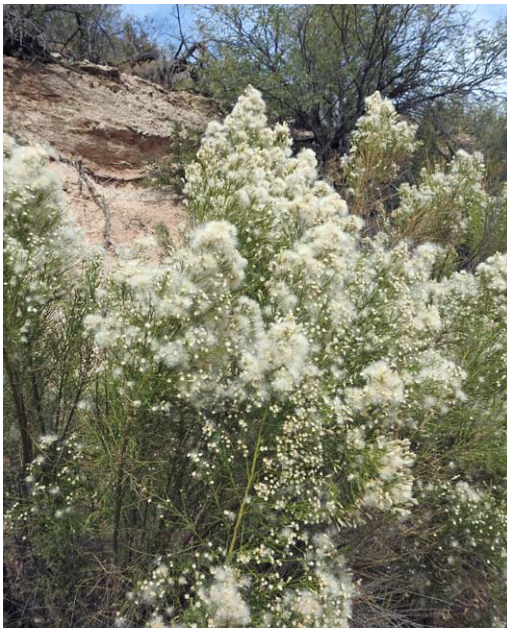

Figures 1 and 2: Desert Broom (*Baccharis sarothroides*). *Photos courtesy Doug Ripley*

Opportunistic Weedy Native Sonoran Desert Plants in Arizona

by Matthew B. Johnson[1]

In recent decades, much attention has been focused on non-native invasive species that threaten our native plant communities, and rightly so. These plants pose serious threats as ecosystem weeds that displace indigenous species and disrupt ecosystem processes, especially by altering the fire regimes of our desert plant communities that did not evolve with fire. In the Sonoran Desert, buffelgrass, fountain grass, Sahara mustard, and red brome are having major and increasing impacts primarily by providing a source of contiguous biomass that dries out and provides fuel for wildfires.

Since before recorded history, humans have intentionally and unintentionally been vectors for moving plants, animals, and disease organisms to regions where they did not previously occur. Our economic activities including agriculture, urbanization, mining, and road infrastructure create disturbances that favor weedy plants. Once introduced into a new region, some plants have the ability to move into relatively undisturbed native plant communities where they negatively impact native plants and the wildlife that depends on those plants. Many plants, both native and exotic, are well-adapted to exploit disturbed sites and become "weedy."

Defining a weed is subjective. A simple definition of a weed is a plant that is growing where it is not wanted. For most people, the idea that a native plant can be a considered a weed in some situations is probably not often considered. Our native plants play important roles in their ecosystems. But several stand out for their ability, in some circumstances, to greatly increase their numbers on disturbed lands and become weedy. Disturbances resulting from human activity provide ideal conditions for these plants to increase at the expense of other species. They are then perceived as weeds by the humans who are responsible for creating the disturbances that led to the plants spreading and increasing in the first place!

Desert broom, burroweed, creosote bush, Mexican palo verde, and sweet acacia are just a few examples of native plants that can become weedy in urban and disturbed areas.

Desert Broom (*Baccharis sarothroides*), in the Asteraceae (Aster Family), is known to most residents of southern and central Arizona for the wind-borne, cottony white "fuzz" that accumulates in drifts when the plants are fruiting in the autumn (Figures 1 and 2). The vegetative growth of desert broom is an attractive bright green and the flowers are an important nectar source for pollinators. Desert broom occurs primarily along larger arroyos and floodplains where it benefits from periodic disturbances caused by flooding. But the seeds are perfectly happy to germinate in soil that has been

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Figures 3 and 4: Burroweed (*Isocoma tenuisecta*). *Photos courtesy Liz Makings*

Opportunistic Weedy Native Sonoran Desert Plants in Arizona *continued*

disturbed by human activity particularly if extra moisture is available. The plants grow quickly and soon reach reproductive maturity. They can rapidly colonize abandoned agricultural land and find road shoulders, alleys, vacant lots, and urban landscapes to their liking. In landscape settings a desert broom can quickly overtop the plant under which it germinated. Desert broom develops a deep, strong taproot and requires considerable effort to remove once established, especially if their "nurse plant" happens to be armed with spines or thorns. Desert broom was a problem plant in urban settings in Tucson during the 1980s and 90s. Since then, in part due to the ongoing drought, its abundance in urban areas seems to have diminished.

Burroweed (*Isocoma tenuisecta*), in the Asteraceae (Aster Family), is found primarily in the southeastern quarter of Arizona (Figures 3 and 4). This low, shrubby plant is able to colonize open ground and rapidly increases in abundance on overgrazed or disturbed soil as long as there is sufficient moisture (Roundy and Biedenbender 1995). Extensive areas that formerly supported native grasses are now dominated by burroweed. While useful in helping to protect the soil in the absence of other plants, burroweed is toxic to livestock. Animals may eat the plants when other forage is unavailable and humans have been affected by drinking milk from cows that have browsed on burroweed (Parker 1972).

Creosote Bush (*Larrea tridentata*), in the Zygophyllaceae (Caltrop Family), originated from a South American ancestor that reached North America many millennia ago (Figures 5 and 6). It was present in Arizona during the height of the last glacial period and has been expanding its distribution in the United States since then. Creosote bush is a major element of plant communities over large areas of the Chihuahuan, Mohave, and Sonoran Deserts. The plants tolerate extremes of heat and aridity. It is a colonizer species, able to germinate and establish on bare ground. In favorable valley habitats creosote can form a near monoculture with few other perennial species present. Creosote bush is appreciated by many for its distinctive aroma following rains and valued by native peoples for traditional medicinal uses. But where creosote has become well-established on overgrazed and degraded rangeland, many of the perennial native grasses and forbs have difficulty recolonizing those areas even when protected from grazing. A study by Mahall and Callaway (1991) demonstrated the ability of creosote bush roots to inhibit root development of white bursage (*Ambrosia dumosa*). The ability of creosote to dominate large areas can lead to a reduction in diversity.

Mexican Palo Verde or Retama (*Parkinsonia aculeata*), in the Fabaceae (Pea Family), likely arrived in Arizona following European colonization but is often considered to be native (Figures 7 and 8). It has been widely introduced in warm regions of the world and frequently naturalizes. In Arizona, Mexican palo verde is now rarely planted as a landscape tree due to its spiny stems, messy leaf litter, and short life span. Several hybrid selections involving Mexican palo verde have been developed that offer unarmed plants with less litter. Naturally occurring hybrids, primarily with the native *Parkinsonia microphylla*, are not uncommon. Mexican palo verde readily germinates along roadsides, in vacant lots, alleys,

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Figures 5 and 6: Creosote Bush (*Larrea tridentata*). *Photos courtesy Doug Ripley and Sue Carnahan*

Opportunistic Weedy Native Sonoran Desert Plants in Arizona *continued*

and arroyos in urban areas and sometimes in natural vegetation in locations remote from settlements. The plants grow vigorously and can quickly form spiny thickets. The long, slender, leaf rachises form a dense thatch on the soil surface beneath the canopy. This thatch appears to retard the germination of native ephemerals. Mexican palo verdes frequently succumb to the larvae of the palo verde borer (*Derobrachus germinatus*) which feed on the roots.

Western Honey Mesquite (*Prosopis glandulosa* var. *torreyana*) (Figures 9 and 10) and Velvet Mesquite (*Prosopis velutina*) (Figures 11 and 12), in the Fabaceae (Pea Family), are both conspicuous native plants within their ranges in Arizona. Both taxa are important for wildlife and were a valued resource for native peoples. They are planted as landscape trees in the state. Mesquite products are growing in popularity and mesquite has considerable potential as a multipurpose tree crop for arid and semi-arid lands. At elevations above the deserts in Arizona, mesquites were historically mostly confined to floodplains along larger watercourses where they formed extensive woodlands or bosques. Several species of mesquite have become serious weeds in warm regions of the world (e.g., Australia, Africa, and Asia) where they were introduced. Our native mesquites can rapidly increase on overgrazed rangeland where there is no longer sufficient fuel to carry wildfires. Livestock readily consume the sweet fruits and the hard seed coats are scarified in the digestive tracts of

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Figures 7 and 8: Mexican Palo Verde or Retama (*Parkinsonia aculeata)*). *Photos courtesy R.A. Villa and Liz Makings*

Opportunistic Weedy Native Sonoran Desert Plants in Arizona *continued*

Figures 9 and 10: Western Honey Mesquite (*Prosopis glandulosa* var. *torreyana*). *Photos courtesy L.H. Landrum*

the animals. It is not uncommon to find mesquite seedlings emerging from "cow patties" during the summer months. Many methods have been employed in attempts to control mesquite on rangeland. The mesquites persist and continue to take advantage of ongoing human-caused disturbances. In addition, Texas honey mesquite, the non-native, eastern *Prosopis glandulosa* var. *glandulosa* has been spreading along major highways in southern Arizona at least since the 1970s. The plants were apparently introduced from seeds in the manure of livestock being transported from Texas through Arizona.

Sweet Acacia (*Vachellia farnesiana*), in the Fabaceae (Pea Family), is widely distributed in the American tropics and subtropics. It is widespread in Sonora and is historically known from apparently naturally occurring populations along the Baboquivari Mountains in southern Arizona (Figures 13 and 14). This species has been extensively introduced into warm regions around the world where it has not infrequently become invasive. Sweet acacia is commonly planted as a landscape tree in desert regions of southern and central Arizona where it is appreciated for its shade, lacy foliage, and showy displays of extremely fragrant flowers (Figure 15). Sweet acacia grows rapidly with sufficient irrigation. In landscape settings where irrigation is limited and other sources of moisture are not available, the plants often decline and suffer extensive die-back. In the past two decades, sweet acacia has increasingly shown up as a volunteer along roadways in southern Arizona, often well away from any developed areas that might have landscape plants to serve as a source of seeds. The extra moisture afforded by the pavement benefits the volunteer sweet acacias. Along an arroyo on the south side of Tucson at least a half mile from the nearest development, numerous large sweet acacias were recently observed. These trees are estimated to be at least 25 years old

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Figures 11 and 12: Velvet Mesquite (*Prosopis velutina*). *Photos courtesy Doug Ripley*

Figures 13 and 14: Sweet Acacia (*Vachellia farnesiana*). *Photos courtesy Doug Ripley*

Opportunistic Weedy Native Sonoran Desert Plants in Arizona *continued*

and appear to be doing well. Like some other native plants, sweet acacia is opportunistic and will take advantage of disturbed locations to become established beyond its historical range.

These examples illustrate the ability of some native Arizona species to become weeds as a result of disturbances that result primarily from human activity. There are certainly other potentially weedy native species. All they require is a suitably disturbed site and the proper environmental conditions.

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Figure 15: Sweet Acacia (*Vachellia farnesiana*) flowers. *Photo courtesy Stephen Hale*

Arizona Exotic and Native Plants that are Toxic to Animals and Humans

by Anthony Knight[1] *Photos by the author unless otherwise noted.*

Introduction

A great diversity of native and exotic plants grow in Arizona, some of which if consumed in quantity by horses, livestock, dogs, and even humans can cause a variety of symptoms including vomiting, diarrhea, liver failure, abortion, fetal deformity, and death.

Plants contain a wide variety of chemical compounds many of which evolved to deter herbivores and insects from eating the plant. With few exceptions plant poisoning only occurs when large quantities of the plant are consumed. In other words it is the quantity of the plant consumed that causes poisoning! Frequently poisoning of livestock and horses occurs when pastures or rangelands are overgrazed, when toxic plants are incorporated in hay, or when animals are introduced to plants to which they are unaccustomed.

In this article only those plants, native or exotic to Arizona, and which pose the greatest risk to animals will be listed. Those that are unusual and have unique toxicity will be described in more detail.

The Arizona native plants that are most toxic to cattle and cause the greatest economic loss are larkspurs (*Delphinium* spp.) and locoweeds (*Astragalus* ssp. and *Oxytropis* spp.).

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Larkspurs are most prevalent in pine and aspen forests. All larkspur species are toxic, especially the tall larkspur species *Delphinium barbeyi* and *D. glaucum*. Respiratory failure and death in cattle result from the action of neuromuscular-blocking diterpenoid alkaloids like methyllycaconitine that present in all parts of the plant and especially in pre-flowering.

Over 70 species of locoweeds grow in Arizona. Most belong to the genus *Astragalus*, with two species in the genus *Oxytropis*. *Astragalus* is the largest genus of flowering plants in Arizona but not all are poisonous. Those that are poisonous attribute their toxicity to an endophytic fungus growing within the plant that produces the toxic alkaloid swainsonine. Other species of *Astragalus* can accumulate toxic levels of the mineral selenium that is toxic to livestock and horses. Signs of locoism in cattle and horses range from abnormal behavior, abortions, and fetal deformities such as crooked legs in calves and foals born to those dams that graze locoweed during pregnancy.

In times of drought, plants that will cause poisoning in cattle and horses grazing them are Burroweed (*Isocoma tenuisecta*) and Rayless goldenrod (*Isocoma pluriflora*). Interestingly, the toxins (benzofuroketones) in these plants are similar to the tremetone in white snakeroot (*Ageratina altissima*) which

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Native Arizona Poisonous Plants

Common name	*Botanical name*	Toxin	Animals Affected	Signs of Poisoning
Larkspur	*Delphinium* ssp.	Alkaloids	Cattle	Muscle weakness, death
Locoweed	*Astragalus* ssp., *Oxytropis* spp.	Swainsonine	Horses, cattle	Neurologic signs, abortion, fetal deformity
Rayless goldenrod	*Isocoma pluriflora*	Tremetone	Horses, cattle	Cardiac degeneration, death
Water hemlock	*Cicuta douglasii*	Cicutoxin	All	Death
Menzies' fiddle	*Amsinckia menziesii*	Pyrrolizidine alkaloids	Horses, cattle, animals	Liver failure, photosensitization
Ragwort	*Senecio* spp.	Pyrrolizidine alkaloids	Horses, cattle	Liver failure, photosensitization
Sacred datura	*Datura wrightii*	Tropane alkaloids	All	Colic, death
Tree tobacco	*Nicotiana glauca* (naturalized species)	Tropane alkaloids	All	Neurologic signs, death
Milkweeds	*Asclepias* spp.	Cardiac glycosides	Horses, cattle	Cardiac arrest, death
Oaks	*Quercus* spp.	Gallotannins	Cattle	Kidney failure



From left: Figure 1. Barberry larkspur (*Delphinium barbeyi)*. Figure 2. Spotted locoweed (*Astragalus lentigenosus*). Figure 3. Rayless goldenrod (*Isocoma pluriflora*). Below: Figure 4. Douglas' Water hemlock (*Cicuta douglasii)*

Arizona Exotic and Native Plants that are Toxic to Animals and Humans *continued*

causes livestock poisoning in the Midwestern United States. Abraham Lincoln's mother, Nancy Hanks Lincoln, died of "Milk Sickness" as a result of drinking milk from cows eating white snakeroot.

The most poisonous of all native Arizona plants is water hemlock (*Cicuta* spp.) that grows in riparian areas at higher altitudes. All parts of the plant are highly toxic and when eaten in small quantities can cause sudden death in all animals including humans who might mistake it for wild carrot (*Daucus carrota*). The European or Spotted water hemlock (*Conium maculatum*) was famously used to poison Socrates in 399 BC in Ancient Greece. It is a noxious weed today in Arizona and is poisonous to all animals that eat it.

Two plants listed as Arizona noxious weeds, Yellow star thistle (*Centaurea solstitialis*) and Russian knapweed (*Rhaponticum repens*) are unique in that they are only poisonous to horses. Both plants are aggressively invasive with seeds which can pass through the digestive system and

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Poisonous Plants Listed in the Arizona Noxious Weed List: **https://agriculture.az.gov/pestspest-control/agriculture-pests/noxious-weeds**

Common name	*Botanical name*	Toxin	Animals Affected	Signs of Poisoning
African Rue	*Peganum harmala*	Alkaloids	Cattle, sheep, horses	Incoordination, death
Halogeton	*Halogeton glomeratus*	Oxalates	Cattle, sheep	Kidney failure
Russian knapweed	*Rhaponticum repens*	Sesquiterpene lactones	Horses	"Chewing disease"
Yellow star-thistle	*Centaurea solstitialis*	Sesquiterpene lactones	Horses	"Chewing disease"
Johnson grass	*Sorghum halepense*	Cyanide	Cattle	Death
Kochia weed	*Kochia scoparia*	Nitrates	Cattle	Death

From top: Figure 5. Yellow Star thistle (*Centaurea solstitialis*). Figure 6. Russian knapweed *(Rhaponticum repens*), *courtesy Wikipedia Commons*. Figure 7. Halogeton in Flower (*Halogeton glomeratus*) and closeup (inset) showing succulent leaves with terminal hair.

Arizona Exotic and Native Plants that are Toxic to Animals and Humans *continued*

manure of horses to infect pastures and trails. The plants contain a group of sesquiterpene lactones that if ingested by horses over a period of weeks will induce irreversible damage to specific areas in the brain that control the horse's ability to chew its food. As there is no treatment, affected horses will starve to death and must be euthanized.

An invasive weed of the arid Western States is Halogeton (*Halogeton glomeratus*). It thrives in alkaline soils and contains high levels of oxalates. Cattle and sheep grazing this plant will develop severe kidney failure and die.

Toxic House and Garden Plants in Arizona

A great variety of house and garden plants are toxic and can poison a wide variety of animals including dogs, cats, horses, livestock, and children that chew or eat them. A familiar plant in Arizona landscapes and gardens that is highly poisonous to all animals including humans is Oleander (*Nerium oleander*). All parts of the Oleander plant contain cardiac glycosides that cause heart arrhythmias and death. Even smoke from burning green oleander leaves if inhaled can cause heart abnormalities.

A less well known Arizona garden plant is Carolina jessamine (*Gelsemium sempervirens*). This vine is however highly poisonous to all animals due to its content of toxic strychnine-like alkaloids gelsemine and gelsenicine. Honey bees may also be poisoned by the plant's nectar.

Another plant common in Arizona gardens is the desert rose (*Adenium* spp.). Native to many parts of Africa, *Adenium* species and their hybrids are well adapted to hot dry environments. Valued for their colorful flowers and heat tolerance, the entire plants are poisonous due to the presence of many cardiotoxic glycosides which act in a similar manner to digitalis. Small quantities of *Adenium* glycosides may help stimulate the heart, but higher doses cause cardiac arrest and death.

Zamia integrifolia (*Z. floridana*) also known as cardboard palm or coontie palm is a perennial that is well adapted to southern Arizona gardens. *Zamia* species are members of the primitive Cycad Family (Cycadaceae) and are native to Florida and several Caribbean islands. Similar genera are

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From left: Figure 8. Carolina jessamine (*Gelsemium sempervirens*), *courtesy Wikipedia Commons*. Figure 9. Desert rose (*Adenium obesum*).

Arizona Exotic and Native Plants that are Toxic to Animals and

Ceratozamia, *Cycas, Dioon*, and *Macrozamia*. The male pollen cones are narrowly cylindrical, while the female seed cones are ovoid, containing orange to red colored fleshy seeds. When ripe the cones split spilling the seeds onto the ground where they are attractive to dogs. The seeds contain various poisonous glycosides that are neurotoxic and cause liver failure leading to death.

Chinaberry tree, Persian lilac, White cedar, Texas umbrella tree, and Pride-of-India are a few of the common names given to *Melia azedarach*. Native to Pakistan, India, Southeast Asia and Australia. Chinaberry trees have been widely planted across the southern States as fast growing heat tolerant trees with lavender colored, fragrant star-shaped flowers. Clusters of yellow/brown berries tend to hang on the tree after the leaves have fallen. All parts of the tree are poisonous but especially the berries. Chinaberry poisoning has been reported in horses, cattle, sheep, goats, pigs, and dogs that eat the fallen ripe berries. The *Melia* toxins A & B (tetranortriterpenes) cause a variety of symptoms including diarrhea, vomiting, salivation, depression, seizures, and death.

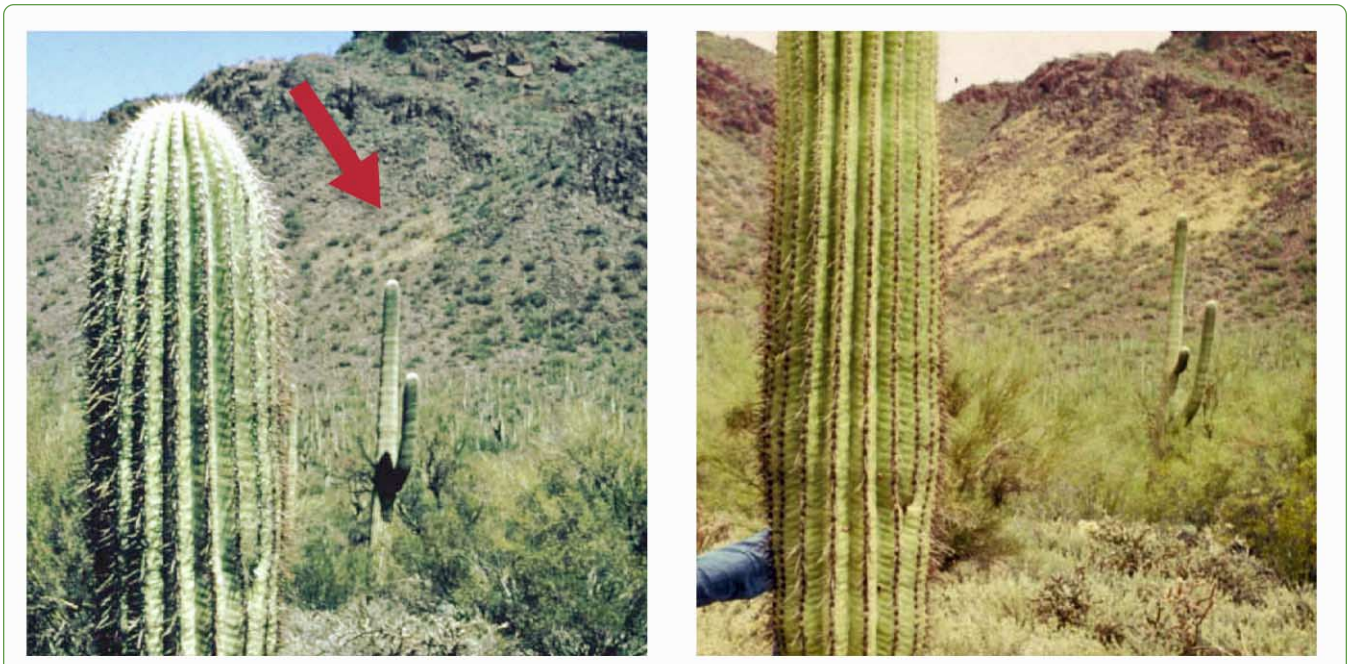
Conclusion

A relatively small but not insignificant number of both native and introduced cultivated Arizona plants contain chemicals that can be toxic to many different animals and humans. A knowledge of the dangers of these species should be widely publicized.

Additional Information Sources on Poisonous Plants

https://csuvth.colostate.edu/poisonous_plants and https://www.ars.usda.gov/is/np/PoisonousPlants/PoisonousPlants.pdf.

Figures 10 and 11. Coontie Palm (*Zamia integrifolia*) plant (left) and ripe seed cone (center). Figure 12. Chinaberry (*Melia azedarach*), *courtesy Wikipedia Commons*.



Buffelgrass on Panther Peak 1989 (left) and 2000 (right). *Photos courtesy Dale Turner*

The Long Journey from Buffelgrass Introduction, Spread and Latency, to an Eruptive Explosion in Arizona

by John Scheuring[1] and Kim Franklin[2]

Buffelgrass (*Pennisetum ciliare*) has become the most notorious noxious weed in southern Arizona. With a distribution spanning nine counties, buffelgrass is equally at home in our cities and our wildlands. Buffelgrass lines roadsides, overruns vacant lots, and fills urban washes. It climbs desert hillsides, displacing native grasses and perennial dicots. Buffelgrass can engulf entire desert landscapes, transforming rich biodiverse desert scrub communities into depauperate grasslands. A long-lived perennial, it accumulates fuel loads much greater than our native grasses, burning hot and furious through desert ecosystems not adapted to fire.

Buffelgrass is a drought-tolerant perennial bunchgrass native to Africa where it is well adapted to arid and semi-arid regions, providing fodder for wild and domestic animals. Buffelgrass thrives on fire, and pastures are often burned during the dry season to stimulate new growth.

Between 1880 and 1930, recurrent droughts in North America and elsewhere decimated cattle herds and impoverished soils. In an attempt to stabilize cattle populations, a worldwide effort was made to find a drought-resistant "miracle grass." Grass species were collected in drought prone areas of North America and Africa and tested in the U.S., Mexico, Australia, and Africa. One of those species was buffelgrass. Another was Lehmann's lovegrass (*Eragrostis lehmannii*). Both were found to be well suited for their ease of establishment, persistence, and fodder production (Cox et al. 1984, 1988). Buffelgrass was also found to be an excellent species to stabilize copper mine tailings.

Although it arrived in Arizona 82 years ago it has become aggressively invasive in only the last 35 years. In this paper we trace the introduction, slow spread, and sudden eruption of this grass. Since there is little information in the literature describing the details of the initial spread and timing patterns, we have interviewed a number of "old timers" who have memories of their initial buffelgrass sightings.

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The Long Journey from Buffelgrass Introduction *continued*

Arizona Introductions

In the early 1930s, Franklin J. Crider, director of the newly established Boyce Thompson Arboretum, led the introduction and testing of exotic grasses in southern Arizona. In 1934 Crider established and became the director of the Soil Conservation Service (SCS) Plant Materials Center in Tucson (Heather Dial, Tucson Plant Materials Center, USDA, personal communication). There he continued his work with exotic grasses, selecting several species, including buffelgrass, for their suitability to the heat and aridity of southern Arizona.

In the 1940s through the 1980s, the Soil Conservation Service, which later became the Natural Resources Conservation Service (NRCS), made numerous plantings on reservations and federal lands with the hope that buffelgrass would spread on its own naturally. Not all plantings were successful. Several experimental plantings were done beginning in 1941 at Aguila near Phoenix. Most did not do well. In the early 1980s, buffelgrass was planted on Bureau of Land Management (BLM) land near Cerro de Represo, west of Tucson. Although the buffelgrass, planted on flat ground, died out, ten years later the slopes of the adjacent 45-acre Cerro de Represo has been engulfed in buffelgrass, the seed undoubtedly originating from the original planting (T.R. Van Devender, Greater Good Charities, personal communication). Evaluation of buffelgrass at the Tucson Plant Materials center ceased in 1991 (Munda 1995).

Also in the early 1980s, buffelgrass was seeded on the flood control structures at White Tanks by the Maricopa County Flood Control District and as part of road construction projects by the Indian Highways Department of the Bureau of Indian Affairs. (Dan James, professional roadside hydroseeder and owner of Desert Seeders, Gila Bend, AZ, personal communication). The Arizona Department of Transportation (ADOT) never used buffelgrass in its roadside seed mixes, preferring instead another exotic grass, Lehmann's lovegrass, for right-of-way stabilization (LeRoy Brady, Chief Landscape Architect, AZDOT, personal communication).

Buffelgrass and Lehmann's lovegrass were seeded to stabilize the tailings of copper mines south of Tucson in the 1960s and 1970s. Both species were found to establish easily and grow as "pioneer plants." At that time, seed supply of these exotic species was abundant, whereas native grass seed was unavailable (Stuart Bengson, Copper Operations, ASARCO Inc., personal communication).

The first herbarium records of buffelgrass in Arizona are from 1938 from the Plant Materials Center in Tucson (https://swbiodiversity.org/seinet/index.php). The number of buffelgrass records has grown each decade since the 1930s. The data reflect slow spread through 1980, rapid increase in the 1980s, and explosion between 1990 and 2020. From the time of first introduction for a period of approximately 40 years, buffelgrass spread slowly, remaining in a state of latency until sudden population upsurge in the 1980s. John Brock (*The Plant Press*, this issue) describes that typical slow spread and lag time in which newly introduced plants become adapted to their new home.

Table 1: Buffelgrass records in herbaria 1930–2020. Data available from SEINet (SEINet images 1938–1982, 1983–2020); https://swbiodiversity.org/seinet/index.php.

Years	Total Plant Specimens	Total Arizona Counties	Arizona Counties
1930–1960	1	1	Pima
1961–1970	6	2	+ Maricopa
1971–1980	10	4	+Yuma, La Paz
1981–1990	23	5	+Yavapai
1991–2000	35	6	+Pinal
2001–2010	75	8	+ Santa Cruz, Cochise
2011–2020	97	9	+Gila

Botanists on Tumamoc Hill, a 364-hectare desert preserve near the heart of Tucson and home of The Desert Laboratory, have been monitoring its flora since 1903. Buffelgrass was first recorded there in 1968. A survey of exotic plants on the Hill in 1983 found only 6 buffelgrass plants growing near the road (Bowers et al. 2006). In 2005 the Hill was surveyed again. Those 6 buffelgrass plants had turned into 485 plants, an increase far larger than that of any of the 34 exotic species recorded in 1983. Buffelgrass had spread to all exposures of the Hill and formed several continuous stands the largest of which was approximately 50 hectares (Bowers et al. 2006). Tony Burgess, a botanist stationed at the Desert Laboratory from the late 1970s through the early 1990s, reported a sudden increase and spread of buffelgrass following above-average rainfall in 1983 and 1984 (Burgess et al. 1991).

In the same period, Sue Rutman noted a similar pattern of buffelgrass spread in Organ Pipe Cactus National Monument. In the 1970s and 1980s, sightings of buffelgrass were relatively rare but significantly increased between 1984 and 1987. By 1994 buffelgrass had spread to up to 25 square miles within the monument (Rutman and Dickson 2002). Similarly, an incipient buffelgrass patch on Panther Peak in Saguaro National Park in 1989 had grown into to a massive infestation

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The Long Journey from Buffelgrass Introduction *continued*

by 2000 as revealed by repeat photography (D.S.Turner and C.S. Funicelli 2000).

Buffelgrass Spread Patterns

With the sustained intentional plantings of buffelgrass on public and reservation lands in southern Arizona, buffelgrass slowly spread to wildlands and increased in abundance in urban areas through the 1980s.

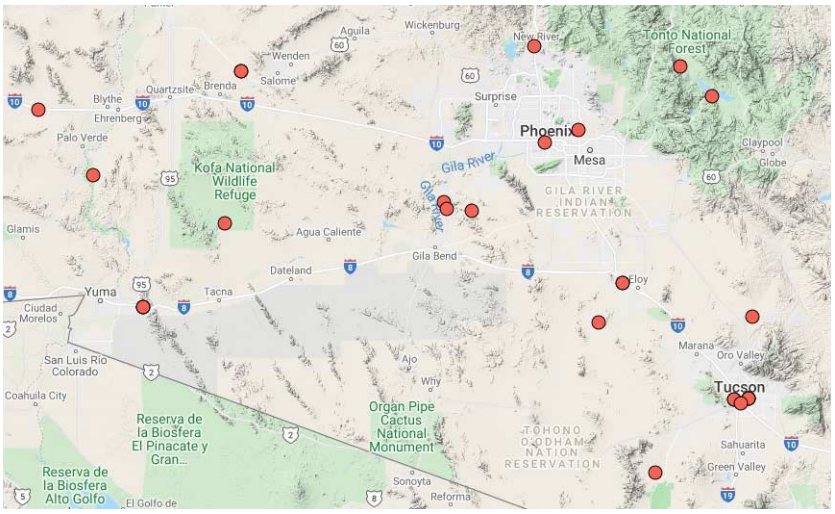

Figure 2. Buffelgrass collection locations 1938 to 1982.

In the late 1980s and through the early 2000s buffelgrass rapidly spread along roadways. Three of the first initial plants detected on Tumamoc Hill were along the main road. In Western Pima County, Rutman noted the heaviest initial infestations along the Mexican border (Mexican Highway 2) and the north-south Arizona Highway 85 (Rutman and Dickson 2002). Van Devender and Dimmit made an extensive buffelgrass survey from the mid-1990s to 2005 and concluded that, at that time (2006), buffelgrass in southern Arizona was found mostly along roadsides and roadside infestations appeared to be the seed source for further infestations into desert wildlands (Van Devender and Dimmit 2006).

Several botanists have noted that the roadside infestation of the early 1990s preceded the later infestations of drainages and hillsides that occurred extensively after 1995 (Tom Van Devender, Greater Good Charities, and James Brock, Professor Emeritus, College of Integrative Sciences and Arts, Arizona State University, Mesa, AZ, personal communications). Windblown buffelgrass seed quickly spreads up the slopes, especially favoring saguaro-palo verde bajadas. David Bertelsen, renowned for his work documenting long-term trends in the flora of the Santa Catalina Mountains, noted the first appearance of buffelgrass in Finger Rock Canyon in the Santa Catalinas in 1990 (Bertelsen 2018). Buffelgrass moved up the slopes of Tucson's Sentinel Peak following the July 4, 1994, fire that was fueled by another invasive grass, red brome grass (*Bromus rubens*) (Diane Hadley, homeowner at the base of Sentinel Peak, AZ and Tony Burgess, botanist and plant ecologist based at the Desert Laboratory on Tumamoc Hill from the 1970s to 1990, personal communications).

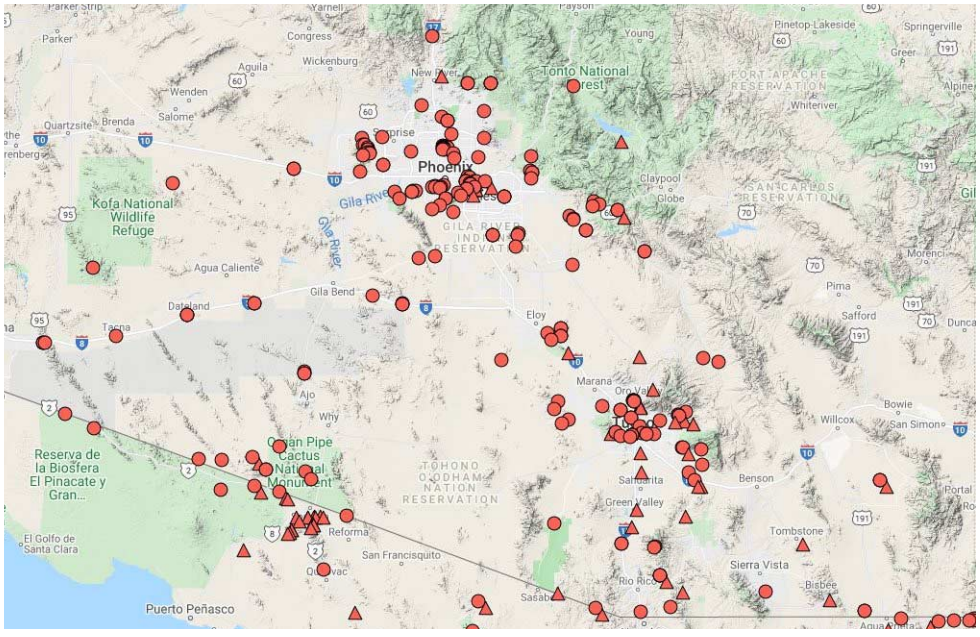

Figure 3. Buffelgrass collection locations 1983 to 2000.

Buffelgrass infestations in the Phoenix area quickly followed those of Tucson with the first sightings along the I-10 frontage road in 1990 and the south end of Indian Bend Wash in Tempe in the mid-1990s. By the late 1990s, buffelgrass was moving up desert slopes at the Spur Cross Park. By the early 2000s buffelgrass was climbing desert hills and infesting state and county roads throughout Maricopa County (John Brock, Professor Emeritus, College of Integrative Sciences and Arts, Arizona State University, Mesa, AZ, personal communication).

continued next page

Roadside buffelgrass.

The Long Journey from Buffelgrass Introduction

continued

Table 2: Phoenix and Tucson airport deviations from average in monsoon rainfall (June 1 to September 30) and winter rainfall (Oct 1 to May 31) between 1981 and 1990 (Crimmins 2020a and 2020b).

	Tucson		Phoenix	
Year	Winter (inches +/- average of 5.0")	Monsoon (inches +/- average of 6.1")	Winter (inches +/- average of 4.6")	Monsoon (inches +/- average of 2.6")
1981	+0.2	+2.1	-1.5	-1.4
1982	-0.9	+1.4	+1.0	-0.1
1983	+2.0	+4.4	+4.8	+2.7
1984	+3.3	+3.9	-0.9	+7.0
1985	+3.0	+0.2	+1.1	+0.2
1986	+2.0	-0.4	+3.6	+0.4
1987	+1.8	-0.6	+0.4	-0.5
1988	-0.2	+0.2	+0.9	-1.1
1989	-0.2	-3.7	+1.1	-0.9
1990	-0.7	+3.9	-1.9	+2.2

Buffelgrass Eruption in the 1980s and 1990s

1983 through 1986 were wet years in both Tucson and Phoenix. This period was punctuated by historic flooding in October 1983 and followed by two years with above average rainfall in both winter and summer monsoon seasons. (Crimmins 2020 a and b). This continuous wet period from 1983 to 1986 was the trigger that set off the massive outbreak of buffelgrass in Arizona in the 1990s.

Buffelgrass in Arizona emerges and grows with enough warmth (above 70°F daytime temperature) and sufficient soil moisture regardless of season. In contrast, perennial native grasses and forbs generally grow during one season and remain dormant or "rest" in the following season. With no requirement for a period of rest and provided adequate moisture, buffelgrass can take advantage of those rest periods to outcompete native species, including brittlebush (*Encelia farinosa*), triangleleaf bursage (*Ambrosia deltoidea*), native grasses, and even foothill palo verde (*Parkinsonia microphylla*).

In addition, buffelgrass quickly germinates and grows in disturbed soil caused by roadside scraping, road widenings, and construction disturbances. Between 1990 and 2020 there were extensive interstate widenings that caused right-of-way soil disturbances resulting in considerable invasive weed infestations which included buffelgrass.

Potential Natural Limits on Buffelgrass

One advantage that buffelgrass has over native grasses is a lack of natural enemies. Few Sonoran Desert animals consume buffelgrass enthusiastically, with the single exception of a native spittle bug, *Aeneolamia albofasciata*. First reported from buffelgrass pastures in Sonora in 1981, this spittlebug was causing declines in pasture productivity just a few years later (Martin et al. 1995). The damage inflicted by this insect on buffelgrass pastures in both northeastern and northwestern Mexico has stimulated a line of research on its control (Martin et al. 1999).

Recent reports of this spittlebug from Santa Cruz and Pima counties in southern Arizona suggest that its range may be moving northward (iNaturalist 2020, available from https://www.inaturalist.org). With enough time, these insects may discover the massive stands of buffelgrass in the mountains surrounding the Tucson Basin, a literal spittlebug all-you-can eat buffet, and perhaps provide some assistance to land managers whose current repertoire of tools does not include biological controls.

Much effort has been directed towards developing a bioherbicide for buffelgrass control. In contrast to a true biocontrol agent, a bioherbicide is not a living organism released into the environment, but rather an herbicide derived from pathogens that attack a target invasive species. Masi et al. (2019) successfully isolated phytotoxic metabolites from two fungal pathogens commonly found in buffelgrass populations in North America. Moreover one of these metabolites, radicinin, has been shown to have a high toxicity on buffelgrass and a low toxicity on native plant species. Much more research is needed to better assess the potential application of radicinin and other phytotoxic metabolites as bioherbicides for buffelgrass.

Extreme weather events might bring new opportunities for the suppression of buffelgrass and other noxious weeds.

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The Long Journey from Buffelgrass Introduction *continued*

Excessively wet winters might favor the growth of pathogens, a phenomenon observed in buffelgrass populations lying in moist areas along roadsides in Tucson in February 2020 (Scheuring, unpublished data). A deep freeze might cause dieback near the upper elevational range limit of a species limited by freezing. Severe drought can result in drastically reduced growth and seed production and even mortality. For example, during a 2003 buffelgrass survey of Ironwood Forest National Monument, Dimmitt and Wiens (2010) recorded a large, healthy stand of buffelgrass that subsequently died due to a chronic, multi-year drought. Given limited resources, the ability to take advantage of opportunities afforded by climate variability may prove to be a key component of successful invasive species control efforts.

Lessons Learned

Governmental, academic, and non-profit organizations have gradually recognized the dangers of exotic plant introductions. As early as 1977 the U.S. federal government recognized the risk of exotic species dispersal and banned the use of species not locally native in mine waste restoration through the Federal Surface Mining and Reclamation Act (Bengson 1988). Since then, many other federal, state, and local laws have been passed attempting to improve the prevention, control, and management of invasive species, but these laws and regulations are often reactive, rather than proactive. Too often they are species-specific responses to emerging crises, and as such they fail to address potential future invaders.

In Arizona, the only limitation to the introduction of an exotic species through nurseries is appearance on the Arizona Noxious Weed List, but listing requires evidence that the species is economically or ecologically harmful to agricultural or horticultural crops, natural habitats or ecosystems, humans or livestock. As the case of buffelgrass demonstrates, the potential for a species to cause massive economic and ecological harm may not become apparent for decades. With a changing climate, and more frequent extreme weather events, we should be monitoring populations of the scores of exotic species already naturalized and lying in latency in urban and wild landscapes throughout Arizona. Moreover, we ought to address the lack of scrutiny of exotic plant introductions through the nursery industry and narrow this potential invasion pathway.

Early control of roadside infestations is imperative to staunch the spread of new weeds from incipient localities. Roadside rights-of-ways jump-started the rapid initial spread of buffelgrass throughout the Sonoran Desert. Its light, airborne seeds readily cling to dust on fast-moving vehicles. Effective and timely roadside weed control is essential to stopping not only the constant flow of buffelgrass seed, but many other invasive plants as well. Roadside weed control is inconsistent across ADOT districts and county and municipal jurisdictions.

Buffelgrass was already recognized as an explosive weed by the early 1990s, but it was not added to the Arizona Noxious Weed list until 2005. This delayed the awareness level of buffelgrass and the focus and release of control funding by federal and state agencies. Following the 2005 update, there was a 15-year delay before the noxious weed list was allowed to be updated again in 2020. Timely response to the pressing issues of emerging noxious weeds requires governmental cooperation and support.

The well-intentioned efforts to rebuild cattle herds and to stabilize berms and mine tailings in the 20th century resulted in the establishment of small buffelgrass populations through many parts of the Sonoran Desert of Arizona. But buffelgrass remained a benign exotic until its population explosion the 1980s. Many other exotic species are now lying in wait for the right conditions to potentially spark their own population explosions. Let us apply the lessons learned from the case of buffelgrass to anticipate the future and already mitigate the consequences of inaction.

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BOOK REVIEW *Ries Lindley, University of Arizona Herbarium, Tucson; and Arizona Native Plant Society, Tucson Chapter*

Diversity in a Grassland: Flora of the Salero Ranch, Santa Cruz County, Arizona

by Susan Davis Carnahan

Canotia 16:1–83. 2020. Available at: **https://canotia.org/volume16.php**

Much of today's science stands in its own shadow, obscured by pedantic and formulaic presentations of what should otherwise be fascinating or illuminating. If you are someone who has often wished that scientists were more cognizant of the need to reach a diverse audience, then you will be delighted by Susan Davis Carnahan's *Diversity in a Grassland: Flora of the Salero Ranch, Santa Cruz County, Arizona*. This flora is so lovingly researched and written that it rises to the level of a natural history of the ranch. The bonus image gallery for the flora could easily be turned into, pick one: a photographic art show or a coffee-table book.

The author has documented 788 species and infraspecific taxa on 6,541 hectares of private land during six and a half years. That count amounts to almost 70% of the species in the entire range of the Santa Rita Mountains in whose foothills Salero Ranch resides. The fact that the ranch is private land is especially significant, as these sorts of species-rich private holdings can remain unknown to botanical science because of the difficulty in getting access and permission to collect in them. Sue obtained permission from 223 of 271 land owners in Salero. Without this effort some very important botanical data would have been lost.

Among those data are plant records under the heading of "rare and interesting." There are over twenty plants listed here, and "rare and interesting" is an understatement. Some of these special plants are new to the United States, such as an undescribed species of *Polystemma* (Apocynaceae), whose closest relatives have been reported only from south of the Mexican border. Another such species is a first record for Arizona called *Solanum houstonii*, a nightshade (Solanaceae), also known only from south of the U.S.-Mexico border until now. These rare and interesting plants might cause an Arizona native to do a double take. The genus might sound familiar, but what was that species epithet? There are *Ipomoea muricata*, a morning glory; *Cynanchum ligulatum*, a Mexican Swallow wort; and *Adenophyllum porophyllum*, a poreleaf dogweed, to name only three. There are an impressive 116 grasses in Salero, three of which are included in rare and interesting plants. They are *Bouteloua eludens*, elusive grama; *Michrochloa kunthii*, smallgrass; and *Muhlenberia palmeri*, Palmer muhly.

Why here? The flora sheds light on the most interesting thing about Salero Ranch, through the ancient geology to the more recent human use of the land, the climate, and finally, the outcome of all these influences, the vegetative communities. It's no surprise that every piece of habitat is unique, but how and why are the stuff of science, and Salero's uniqueness has resulted in that condition mentioned in the title, diversity.

Starting with the ancient, the geology offers an initial explanation for the Salero Ranch diversity. Since the late Triassic (about 200 million years ago) a great deal has happened on the ranch. There have been intrusions of different kinds of igneous rocks, and there has been volcanic activity. There is also sedimentary rock in various incarnations, although there is no actual limestone. There has also been faulting and fracturing. Most of the study area is dominated by a dropped fault-block known as a graben, and within the graben, are lesser down-dropped fault blocks, all of which create a wonderfully messy and tumultuous topography. That topography created pathways for water to move, both above and below ground, and it created an opportunity for many microhabitats, each somewhat different from the other. Imposed on the geology is the climate. With around 450 mm of rain (~18 inches), there is enough moisture available to make the topography very productive.

Human impacts on the land are most noticeable from the period of written history, when mining and cattle ranching became the chief "uses" of the land. This discussion of land use is both delightful and thorough. Human impacts from the time of the Salero mine until now explain a good deal of the vegetative outcomes, especially concerning non-native plants. Thirty-four of the 115 grasses on the ranch are non-natives, and a few are thoroughly entrenched on the landscape. Perennials like Weeping and Lehmann's lovegrass are almost total dominants in some areas of the grasslands on Salero.

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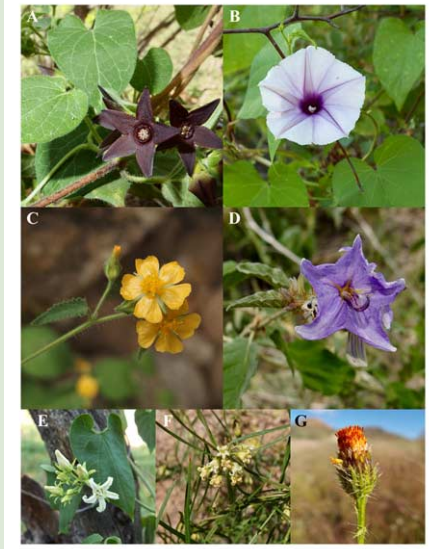

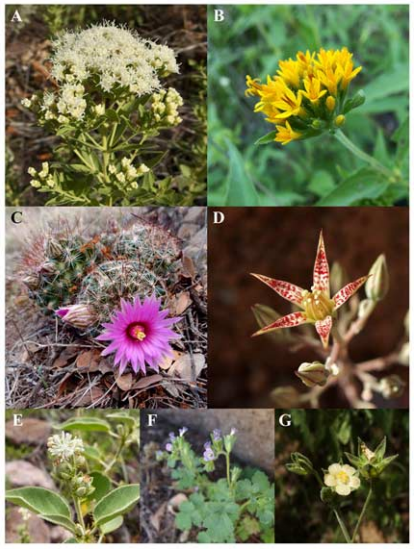

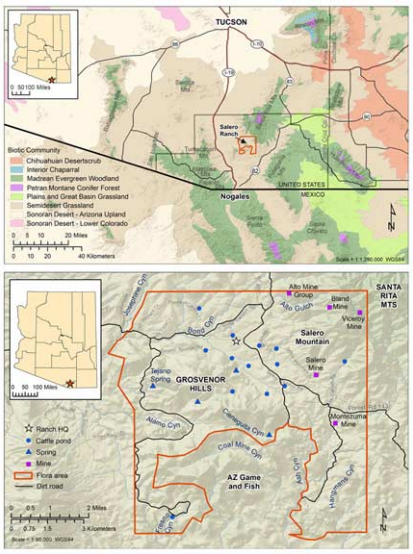

BOOK REVIEW Diversity in a Grassland: Flora of the Salero Ranch, Santa Cruz County, Arizona *continued*

Short-lived Natal grass has become so prevalent in recent years on south-facing slopes that it creates a fire hazard when it is dry. Other exotic grasses have also become established on the ranch, and pose issues for the native environment in their totality, if not to individual species.

Putting aside the discussion of exotic grasses and human impacts, it is hard to read this flora and not feel a little optimistic. The documentary photos of the land are beautiful landscapes, and the plant photos are an independent work unto themselves. This is Arizona at its best, and science writing at its finest. The Salero flora is scientific documentation concerning a plant study, but it reads like entertainment. The flora touches all the bases necessary for a complete and very useful science document, but offers all the interest of botany for a diversity of plant lovers. It would fit well on anyone's bookshelf right there between Janice Bowers and Kathryn Mauz.

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Figures 1 and 2. Stinknet plants prior to bloom (2 February 2020) and in bloom (17 March 2020). *Photos courtesy Michael Chamberland*

The Short Journey from Stinknet Introduction and Spread to Eruptive Explosion in Arizona

by John Scheuring[1] and Michael Chamberland[2]

Stinknet (*Oncosiphon pilulifer*) was largely unknown to Arizonans in 2000. By 2020, it had invaded the Phoenix Metro Area across urban, suburban, and outlying natural areas alike. Rapidly spreading along roadsides, the stinknet infestation is now in full expansion around Tucson, Casa Grande, Buckeye, and Ajo. It is the fastest spreading invasive weed ever to have occurred in Arizona.

This paper traces the brief journey from the first sightings of stinknet in Arizona to its detection in multiple locations in central Arizona, and its explosive growth in the years 2017–2020.

The Plant

Stinknet is a cool-season annual plant originating from South Africa (Kolokoto and Magee 2018). Seedlings produce deep green finely divided carrot-like leaves. Starting as a rosette of leaves, stinknet later bolts with longer stems (Figure 1). The plant has a distinctive pungent odor, like turpentine, most noticeable when foliage is crushed. Starting around mid-February, stinknet becomes conspicuous with ball-shaped yellow blooms at the top of the stems (Figure 2). Stinknet is a member of the Sunflower Family, and the balls are flower heads composed of numerous tiny individual flowers (florets). Starting in early April, the yellow flower heads will transition to tan-colored seed heads of the same size and shape. This will occur later in the spring during favorable growth conditions. Stinknet may produce 100 seeds per seed head, with potentially hundreds of seed heads on larger mature plants. Plants begin to die and dry out after seed set and with the onset of summer conditions. The dry plants lose their leaves and appear as upright standing stems, often coppery to a dark reddish color, topped with tan-colored globes full of seeds (Figure 3). Dried stinknet with intact seed heads may continue standing for months, long after the plants have died. The dry plants are highly flammable (Chamberland 2020).

Germination and Development

Seed germination may begin in November or following the first significant cool-season rain storm. The first flush of germination is the most consequential, and will yield a cohort of the largest plants. However, additional rainfall during the course of the winter can initiate new germination from the soil seed bank. This pattern of staggered germination is challenging for the control of stinknet, which may need to be revisited multiple times during the winter. Seedlings germinating later in the winter may reach maturity at a small size with greatly reduced branches. Years with poor rainfall may yield similar undersized stinknet plants, which may not be easily noticed or readily identified when compared to robust stinknet plants. Undersized plants will produce fewer flower heads and sometimes only one flower head.

continued next page

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[1]University of Arizona, Maricopa County Cooperative Extension.

Figure 3. Dried dead stinknet plants with spherical seed heads and reddish dry stems, 23 August 2019. *Photo courtesy Michael Chamberland*

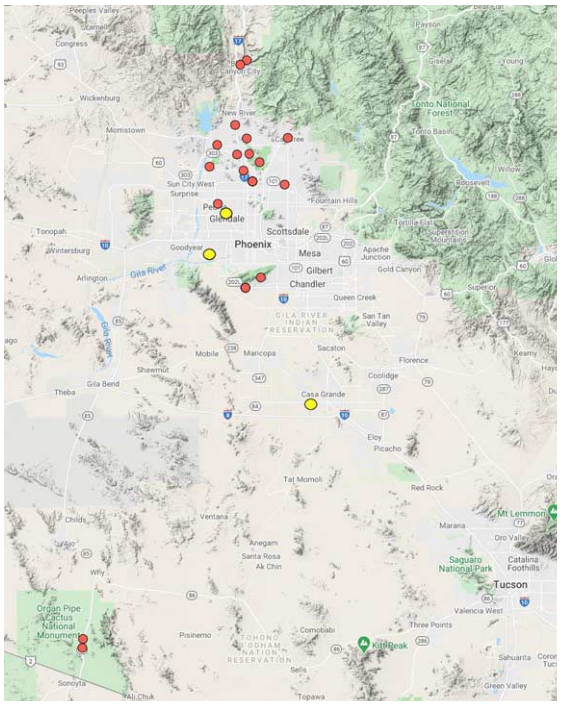

Figure 4. Stinknet plants collected between 1997 and 2004 (yellow circles) and collected during the 2005 calendar year (red circles). *Adapted from SEINet-generated map.*

The Short Journey from Stinknet Introduction *continued*

Stinknet Seeds and Dispersal

Stinknet is an obligate annual reproducing and spreading only by seeds. All stinknet plants in Arizona die during the summer. The species persists through viable seeds in the soil seed bank and through viable seeds in seed heads on standing dried plants.

Stinknet seeds have no obvious structures to aid dispersal. The seeds are tiny, under 1/16 inch in length. Often the dried corolla of the flower, which is several times longer than the seed itself, remains attached to the seed at the time seeds are dispersed from the seed head.

Stinknet's method of holding dried seed heads aloft, poised for dispersal with disturbance, is likely instrumental in its spread. The small size of stinknet seeds permits a variety of means of dispersal.

Stinknet can be observed proliferating along roadsides in Arizona. Many kinds of roadside plants are known to benefit from the runoff of rainfall from paved road surfaces to the roadside. When vehicles pull off to the roadside into patches of seed-laden stinknet, vehicles and their occupants can break apart seed heads, freeing seeds to blow with the wind of passing traffic, and carrying seed or seed-infused soil to new sites. Seeds can be carried long distances with vehicles, equipment, and on clothing, with a likelihood of being dropped at residential or recreational destinations.

The lightweight stinknet seeds have potential to blow with the wind, especially when first released from the seed head. Seeds have been reported to float and move with water flow down watercourses.

Arizona Introduction and Spread

We do not know when or how stinknet came to the U.S. Introduced weeds often go unnoticed as they become established and form populations in the wild. Verifiable documentation of these occurrences is made when plants are noted, usually by botanists or plant enthusiasts, who preserve a dried pressed sample as a herbarium specimen.

The first documented occurrence of stinknet in the U.S. was in 1981 in Riverside County, California. Stinknet spread for over a decade in California, through Riverside and San Diego Counties, before being seen in Arizona. The introduction of stinknet to Arizona was most likely due to the inadvertent transport of seeds from California to Arizona on a vehicle or in infested soil.

The first record of stinknet in Arizona is from a specimen collected in 1997 at the Tres Rios water treatment plant in Phoenix. One specimen was collected in Glendale in 2002 and another in 2004 near Casa Grande. In 2005 a remarkable total of 25 specimens were collected from a range of sites in Arizona, from the Black Mesa foothills in Yavapai County to Organ Pipe Cactus National Monument in southwest Arizona (Figure 4). An account of stinknet's presence in Arizona was first published in a scientific journal as a consequence of the numerous collections made following the rainy winter of 2005 (Landrum et al. 2005).

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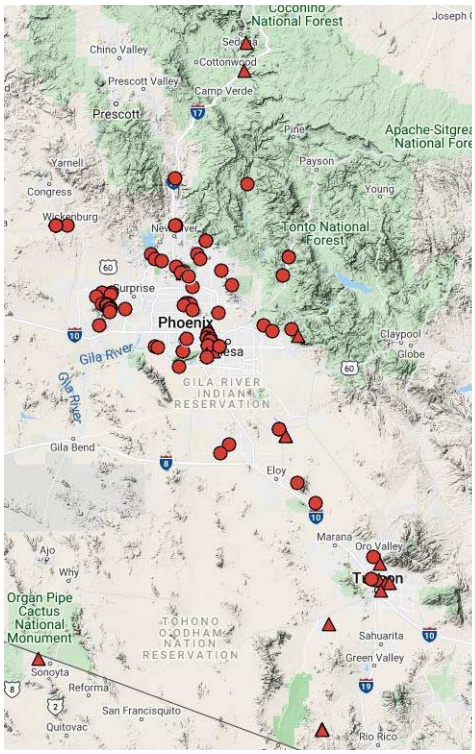

Figure 5. Stinknet documented occurrences between 2006 and 2020. Herbarium collections (red circles) and observations (red triangles). *Adapted from SEINet-generated map.*

Figure 6. Stinknet in bloom at the Ben Avery Shooting Facility, March 2019. *Photo courtesy John Scheuring*

The Short Journey from Stinknet Introduction *continued*

The authors noted that stinknet had potential to become a weed of significance.

The first stinknet plant in Tucson was collected in 2015. Between 2016 and 2020, stinknet populations exploded across metropolitan Phoenix and Maricopa County and along major roadways from New River to Tucson (Figure 5).

Stinknet Pattern of Spread

The stinknet infestation in the Phoenix area first became widespread north of the Metro Area in the vicinity of New River. The Ben Avery Shooting Facility (Figures 6 and 7) is noted as an area of early establishment of a major stinknet population in 2005 (Ed Northam, weed scientist with USDA, UofA Extension, and USFS, personal communication). Stinknet infestations were detected in communities along I-17 north of the Carefree Highway starting around 2007. The earliest and heaviest infestations in the Phoenix Metro Area radiated east from the Ben Avery Shooting Facility along the Carefree Highway through the Carefree and Cave Creek communities (Ed Taylor, professional herbicide applicator and owner of EST LLC, New River, AZ, personal communication).

Visitation to recreation sites infested by stinknet may have been instrumental in spreading the weed. The Ben Avery Shooting Facility welcomes visitation for outdoor activities, particularly during an annual "Arizona Outdoors" event during the last two weeks of March, a time that can coincide with the early onset of stinknet seed maturation in some years. Mature seed from prior years' stinknet growth would also be present in the soil and on standing dead plants. In Spring 2020, John Scheuring discovered stinknet plants in the camping area of Catalina State Park outside Tucson.

Stinknet seed can be spread by road construction equipment. Stinknet was found at a road construction site along Highway 85 running through Organ Pipe Cactus National Monument in 2005 (SEINet 2020). As this was an isolated infestation with no plants found north or south along Hwy 85, the most likely source was from soil contaminated with stinknet seeds and brought in by the construction vehicles. This population of stinknet has since been eradicated. In the vicinity of Casa Grande, early roadside infestations may have been introduced by road construction crews (Dan James, professional roadside hydroseeder and owner of Desert Seeders, Gila Bend, AZ, personal communication).

Ana Lilia Reina-Guerrero collected the first stinknet plant in Tucson in 2015 on an empty lot adjacent to the I-10 Prince Road

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Figure 7. Roadside stinknet infestation forming seed heads while plants continue to bloom in the distance, outside of Ben Avery Shooting Facility, 28 March 2020. *Photo courtesy Michael Chamberland*

Figure 8. Stinknet I-17 off-ramp infestation, March 2017. *Photo courtesy John Scheuring*

The Short Journey from Stinknet Introduction *continued*

off-ramp. The infestation was already well established on recently disturbed soil. The lot had been the road construction equipment yard of the I-10 road widening project between 2011 and 2014. The leased heavy equipment came from Phoenix and was certainly the source of the infestation. By 2020, that infestation had become "Tucson's stinknet ground zero" spreading along the adjacent Santa Cruz River and Silverbell Golf Course, the Union Pacific railway tracks, and parcels and roadways 15 blocks away.

The Role of Winter Precipitation in Stinknet Spread and Detection

The bright yellow flowers of stinknet are conspicuous and easily noted by botanists and collectors. Stinknet is not easily confused with any native Arizona plants. Between 1997 and 2004 only three locations had been documented in Arizona. In 2005 alone there were 24 locations reported (SEINet 2020). The 2005 winter season was ideal for stinknet germination and growth as there was sustained above average rainfall from October through May. The Phoenix airport received 8.2 inches of rainfall, which was 3.6 inches of rainfall over and above the average of 4.6 inches falling between October and May.

Between 2005 and 2015, stinknet slowly expanded throughout Maricopa County, largely unnoticed by the public. Due to early season rains favoring stinknet emergence, stinknet became visible along medians and properties in the Phoenix Metro Area during the winter of 2016.

The wet winters of 2019 and 2020 produced visibly extensive stands of stinknet along Arizona highways and urban public lands in Maricopa County, including along highways all the way southwards to Tucson, and westwards to Buckeye (Figures 8 and 9).

The high rainfall years of 2005 and 2019, and 2020, with well above-average winter rains, were seasons when stinknet gained ground, built biomass and increased seed production to further its spread across the state (Table 1).

Table 1. 2019 and 2020 Phoenix and Tucson airport rainfall deviations from average in the Winter Seasons, October 1 to May 30 (Crimmins 2020a and b).

Year	Phoenix winter rain deviation above average (4.6 inches)	Tucson winter rain deviation above average (5.0 inches)
2019	+4.3	+4.5
2020	+1.2	+0.6

Lessons to be Learned

When stinknet was first establishing in Arizona, it was already known as a weed in California. Stinknet proliferated surprisingly fast in Arizona's Sonoran Desert, in a climate quite different from the habitats stinknet occupied in California. The two infested areas remain separated by a wide stretch of desert.

continued next page

The Short Journey from Stinknet Introduction *continued*

As stinknet became discussed in Arizona, the common name "globe chamomile" was popularly used. When bouquets of stinknet started to show up in 2017 for sale in Phoenix area farmers' markets, labelled as "wild chamomile," weed experts expressed concern about this common name. In addition to having no properly documented medicinal use, reports of allergic reactions drew concern. People with sensitive skin complain about skin burns and rashes after handling stinknet plants. During flowering, some people complain of respiratory difficulties. These same reactions are well known to the people of Cape Province, South Africa, where stinknet is native (A. Schauss, CEO of AIBMR Life Sciences, Guest Lectured in Capetown Province, South Africa, personal communication). A switch to the name stinknet was encouraged to convey better the undesirable aspects of the plant, to disassociate it from herbal chamomile, and to be consistent with California where the name stinknet was already in use. The name stinknet has now been widely accepted in Arizona.

The proliferation of stinknet along roadways and its detection at recreation locations emphasizes the role of vehicles and human activity in facilitating its spread. Movement of soil contaminated with stinknet seed is another major source of infestation, as witnessed by the road construction site infestations along Highway 85 in 2005 and in Tucson in 2015.

Once stinknet becomes well established, its control is not possible without chemical applications. Roadside infestations must be controlled as soon as stinknet appears in order to thwart rapid expansion of the outbreak. Post-construction weed control must be implemented for at least three years to exhaust the soil seed bank. As soon as stinknet appears in a neighborhood, it must be eliminated to stop its further spread.

With the sudden appearance of stinknet, there was no information on chemical control methodology available. Stinknet treatment in Arizona was pioneered by one professional herbicide applicator in the private sector, in response to requests by property owners experiencing infestations. Effective treatments were determined by trial and error. Currently, volunteer weed specialists are conducting ad hoc experimental trials to determine the most effective herbicide controls. With the growing threat of new invasive weeds in Arizona, field control research support is needed from our public institutions.

In January 2020, stinknet was added to the Arizona State Noxious Weed List, together with a set of other serious weeds warranting listing. This came after a delay of 11 years in which updates to the Weed List were prevented by a moratorium on new state regulations (Ducey 2020). Public awareness and concern about emerging noxious weeds needs to be matched by political concern and support for action.

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Figure 9. Stinknet in the I-10 median at Riggs Road, March 2020. *Photo courtesy John Scheuring*

Figure 1. A. Intact tropical deciduous forest near Sabinito Sur. B. *Pennisetum ciliare* pasture in former tropical deciduous forest with Sierra de Álamos in the background. *Photos by T. R. Van Devender in 1992.*

Notes on Non-Native Plants in Sonora

by Thomas R. Van Devender[1], J. Jesús Sánchez-Escalante[2], and Ana Lilia Reina-Guerrero[1]

Introduction

Introduced exotic plants abound throughout the Sonoran Desert Region in Arizona in the United States and Sonora in Mexico. Their abundances and ecological roles can be viewed from several perspectives. With the notable exception of riparian habitats, introduced species usually account for relatively low percentages of local floras.

Ecologically, the diversity and abundance of introduced species are greatest in riparian (river bottoms, arroyos, washes. etc.) and pseudoriparian (edges of roads, etc.) habitats because they are naturally disturbed and unstable dispersal corridors that harvest water, nutrients, and seeds from large areas (Stromberg and Chew 1997). Successful invaders are often short-lived, grow rapidly, and have high reproductive effort. Longer-lived non-natives are usually survivors not easily killed by environmental stresses (floods, fire, drought, freezes, heavy grazing, etc.).

Unfortunately, a few exotics have the potential to cause ecological and economic havoc in the Sonoran Desert Region and threaten to change landscapes irrevocably. Competition with native species is typically intense, illustrated by the examples below. When a new species is introduced into an ecosystem, vegetation structure and species composition can be dramatically altered. The introduction of fire as an ecological process in desertscrub, thornscrub, and tropical deciduous forest (TDF) can be devastating. The worst invasive species in Sonora is *Cenchrus ciliaris* (buffelgrass, *zacate buffel*). Vast areas have been cleared in Sonoran desertscrub, thornscrub, and tropical deciduous forest to plant this grass (Figure 1).

This paper updates our knowledge of the non-native plants of Sonora, and discussions of some recent movements of Sonoran non-native plants. Improved coverage in the SEINet network, especially the Madrean Discovery Expeditions database (**madreandiscovery.org**), has greatly increased our knowledge of the distributions of plants in Sonora.

Sonoran Non-Native Plants

Van Devender et al. (2009) presented a summary of the non-native plants of Sonora. It is also available online on the SEINet Red de Herbarios del Noroeste de México portal: **https://herbanwmex.net/portal/checklists/checklist.php?clid=5726&pid=**. Here we update the status and nomenclature of the non-native plants of the state. A current list of non-native species is presented in Table 1. Since 2006, 20 additional non-native plant taxa have been discovered in Sonora, an increase from 6.4% to 6.9% of the state flora. The number of non-natives in the Asteraceae and Poaceae increased by six and five species. The number of non-native herbs increased from 76.5 to 82.0%.

Currently, the flora of Sonora has 3,842 vouchered taxa (Van Devender and Sánchez-E. unpubl. data), including 266 non-native species (6.9%), including those known to be established as well as those only known from a few collections. Only 35 species of non-natives are invasive (13.2%). Four families account for 48.9% of the non-native: Poaceae (73 species), Asteraceae and Brassicaceae (20 species each), and Fabaceae (17 species). Other families with significant numbers of non-natives are Amaranthaceae (9), Solanaceae (8), Lamiaceae and Polygonaceae (7), and Apiaceae and Malvaceae (5).

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[1]Greater Good Charities, 6262 N. Swan Rd., Suite 160, Tucson, AZ 85718. [2]Herbario USON, Universidad de Sonora-DICTUS, Edificio 1A, Niños Héroes entre Rosales y Pino Suárez, Col. Centro, Hermosillo, Sonora, México, CP 83000

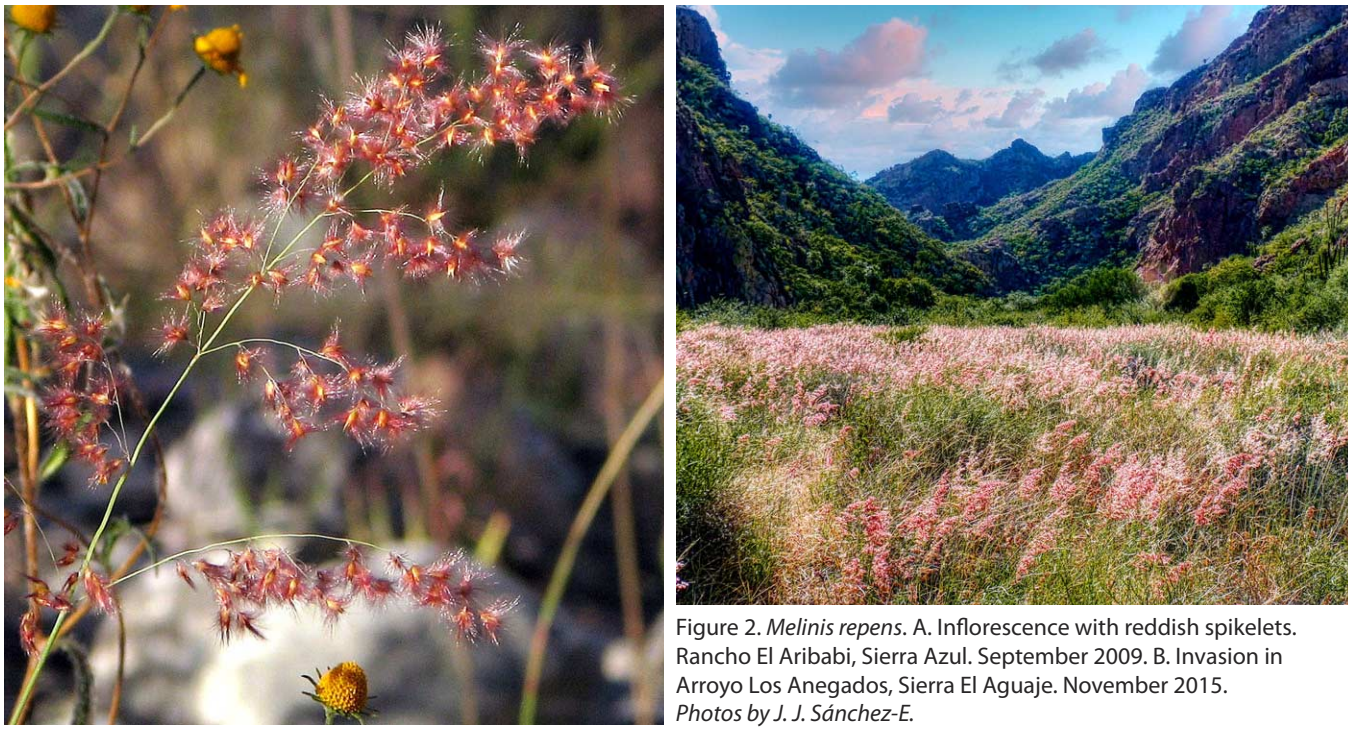

Figure 2. *Melinis repens*. A. Inflorescence with reddish spikelets. Rancho El Aribabi, Sierra Azul. September 2009. B. Invasion in Arroyo Los Anegados, Sierra El Aguaje. November 2015. *Photos by J. J. Sánchez-E.*

Notes on Non-Native Plants in Sonora *continued*

The majority of the non-native species are herbs (82.0%), including annual (149 species) and perennial herbs (69 species). Woody non-natives are less common, but include trees (26 species), shrubs (15 species), succulents (5 species), and woody vines (4 species). Most (70.7%) of the Sonoran non-natives are from the Old World, especially Asia, Africa, and Europe. Sixty-seven species (25.2%) are native to the New World, including South America (38 species), Central America (22 species), Mexico (29 species), the Caribbean (2 species), the United States (7 species), and Canada (2 species), plus pantropical (3 species) and worldwide weeds (2 species).

Non-native plants can be grouped by the general occurrence in Sonora. Exotic species associated with human activities include ornamentals (garden herbs, hedges, shade trees, etc., 53 species), cultivated species (food, fiber, medicine, cultural, wood, etc., 41 species), agricultural (14 species), forage (13 species), and urban (13 species) species. More generally, non-natives are found in disturbed (90 species), riparian (25 species, including three aquatic plants), and roadside (15 species) habitats. Four species (*Hackelochloa granularis*, *Pteris cretica*, *Tagetes minuta*, and *Urochloa reptans*) are only known in Sonora from undisturbed natural habitats.

Species on the Move

*Melinis repens (*Natalgrass, *zacate rosado*)

Melinis repens is an attractive perennial grass native to southern Africa that is widely introduced in Australia, North America, and elsewhere (Figure 2A). In Mexico, it is a serious fire-prone, invasive species in the central highlands, including Querétaro (Serrano-C. et al. 2009) and Durango (González-E. et al. 2009). In Durango, it threatens native plants in grasslands and openings in pine-oak forests in the Sierra Madre Occidental (SMO). It is a serious invasive with *Dichanthium annulatum* (Kleberg bluestem, *zacate carretero*) and *Pennisetum ciliare* in the Rio Grande delta in southern Texas (Best 2009).

Van Devender and Reina-G. (2016) studied the flora of the Municipio de Yécora in the SMO in easternmost Sonora for 15 years beginning in 1995. During this period, *M. repens* increased dramatically. In September 2003, Mountain Pima Indian Luis Coyote said that *zacate rosado* was a new arrival in El Kípor. He thought that the government had dropped seeds from airplanes. El Kípor is located at 1640 m elevation in an area with pine-oak forest on the ridges and oak woodland and montane grasslands on lower slopes and in valleys. In September 1998 near Guadalupe Tayopa, *M. repens* dominated a rocky volcanic slope at 900 m elevation. The vegetation is a relictual low-elevation oak woodland on acidic volcanic slopes in a tropical deciduous forest zone (Goldberg 1982). Sánchez-E. et al. (2008) reported *M. repens* to be abundant at Rancho Santa Bárbara, ca. 43 km northeast of Álamos in southern Sonora. Santa Bárbara is in the westernmost SMO with pine-oak forest and oak woodland at 1250 m elevation and tropical deciduous forest in deep canyons below. The first patch of *M. repens* was seen in this area in the

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Figure 3. *Melinis repens* in the Sierra Pinitos. April 2009. A. Extensive burn area. B. Surviving/damaged *Fouquieria splendens* (ocotillo), *Lysiloma watsonii* (feather bush, *tepeguaje*), and *Stenocereus thurberi* (organpipe cactus, *pitahaya*) are visible. *Photos by T.R. Van Devender*

Notes on Non-Native Plants in Sonora *continued*

1990s (Raúl Álvarez-Valdez, pers. comm. in 2008). *Melinis repens* was already present in TDF in southern Sonora along the Río Cuchujaqui in 1993 (Van Devender), the Sierra de Álamos in 1993 (Van Devender), and the Río Mayo in 1996 (Richard S. Felger).

In February 1995, Felger collected *M. repens* in the remote Cañón Las Barajitas in the Sierra Aguaje north of San Carlos, Sonora. This is an isolated mountain range on the coast of the Gulf of California in the southernmost Sonoran Desert with tropical thornscrub species on its slopes. Laura Moreno-M. and Sánchez-E. found it occasionally in Cañón La Balandrona in October 1999 and Cañón Los Anegados in May 2000 (Figure 2B). By December 2001, Felger and Sánchez-E found it common and widespread in Cañón La Balandrona. Today these areas are completely dominated by *M. repens*, likely in response to heavy rains from Hurricanes Henrieta (2007), Norberto (2008), and Jimena (2009). In 1984, J.E. Hoffman collected *M. repens* along MEX2 in the Sierra Pinito (Figure 3). In April 2009, it had covered and burned the entire southern slopes of the range.

There are currently 338 records of *M. repens* from Sonora in the SEINet databases. It is widely distributed in the state except for the lower, drier, hotter Sonoran Desert in the west. It is rare or absent between Nogales and the Chihuahuan border, likely due to colder winter temperatures in grassland valleys.

In August 2004, Van Devender and Reina-G. saw a slope in the Mule Mountains along AZ80 northwest of Bisbee covered with *M. repens*. Based on their observations in Mexico, they raised the alarm about its invasive potential to Arizona conservationists. Today, its range in Arizona extends to a large cluster centered on Tucson and the Santa Catalina Mountains, with outlier collections to the north in Aravaipa Canyon, Dragoon Mountains (Doug Ripley and Jim Verrier), Galiuro Mountains (David Bertelsen), and the Picacho Mountains (John F. Wiens). We expect the range of *M. repens* to expand northward with continued global warming.

Eruca vesicaria subsp. *sativa*. Arugula, salad rocket.

Eruca vesicaria var. *sativa* is a spicy green used in salads, especially in Italy (Figure 4). This European annual has been reported as invasive in numerous countries. In North America, it is widespread from Canada to southern Mexico (Felger 2000). In Arizona and Sonora, it is a winter-spring annual (February to May). In Arizona, it was reported as occasional escapees from vegetable gardens from 1906 through 1962. Although it was known from near Gila Bend since 1960, it has recently exploded in this area as far west as Sentinel and Yuma. In the wet spring of 2005, it was the most abundant annual from Gila Bend west along I-8 for 70 kilometers in an area of at least several hundred square kilometers. The plants reached about a meter tall and extended in an almost unbroken carpet beyond the highway in both directions across undisturbed valleys and rocky slopes.

In Sonora, *E. vesicaria* was collected in 1912 in southern Sonora at Ontagota in the Yaqui Valley, likely grown in a community garden. In 1915, this American mining settlement was overrun by Yaqui Indians in the strife of the Mexican Revolution. More recent records of *E. vesicaria* in northwestern Sonora in the Lower Colorado River Valley subdivision of the Sonoran Desert were from San Luis Río Colorado and Sonoyta (Felger 2000). The Sonoyta population, likely from the Gila Bend population via AZ85, has been persistent since 2013 or earlier along MEX8 on the southwest side of town, and both west and southeast along MEX2 in Sonoran desertscrub at 324 to 442 m elevation.

In 2007, *E. vesicaria* was found along MEX2 west and east of Agua Prieta (adjacent to Douglas, Arizona) in Chihuahuan

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Figure 4. *Eruca vesicaria* var. *sativa* from west-northwest of Sonoyta. February 2013. A. flower. B. Leaf. *Photos by T.R. Van Devender*

Notes on Non-Native Plants in Sonora *continued*

desertscrub at 1215 to 1321 m elevation. It has been collected east of Agua Prieta in desert grassland along MEX2 in Sonora at 1495 to 1499 m elevation (2009–2010), and in Chihuahua at 1533 m elevation.

Eruca vesicaria has also been collected in a few other localities in Sonora. In 2020, it was found along with *Brassica tournefortii* (Sahara mustard, *mostaza del Sahara*) in a cemetery along MEX 15 at Estación Llano in the Plains of Sonora subdivision of the Sonoran Desert in central Sonora. In 2012 it was collected along SON 104 near Moctezuma in foothills thornscrub at 637 m elevation in central Sonora. In 2005, it was found at Agua Amarilla along MEX16 west of Yécora in east-central Sonora. This is an unusual relictual pine-oak forest on hydrothermally altered soils in a tropical deciduous forest at 900 m elevation.

The conservation community in Arizona is concerned about *E. vesicaria* as an invasive species in the Sonoran Desert in Arizona below 610 m elevation. However, collections in Sonora demonstrate that it is adaptable and can live in more tropical areas as well as at higher elevations in colder habitats. It is clear that highways are the main dispersal vectors and that it only rarely enters natural habitats away from them.

Invaders from the North

Several non-natives have entered Sonora from Arizona in the north.

Eragrostis lehmanniana (Lehmann's lovegrass)

This is a notorious invasive species in desert grassland in Arizona. Surprisingly, in Sonora it is mostly found within 50 kilometers of the Arizona border in the northeastern part of the state. Most records are in desert grassland or Chihuahuan desertscrub at 1140 to 1775 m elevation from Cananea to Agua Prieta and east to the Chihuahua border in the Sierra San Luis. Outliers have been found in the Sierra La Madera west-northwest of Magdalena de Kino (Sonoran desertscrub, 740 m elevation), Sierra Buenos Aires (desert grassland, 670 m elevation, and oak woodland, 1707 m elevation), and Rancho San Fernando, Sierra La Madera near Moctezuma (oak woodland, 1490 m elevation). *Eragrostis lehmanniana* has not reached desert grassland in many areas to the south. In Sonora, it is a serious invasive only in the foothills of the Sierra San José near Naco and in the Sierra San Luis (Figure 5).

Eragrostis echinochloidea (African lovegrass)

This is a South African perennial grass that is most common in Arizona in the Santa Catalina Mountains and Tucson, where it has recently expanded into lower elevations. *Eragrostis echinochloidea* has been found as far north as Phoenix, east to Willcox, south to Rio Rico and the southwestern side of the Santa Rita Mountains. It extends from Tombstone to the Mule Mountains and south to Bisbee. It occurs close to the border in the Buenos Aires National Wildlife Refuge in the Altar Valley and near Naco. It has only been found in two places in Sonora: the MEX 15 bypass in Magdalena de Kino and Rancho Las Playitas near Bacoachi. The Las Playitas locality is on a working cattle ranch not close to a highway. *E. lehmanniana* has not reached this desert grassland yet.

Eragrostis superba (Wilman lovegrass)

This is another African grass that is known from the Superstition Mountains near Phoenix and the Verde Valley as far south the

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Notes on Non-Native Plants in Sonora *continued*

Figure 5. Desert grassland invaded by *Eragrostis lehmanniana* on the lower slopes of the Sierra San José near Naco. September 2017. *Photo by Dale S. Turner*

Sonoran border (Figure 6A). It is especially common in the northern Santa Rita Mountains and from Nogales northwest to Ruby and Arivaca. It is known to be close to the border in Nogales, the Patagonia and Huachuca Mountains, Naco, and the San Bernardino National Wildlife Refuge east of Douglas. The only record from Sonora is from Rancho Los Fresnos near the border just southwest of the Huachuca Mountains. We expect the range of *Eragrostis superb*a to expand farther into Sonora. *E. echinochloidea* and *E. superba* are not yet invasive in Sonora.

Bromus rubens (red brome) and *B. tectorum* (cheatgrass)

These winter annual grasses are native to Eurasia and Africa and are serious invasive species in the western United States that are fire prone, causing extensive damage to natural communities. *Bromus rubens* has only been collected in a few places in Sonora (Figure 6B). It was collected on Pinacate Peak in the El Pinacate and Gran Desierto de Altar Biosphere Reserve from 1985 to 1987, and in Sonoyta in 1992. The only Sonoran record of *B. tectorum* was at El Papalote in the northernmost Pinacates northwest of Sonoyta in 1986. Van Devender and Reina-G. led Arizona Native Plant Society groups to the Pinacates in 2012 and 2019. They also did plant inventories throughout the Sonoyta area in 2012–2013. Neither *B. rubens* nor *B. tectorum* were found in these intensive spring surveys, suggesting a brief southern range extension during wet winters in the late 1980s. In 2005, *B. rubens* was found in the Sierra El Humo, which is ca. 39 kilometers southwest of the Baboquivari Mountains in Arizona. *B. rubens* has also been found in Arroyo Guadalupe 40 kilometers east of Agua Prieta in northeastern Sonora. The plants were close to the border and likely spread from the disturbance along the border patrol road on the Arizona side of the border. Winter rainfall annuals like these will likely decline with increased winter drought in the future.

Oncosiphon piluliferum (stinknet, *manzanilla apestosa*)

This winter-spring annual is native to South Africa and is invasive in the United States in California and Arizona (Figure 7). In Arizona, it flowers from February to May. First seen in Los Angeles and San Diego in the early 1980s, it heavily infested the counties between those cities. It was first collected in Phoenix in 1997 and began to expand rapidly about 2005. It is presently a serious invasive throughout Maricopa County. In March 2005, Sue Rutman found it along US85 in Organ Pipe Cactus National Monument in Pima County. Reina-G found it in March 2020 along the border road near the wall construction in the Monument. It was first seen in Tucson in March 2015 (Reina-G. and Van Devender). All of these localities are areas where heavy equipment from Phoenix was parked. John F. Scheuring mounted an intensive control program in Tucson soon after its discovery. In April 2019, Rutman found an infestation at Three Points west of Tucson, In April 2020, Reina-G. and Van Devender found a population in the cemetery in Arivaca. In April 2020, Alejandro Ramos found it in a neighborhood in Hermosillo, Sonora. It was likely transported on the tires of a personal vehicle returning from a family visit to relatives in the Phoenix area. It is not yet invasive in Sonora but has high potential. The only other

Figure 6. A. *Eragrostis superba fruit*. October 2007. *Photo by T.R. Van Devender*
B. *Bromus rubens.* Diablo Canyon, Ajo Mountains. March 2020. *Photo by Diane Drobka*

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Figure 7. *Oncosiphon piluliferum*. A. and C. Dense infestation, flowers. Arizona Department of Transportation heavy vehicle parking area on upper right. Prince Road at I-10, Tucson. April 2015. *Photos by T.R. Van Devender.* B. Plant. Colonia Apolo, Hermosillo. April 2020. *Photo by Alejandro Ramos.*

Notes on Non-Native Plants in Sonora *continued*

observations from Mexico are in Baja California in Tijuana (2.9 km south of the California border).

North Out of the Tropics

Non-native plants have been moving northward along MEX 15 in Sonora.

Dichanthium annulatum (Kleberg bluestem, *zacate carretero*)

This African forage grass was a common roadside weed in southern Sonora in the early 1990s (Martin et al. 1998), as well as in south Texas (Best 2009). This grass occurs from tropical areas near Álamos and Navojoa in southern Sonora north to near Querobabi in the Plains of Sonora subdivision of the Sonoran Desert about 140 km south of the Arizona border. An outlier population was collected from the Sierra Anibácachi 10 km south of the border at Agua Prieta. In Arizona, it has persisted at a truck stop along the Mariposa Road northwest of Nogales since 2005. In 2003, *D. annualatum* escaped from Biosphere 2 in Oracle (Felger et al. 2005). It was later collected near Tucson (Van Devender and Reina-G., 2004), Tempe (Dixie Z. Damrel, 2005), New River north of Phoenix (Darin Jenke, 2011), and the Santa Cruz River in Tucson (Reina-G., 2014). We can expect to find this grass in more areas in northern Sonora and southern Arizona.

Leucaena leucocephala (white leadtree, *guaje*)

This tree is native to southern Mexico and northern Central America but is introduced throughout the tropics (Figure 8). This "miracle" tree has been used for forage, pulpwood for paper, and the young pods and seeds are eaten by people. But it is highly invasive in many parts of the world. Howard S. Gentry's book "Río Mayo Plants" was the first extensive floristic study of tropical deciduous forest in northwestern Mexico (Gentry 1942). He did not find *L. leucocephala* in his 1933–1939 fieldwork. Since then, this tree has expanded into most of Sonora except for the Sonoran Desert in the northwest. It follows roads and riparian drainages and is common in urban areas. In Arizona, it is most common around Phoenix, but recent reports suggest that it is expanding in the Tucson area. We expect the range of *L. leucocephala* to expand northward with continued global warming.

Ricinus communis (castor bean, *higuerilla*)

Ricinus communis is a large perennial herb native to the southeastern Mediterranean region, eastern Africa, and India, but is introduced throughout tropical regions and widely grown elsewhere as an ornamental plant (Figure 9). Gentry (1942) did not record it in the Río Mayo flora in southern Sonora. Since then, it has expanded into most of the state except for the

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Notes on Non-Native Plants in Sonora *continued*

Sonoran Desert in the northwest. It extended into the Sonoran Desert near Hermosillo along the Río Sonora. It was also collected in 1973 in Arroyo San Ignacio northwest of the Seri Indian village Desemboque along the coast of the Gulf of California (Richard S. Felger, 1973). The northernmost record is near Terrenate on the Río Magdalena (69 km south of the Arizona border). We expect the range of *R. communis* to expand northward with continued global warming.

Climate Fluctuations

Plants often thrive and expand their ranges during periods of good climatic conditions and contract during droughts or after catastrophic freezes. By the summer of 2006, it was estimated that ca. 1 million hectares of *Cenchrus ciliaris* had been planted in Sonora (Ibarra-F. et al. 2009). It is now ubiquitous but not noticeably expanding its range. The survival and condition of planted pastures often reflect climatic fluctuations. The abundances of common, relatively non-invasive species like *Descurainia sophia* (common tansy mustard) and *Sisymbrium irio* (London rocket, *pamitón*) fluctuate dramatically tracking winter rainfall. Above, we reported the expansion of *Eruca vesicaria* in the Gila Bend area in the wet spring of 2005. *Bassia scoparia* (summer cypress, burningbush) is a large summer annual native to Eurasia that is widespread and common in the western United States. In Sonora, it has only been seen a few times along the Arizona border from Naco east to Agua Prieta and the Animas Valley. In July to August 2010, there was a large

Figure 8. *Leucaena leucocephala* in Hermosillo, Sonora. February 2018. *Photo by J. J. Sánchez-E.*

population in Esqueda along MEX17 and the railroad. It was not present in subsequent years.

Changes in abundance and distribution are normal in environments with fluctuating climates. Species usually have an environmental zone where they are invasive, while at higher or lower elevations, they may only be present. What is not obvious is that exceptionally favorable conditions may be triggers that release non-natives into new areas or habitats. The expansion of *Pennistetum cilare* and *Brassica tournefortii* (Dimmitt and Van Devender 2009) likely occurred in this manner. With global climate warming and redistribution of seasonal rains, we can expect summer rainfall non-natives to expand more rapidly than expected, and some winter-rainfall non-natives to contract their ranges.

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Figure 9A. *Ricinus communis.* A, C. Plant; flowers and fruit. Rancho San Antonio near Playa San Bartolo, Costa de Hermosillo. January 2020. *Photo by J.J. Sánchez-E.* B. Flowers. Colonia La Manga, Hermosillo. December 2010. *Photo by A.L. Reina-G.*

Notes on Non-Native Plants in Sonora *continued*

Acknowledgments

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Table 1. Non-native species of Sonora, Mexico. * = invasive species.

Acanthaceae

Justicia spicigera. Firecracker bush, *niple*. Shrub. Mexico to South America.

Odontonema cuspidatum. Firespike. Shrub. Mexico to Central America.

Ruellia malacosperma. Softseed wild petunia. Perennial herb. Mexico.

Aizoaceae

Mesembryanthemum nodiflorum. Slenderleaf ice plant, *hielitos.* Annual. Africa.

**Mesembryanthemum crystallinum*. Ice plant, *hielitos*. Annual. Africa, Eurasia.

Amaranthaceae

Amaranthus albus. Prostrate pigweed, *quelite.* Annual. Mexico to Central America.

Amaranthus cruentus. Red amaranth Annual. Central America.

Atriplex semibaccata. Australian saltbush, *chamizo*. Perennial herb. Australia.

Bassia hyssopifolia. Fivehorn smotherweed, *salado negro*. Annual. Eurasia.

Chenopodiastrum murale. Nettleleaf goosefoot, *chual.* Annual. Europe.

Chenopodium album. Lamb's quarters. Annual. Europe.

Salsola paulsenii. Barbwire Russian thistle. Annual. Eurasia.

**Bassia scoparia*. Summer cypress, burningbush, *coquia*. Annual. Asia.

**Salsola tragus*. Russian thistle, *chamizo volador*. Annual. Eurasia.

Anacardiaceae

Schinus molle. Brazilian peppertree, *pimiento*, *pirul*. Tree. South America.

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Table 1. Non-native species of Sonora, Mexico. * = invasive species.

Spondias purpurea. Hog plum, *yoyomo, ciruelo*. Tree. Mexico to South America.

Apiaceae

Ammi majus. Bishop's weed, *encaje*. Annual. Africa, Europe.

Anethum graveolens. Dill, *eneldo*. Annual. Europe.

Ciclospermum leptophyllum. Marsh parsley. Annual. South America.

Coriandrum sativum. Coriander, *cilantro.* Annual. Europe.

Foeniculum vulgare. Sweet fennel, *hinojo*. Perennial herb. Africa, Eurasia.

Apocynaceae

Cascabela thevetioides. Luckynut. Shrub. Mexico to South America.

Nerium oleander. Oleander, laurel. Shrub. Africa, Eurasia.

**Cryptostegia grandiflora*. Indian rubbervine, *clavel de España*. Woody vine. Madagascar

Araceae

Colocasia esculenta. Wild taro. Perennial herb. Asia.

Arecaceae

Phoenix dactylifera. Date palm, *palma datilera.* Tree. Africa.

Washingtonia filifera. California fan palm, *palma*. Tree. Western United States and Canada.

Asparagaceae

Agave fourcroides. Henequen. Rosette succulent. Mexico.

Asparagus officinalis. Asparagus, *aspárrago.* Perennial herb. North Africa, Eurasia.

Asphodelaceae

Asphodelus fistulosus. Onionweed. Perennial herb. Eurasia.

Asteraceae

Acroptilon (*Centaurea*) *repens*. Russian knapweed. Perennial herb. Eurasia.

Calendula officinalis. Scotch marigold. Perennial herb. Europe.

Carthamus tinctorius. Safflower, *cártamo*. Annual. Asia.

Centaurea melitensis. Malta starthistle, *tocolote*. Annual. Africa, Europe.

Chrysanthemum coronarium. Crown daisy. Annual. Eurasia.

Cichorium intybus. Chicory Perennial herb. Africa, Eurasia.

Cotula australis. Annual. Australia-New Zealand

Lactuca saligna. Willowleaf lettuce. Annual. Africa, Europe.

Lactuca serriola. Prickly lettuce. Annual. Europe.

Oncosiphon piluliferum. Stinknet, *manzanilla apestosa*. Annual. South Africa.

Pseudognaphalium luteoalbum. Jersey cudweed. Annual. Africa, Eurasia.

Senecio vulgaris. Common groundsel. Annual. Europe.

Silybum marianum. Milk thistle. Annual. Africa, Eurasia.

Sonchus arvensis subsp. *uliginosus*. Spiny sowthistle, *chinita*. Annual. Europe.

Sonchus asper subsp. *asper*. Spiny sowthistle, *chinita*. Annual. Europe.

Sonchus oleraceus. Common sowthistle, *chinita*. Annual. Europe.

Sonchus tenerrimus. Common sowthistle, *chinita*. Annual. Europe.

Tagetes minuta. Annual. South America.

Taraxacum officinale. Common dandelion, *diente de león*. Perennial herb. Eurasia.

Zinnia peruviana cultivar. Zinnia, *india.* Annual. Southwest United States to Mexico.

Balsaminaceae

Impatiens balsamina. Garden balsam. Annual. Asia.

Bignoniaceae

Crescentia alata. Gourd tree, *ayal, tecomate*. Tree. Mexico to Central America.

Tecoma stans var. *stans*. Trumpetbush, *gloria, lluvia de oro*. Tree. Mexico to South America.

Brassicaceae

Brassica juncea. Chinese mustard, brown mustard, *mostaza*. Annual. Africa, Eurasia.

Capsella bursa-pastoris. Shepherd's purse, *bolsa del pastor*. Annual. Europe.

Cardamine cf. *oligosperma*. Bittercress, *berro amargo*. Annual. Western United States and Canada.

Chorispora tenella. Purple mustard, crossflower. Annual. Eurasia.

Erysimum repandum. Spreading wallflower. Annual. Europe.

Hirschfeldia incana. Greek mustard, *mostacilla*. Annual. Europe.

Nasturtium officinale. Watercress, *berro*. Perennial herb. Europe.

Raphanus raphanistrum. Wild radish, *rábano silvestre*. Annual. Eurasia.

Raphanus sativus. Cultivated raddish, *rábano*. Annual. Europe.

Rapistrum rugosum. Annual bastard cabbage, *mostaza*. Annual. Africa, Eurasia.

Sinapis arvensis. Charlock mustard, *mostaza*. Annual. Europe.

Sisymbrium irio. London rocket, *pamitón*. Annual. Europe.

Sisymbrium orientale. Indian hedge mustard, *pámita.* Annual. Europe.

Thlaspi arvense. Field pennycress Annual. Africa, Eurasia.

**Brassica nigra*. Black mustard, *mostaza*. Annual. Europe.

**Brassica rapa*. Field mustard, *nabo.* Annual. Asia.

**Brassica tournefortii*. Sahara mustard, *mostaza del Sahara*. Annual. North Africa, Europe.

**Descurainia sophia*. Common tansy mustard. Annual. Africa, Europe.

**Eruca vesicaria* subsp. *sativa*. Arugula, salad rocket. Annual. Europe.

**Lepidium didymum*. Procumbent pepperwort. Annual. South America.

Cactaceae

Opuntia engelmannii var. *linguiformis.* Cow's tongue prickly pear cactus, *nopal.* Stem succulent. Texas, Coahuila, Mexico.

Peniocereus serpentinus. Snake cactus, *reina de la noche*. Stem succulent. Mexico.

Campanulaceae

Hippobroma longiflora. Star of Bethlehem, *revienta caballo*. Annual. Caribbean.

Cannabaceae

Cannabis sativa. Marijuana, *marihuana, mota*. Annual. Asia.

Capparaceae

Cleome aculeata. Prickly spiderflower. Annual. South America.

**Cleome viscosa*. Asian spiderflower, Sticky beeplant. Annual. Africa, Australia.

Caryophyllaceae

Corrigiola andina. *Corrigiola*. Annual. South America

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Table 1. Non-native species of Sonora, Mexico. * = invasive species.

Herniaria hirsuta subsp. *cinerea.* Hairy rupturewort. Annual. Africa, Eurasia.

Saponaria officinalis. Soapwort, *jabón de palo*. Perennial herb. Europe.

Convolvulaceae

Cuscuta tinctoria. Dodder, *barba de león*. Annual. Mexico to Guatamala.

Ipomoea carnea subsp. *fistulosa.* Bush morning glory, *gloria de la mañana*. Shrub. Mexico to South America.

Ipomoea heptaphylla. Palmleaf morning glory, *trompillo.* Annual vine. Southeastern United States to South America, Old World.

Ipomoea X *leucantha*. Morning glory, *trompillo.* Perennial herb. Central and southeastern United States to Mexico.

Merremia dissecta. Noyau vine, *trompillo blanco casero*. Woody vine. Mexico to South America.

**Convolvulus arvensis.* Common bindweed, *correhuela.* Perennial herb. Europe.

Cucurbitaceae

Citrullus lanatus. Watermelon, *sandía.* Annual vine. Africa.

Cucumis anguria. Burr cucumber, *pepinito espinoso.* Annual vine. Africa.

Cucumis dipsaceus. Hedgehog gourd, *huevos de gato*. Annual vine. Africa.

Cucumis melo var. *cantalupo*. Cantaloupe, *melón*. Annual vine. Europe.

Cucumis melo var. *dudaim.* Dudaim melon, *melón granada.* Annual. Africa.

Cucumis sativus. Garden cucumber, *pepino*. Annual. Asia.

Lagenaria siceraria. Bottle gourd, bule. Annual vine. Africa.

Luffa aegyptiaca. Sponge gourd, *estropajo*. Annual vine. Africa, Asia.

Momordica charantia. Bitter melon, *melón amargo*. Annual vine. Old World tropics.

Cyperaceae

Cyperus difformis. Variable flatsedge. Annual. Old World tropics.

Cyperus involucratus. Umbrella papyrus, *papiro.* Perennial herb. Madagascar

Cyperus iria. Ricefield flatsedge. Annual. Africa, Australasia.

Cyperus rotundus. Nutsedge, *coquillo*. Perennial herb. Africa, Eurasia.

Euphorbiaceae

Euphorbia hypericifolia. Spurge, *golondrina*. Annual. Pantropical.

Euphorbia peplus. Spurge, *golondrina.* Annual. Eurasia.

Euphorbia velleriflora. Spurge, *golondrina*. Perennial herb. Mexico to Central America

Jatropha gossypiifolia. Shrub. Mexico, South America, and the Caribbean islands

**Ricinus communis*. Castor bean, *higuerilla*. Perennial herb. Africa, Eurasia.

Fabaceae

Arachis hypogaea. Peanut, *cacahuate.* Annual. South America.

Caesalpinia gilliesii. Yellow bird-of paradise, *tabachín amarillo*. Shrub. South America.

Gleditsia triacanthos. Honeylocust. Tree. Central United States.

Gliricidia sepium. Quickstick, *mata ratón, madre de cacao*. Tree. Mexico to Central America.

Medicago lupulina. Black medick, *trébol de flor amarilla*. Annual. Africa, Eurasia.

Medicago polymorpha. Burclover, *trébol*. Annual. Eurasia.

Medicago sativa. Alfalfa. Annual. Eurasia.

Melilotus albus. White sweetclover, *trébol*. Annual. Europe.

Melilotus indica. Sourclover, *trébol amargo.* Annual. North Africa, Eurasia.

Melilotus officinalis. Yellow sweetclover, *trébol.* Annual. Eurasia.

Pediomelum rhombifolium. Gulf Indian breadroot. Perennial herb. Southwestern United States to Mexico.

Phaseolus vulgaris. Common bean, *frijol.* Annual. Mexico to Central America.

Prosopis aff. *chilensis.* Chilean mesquite, *mezquite chileno*. Tree. South America.

Prosopis glandulosa var. *glandulosa*. Texas mesquite, *mezquite.* Tree. United States (Kansas to Texas) to northeastern Mexico

Spartium junceum. Spanish broom. Shrub. Europe.

**Leucaena leucocephala*. White leadtree, *guaje.* Tree. Southern Mexico. Northern Central America.

**Parkinsonia aculeata*. Mexican paloverde, *guacaporo.* Tree. Caribbean, South America.

Fumaricaceae

Fumaria officinalis. Common fumitory. Annual. Eurasia.

Fumaria parviflora. Fineleaf fumitory. Annual. Europe.

Gelsemiaceae

Gelsemium sempervirens. Evening trumpetflower. Woody vine. Southeastern United States to Central America.

Geraniaceae

Erodium cicutarium. Filaree, *alfilerillo*. Annual. Europe.

Halogoraceae

Myriophyllum spicatum. Eurasian watermilfoil, *pluma de perico*. Perennial herb. North Africa, Eurasia.

Hemerocallidaceae

Hemerocallis fulva. Orange daylily. Perennial herb. Europe.

Lamiaceae

Lamium amplexicaule. Henbit deadnettle. Annual. North Africa, Eurasia.

Leonotis nepetaefolia. Lion's ear, *cordoncillo de San Francisco*. Annual. Pantropical.

Marrubium vulgare. Horehound, *marrubio*. Perennial herb. North Africa, Eurasia.

Mentha spicata. Spearmint, *hierbabuena*. Perennial herb. Eurasia.

Ocimum basilicum. Common basil, *albahacar.* Perennial herb. Africa.

Physostegia virginiana. Obedient plant. Perennial herb. United States.

Vitex rotundifolia. Chastetree, *carnavalito.* Shrub. Australasia.

Malvaceae

Abutilon theophrasti. Velvetleaf. Annual. Asia.

Corchorus olitorius. Nalta jute. Shrub. Asia.

Gossypium hirsutum. Upland cotton, *algodón.* Annual. Central America.

Hibiscus syriacus. Rose of Sharon. Shrub. China

Malva parviflora. Cheeseweed mallow, *malva.* Annual. Eurasia.

Meliaceae

Melia azederach. Chinaberry tree, *piocha.* Tree. Asia.

Molluginaceae

Mollugo cerviana. Carpetweed. Annual. Europe.

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Table 1. Non-native species of Sonora, Mexico. * = invasive species.

Moraceae

Ficus carica. Fig, *higuera*. Tree. Asia.

Morus alba. Common mulberry, *mora*. Tree. Asia.

Myrtaceae

Eucalyptus camaldulensis. River redgum, *eucalipto*. Tree. Australia.

Psidium guajava. Guava, *guayab*a. Tree. Southern Mexico to Central America.

Nyctaginaceae

Mirabilis jalapa. Four o'clock, *maravilla*. Perennial herb. South America.

Onagraceae

Oenothera speciosa. Pink primrose. Perennial herb. Southeastern United States to Mexico.

Papaveraceae

Papaver somniferum. Opium poppy, *amapola*. Annual. Europe.

**Glaucium corniculatum*. Blackspot hornpoppy. Annual. Eurasia.

Pedaliaceae

Sesamum orientale. Sesame, *ajonjolí*. Annual. Asia.

Pinaceae

Pinus sylvestris. Scots pine, *pino rojo*. Tree. Eurasia.

Plantaginaceae

Plantago major. Common plantain, *plantén*. Perennial herb. Eurasia.

Veronica anagallis-aquatica. Water speedwell. Perennial herb. Africa, Europe.

Veronica persica. Birdeye speedwell. Annual. Asia.

Poaceae

Avena sativa. Oats, *avena*. Annual. Europe.

Bothriochloa ischaemum. King Ranch bluestem, Texas yellow beardgrass. Perennial herb. Eurasia.

Bothriochloa pertusa. Pitted beardgrass. Perennial herb. Africa, Asia.

Bromus berterianus. Chilean grass Annual. South America.

Bromus catharticus. Rescue grass. Annual. South America.

Bromus rubens. Red brome. Annual. Africa, Eurasia.

Bromus tectorum. Cheatgrass. Annual. Africa, Eurasia.

Cenchrus brownii. Slimbristle sandbur, *guachapori*. Annual. Mexico to South America.

Chloris barbata. Swollen fingergrass, *zacate borregero*. Annual. Australia.

Chloris verticillata. Tumble windmill grass. Perennial herb. Central United States.

Dactyloctenium aegyptium. Crowfootgrass. Annual. Old World tropics.

Dichanthium aristatum. Angleton bluestem. Perennial herb. Asia.

Digitaria bicornis. Asian crabgrass. Perennial herb. Australasia.

Digitaria ischaemum. Smooth crabgrass. Annual. Eurasia.

Digitaria sanguinalis. Hairy crabgrass. Annual. Eurasia.

Digitaria ternata. Blackseed crabgrass. Annual. Africa, Asia.

Echinochloa colonum. Jungle ricegrass. Annual. Old World tropics.

Echinochloa crusgalli var. *crusgalli*. Barnyard grass. Annual. Asia.

Echinochloa crusgalli var. *zelayensis* . Cockspur, Japanese millet. Annual. Asia

Echinochloa crus-pavonis. Gulf cockspur grass. Annual. Africa, Eurasia.

Eleusine indica. Indian goosegrass. Annual. Old World tropics.

Eragrostis barrelieri. Mediterranean lovegrass. Annual. Eurasia.

Eragrostis cilianensis. Stinkgrass, *zacate apestoso*. Annual. Africa, Eurasia.

Eragrostis ciliaris var. *ciliaris*. Gophertail grass. Annual. Africa, Asia.

Eragrostis curvula. Weeping lovegrass. Perennial herb. Africa.

Eragrostis echinochloidea. African lovegrass. Perennial herb. Africa.

Eragrostis pilosa var. *pilosa*. Indian lovegrass. Annual. Africa, Eurasia.

Eragrostis superba. Wilman lovegrass. Perennial herb. Africa.

Eragrostis unioloides. Bug's eye grass. Annual. Africa, Asia.

Festuca arundinacea. Tall fescue. Annual. Africa, Eurasia

Festuca perennis. Perennial ryegrass. Perennial herb. Africa, Eurasia.

Festuca temulenta subsp. *temulenta*. Darnel ryegrass. Annual. Europe.

Hackelochloa granularis. Pitscale grass. Annual. Africa, Australasia.

Hordeum aegiceras. Beardless common barley, *cebada*. Annual. Asia.

Hordeum marinum subsp. *gussoneanum*. Mediterranean barley, *cebada*. Annual. Africa, Eurasia.

Hordeum murinum subsp. *glaucum*. Foxtail barley, *cebada*. Annual. Africa, Eurasia.

Hordeum murinum subsp. *leporinum*. Mouse barley, *cebada*. Annual. Africa, Europe.

Hordeum vulgare. Common barley, *cebada*. Annual. Africa, Asia.

Megathyrsus (*Panicum*) *maximus*. Guineagrass. Perennial herb. Africa, Asia.

**Melinis repens*. Natalgrass, *zacate rosado*. Perennial herb. Southern Africa.

Panicum antidotale. Blue panicgrass, *zacate panizo azu*l. Perennial herb. Asia.

Panicum coloratum. Kleingrass, *zacate klein*. Perennial herb. Africa.

Panicum miliaceum. Broomcorn millet. Annual. Asia.

Paspalum dilatatum. Dallisgrass. Perennial herb. South America.

Pennisetum ciliare. Buffelgrass. Perennial herb. Southern Africa.

Pennisetum setaceum. Fountaingrass, *plumitas*. Perennial herb. Africa, Asia.

Phalaris canariensis. Canarygrass. Annual. Africa.

Phalaris minor. Littleseed canarygrass. Annual. Africa, Eurasia.

Phalaris paradoxa. Hood canarygrass. Annual. Africa, Eurasia.

Poa annua. Annual bluegrass. Annual. Europe.

Polypogon viridis. Beardless rabbitfoot grass. Perennial herb. Africa, Eurasia.

Schedonus arundinaceus. Tall fescue. Perennial herb. Africa, Eurasia.

Setaria adhaerans. Bur bristlegrass. Annual. Pantropical.

Setaria pumila. Yellow bristlegrass. Annual. Old World tropics.

Setaria setosa. West Indian bristlegrass. Perennial herb. South America.

Sorghum bicolor. Sweet sorghum, *sorgo*. Annual. Africa.

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Table 1. Non-native species of Sonora, Mexico. * = invasive species.

Sorghum X *almum*. Columbus grass, *zacate maravilla*. Perennial herb. South America.

Stenotaphrum secundatum. Saint Augustine grass. Perennial herb. Africa, South America.

Tragus berteronianus. Spiked burgrass Annual. Africa, Asia.

Triticum aestivum. Common wheat, *trigo.* Annual. Old World.

Urochloa panicoides. Liverseed grass. Annual. South Africa.

Urochloa reptans. Running grass. Annual. Asia.

Zea mays var. *mays*. Corn, *maiz.* Annual. Mexico.

Zea mays var. *mexicana. Teosinte.* Annual. Mexico.

**Arundo donax*. Giant reed*, carrizo.* Shrub. Asia.

**Avena fatua*. Wild oat, *avena silvestre*. Annual. Eurasia.

**Cenchrus ciliaris*. Buffelgrass, *zacate buffel.* Perennial herb. Africa, Eurasia.

**Cynodon dactylon*. Bermudagrass, *zacate inglés*. Perennial herb. Asia.

**Dichanthium annulatum*. Kleberg bluestem, *zacate carretero*. Perennial herb. Africa, Asia.

**Eragrostis lehmanniana*. Lehmann lovegrass, *zacate africano*. Perennial herb. Africa.

**Polypogon monspeliensis*. Rabbitfoot grass, *zacate cola de zorra*. Annual. Africa, Eurasia.

**Schismus arabicus*. Arabian grass. Annual. Africa, Eurasia.

**Schismus barbatus*. Mediterranean grass. Annual. Africa, Eurasia.

**Sorghum halepense*. Johnsongrass, zacate Johnson. Perennial herb. Africa, Asia.

Polygonaceae

Pericaria persicaria. Spotted ladysthumb. Perennial herb. Eurasia.

Polygonum argyrocoleon. Silversheath knotweed. Annual. Eurasia.

Polygonum aviculare. Prostrate knotweed. Perennial herb. Worldwide.

Polygonum convolvulus. Black bindweed, *azahar de novio*. Annual. Eurasia.

Rumex aceosella. Sheep's sorrel. Perennial herb. Eurasia, British Isles.

Rumex crispus. Curly dock. Perennial herb. Africa, Eurasia.

Rumex obtusifolius. Bitter dock. Perennial herb. Africa, Eurasia.

Rumex stenophyllus. Narrowleaf dock. Perennial herb. Eurasia.

Pontederiaceae

**Eichhornia azurea*. Anchored water hyacinth. Perennial herb. Mexico to South America.

**Eichhornia crassipes*. Common water hyacinth, patito. Perennial herb. South America.

Primulaceae

Anagallis arvensis. Scarlet pimpernel. Annual. Eurasia.

Anagallis minima. Chaffweed. Annual. Europe.

Pteridaceae

Pteris cretica. Cretan brake. Perennial herb. Africa, Eurasia.

Ranunculaceae

Consolida ajacis. Doubtful knight's spur. Annual. Eurasia.

Rhamnaceae

Ziziphus jujuba. Chinese jujube, *dátil chino*. Tree. Asia.

Rosaceae

Prunus persica. Peach, *durazno*. Tree. Asia.

Pyrus communis. Common pear, *pera*. Tree. Eurasia.

Rutaceae

Casimiroa edulis. White sapote, *zapote blanco*. Tree. Mexico to South America.

Ruta graveolens. Subshrub. Eurasia.

Salviniaceae

**Salvinia molesta*. Giant salvinia, *helecho flotador gigante*. Perennial herb. South America.

Scrophulariaceae

Verbascum virgatum. Wand mullein, *barbasco*. Perennial herb. Africa, Europe.

Simaroubaceae

**Ailanthus altissima*. Tree-of-heaven, *falso nogal*. Tree. Asia.

Solanaceae

Nicandra physalodes. Apple of Peru. Annual. South America.

Nicotiana tabacum. Pima tobacco, *papante, macuchi*. Annual. South America.

Petunia axillaris. Large white petunia*, petunia*. Annual. South America.

Solanum lycopersicum. Tomato*, tomate*. Annual. Mexico to South America.

Solanum pseudocapsicum. Jerusalem cherry, *naranjito de amor.* Shrub. Mexico to South America.

Solanum seaforthianum. Brazilian nightshade, *bellísima.* Woody vine. Central, South America.

**Nicotiana glauca*. Tree tobacco, *Juan loco, palo loco*. Shrub. South America.

**Solanum sisymbrifolium*. Sticky nightshade. Perennial herb. South America.

Tamaricaceae

**Tamarix aphylla*. Athel, *pino salado*. Tree. Africa, Asia.

**Tamarix chinensis*. Saltcedar, *pino salado*. Tree. Asia.

Tropaeolaceae

Tropaeolum majus. Nasturtium, *mastuerzo.* Annual. South America.

Ulmaceae

Ulmus pumila. Siberian elm, *olmo*. Tree. Asia.

Verbenaceae

Glandularia pulchella. South American mock vervain, *alfombrilla.* Perennial herb. South America.

Lantana camara Mozelle cultivar. Lantana, *confituría negra, negrito*. Shrub. Mexico to South America.

Xanthorrhoeaceae

Aloe vera. Aloe, *sábila.* Rosette succulent. North Africa.

Zygophyllaceae

Tribulus cistoides. Jamaican feverplant, burrnut, *toboso.* Perennial herb. Africa, Australasia.

Tribulus terrestris. Puncture vine, *toboso*. Annual. Old World tropics.

Frank (seated in center) and his hiking friends. Santa Catalina Mountains, August 2019. *Photo courtesy Lyn Loveless*

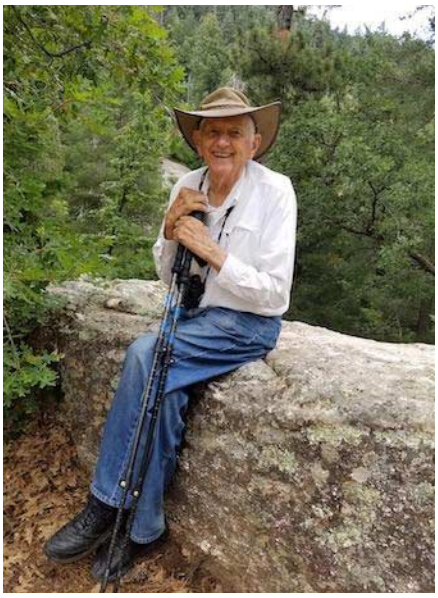
In Memory of Frank S. Rose *(1927–2020)*

by Lyn Loveless and Jim Verrier, Arizona Native Plant Society, Tucson Chapter

Long-time AZNPS member and Tucson botanist Frank S. Rose passed away on October 15, 2020 at his home in Tucson, surrounded by his family. Frank was a warm and steady presence at our monthly meetings and other AZNPS events, greeting old friends, welcoming new ones, and sharing his insights into plant biology. Frank and his wife Louise came to Tucson in 1982, where he served as pastor of the Sunrise Chapel until 2003. Beginning in 2011, he led almost-weekly plant walks at locations in the Santa Catalina Mountains, taking these over from Dr. Bob Porter and Joan Tedford. Frank was generous with his time and his knowledge, and many Tucson naturalists came to learn and appreciate the mountain flora through his efforts. He was also a talented watercolorist, artistry that he practiced most of his life.

Upon arriving in Tucson, he began painting and photographing the wildflowers of his beloved Santa Catalinas. One day, Frank happened to meet Joan Tedford in Molino Basin, while Joan was checking on the status of a single plant of *Clitoria mariana* that had been sighted in the streambed. This chance encounter led to a good friendship and a rich botanical partnership on the mountain. Frank's keen eye would often notice that certain plants seemed different, while Joan would key out and identify Frank's many mystery plants. While Joan would never identify herself as a botanist, she was, in fact, a very good botanist and a passionate plant person who was a botanical mentor to Frank.

The eventual 2011 publication of his book, *Mountain Wildflowers of Southern Arizona: A Field Guide to the Santa Catalina Mountains and other Nearby Ranges*, was a culmination of Frank's conversion to botany. He went on to author several other botanical books: *Mountain Trees of Southern Arizona*, *Small Wonders*, and most recently *Catalina Mountains: A Guide Book with Original Watercolors*. He was an active member of our society and contributed his insights and enthusiasm to our meetings and our outreach. Frank was scheduled to lead two close-to-home plant forays last April, but these were subsequently cancelled because of the pandemic. For many of us, however, every future plant walk we make along the Catalina Highway will be a reminder of Frank's generosity, kindness, and quiet appreciation of the beauty of plants in our lives. He will be deeply missed. Our condolences go to his family and close friends at the loss of a great spirit.



Above: Frank in his element. *Photo courtesy Jeffrey Neff.*

Left: Frank Rose photographing wild orchids, Chiricahua Mountains, July 2016. *Photo courtesy Doug Ripley*

Remembering Frank Rose

by Edward Gelardin, MD
Longtime Friend and Companion

Frank Rose came into the Native Plant Society as a late bloomer. A retired minister, he didn't start his career with plants until the age of 72. But once embarked, he was an enthusiastic student, teacher, and proselytizer. His energy was prodigious. He drove up the mountain two or three times a week to walk the trails with his camera. In the winter he was on the desert trails. He was photographing, painting, or writing about our plants almost every day until he died 21 years later. By that time, he had painted hundreds of watercolor flower portraits and taken thousands of photos of the plants on Mt. Lemmon. This work manifests to us in the forms of a poster, four books, painting exhibitions in art galleries, note cards, interpretive walks (including weekly teaching ones with the Sabino Canyon Naturalists), and illustrated talks to many groups.

In the early years when he was on the trail, he'd pause to chat with other walkers and, after testing to see if they had even a little interest in the flowers around them, he'd introduce them to his book. He always carried extra copies in his car trunk. It was a soft sell, but an effective one. Later on, the situation had reversed. He had become a famous figure on the mountain and in the community. He hardly ever went out on the trail without someone stopping to say to him, "Aren't you Frank Rose?," or someone pulling out one of his guides and saying, "Yes, that's him."

To the end, he still loved to talk with people he knew and those he hadn't known. They, in turn, were universally drawn to this tall, friendly man and they responded to his gentle warmth with affection. He was able to continue his vigorous pace until the last year when his bone marrow wasn't producing enough red blood cells to provide oxygen for his muscles and he became progressively weaker (pancytopenia).

Frank died peacefully at age 93, his mind and spirit going strong till the last, but his body wore out. His works will remain, but his personhood will be missed by those who knew him in AZNPS and beyond.

From left: Richard Felger with *Verbesina felgeri*, Nacapule Canyon, near San Carlos, Sonora, Mexico; October 2015. *Photo courtesy Jim Malusa.* Richard Felger, Tiburón Island, Sonora. April 2007. *Photo courtesy Ben Wilder.*

Pax et Prosopis

Dr. Richard Stephen Felger (19 Aug 1934 – 31 Oct 2020)

Remembering Richard S. Felger and Frank Rose. Sadly, two long-time members and active participants in the Arizona Native Plant Society recently passed away — by Susan D. Carnahan, University of Arizona Herbarium, Tucson

The world lost a great botanist, desert researcher, and ethnobiologist, and I lost a dear friend and colleague, when Richard Felger passed away recently at the age of 86. He died at home in Silver City, New Mexico, with his soulmate and wife of 26 years, Silke Schneider, by his side. It's impossible to summarize Richard's long and rich life in a single page: Taxonomist, Sonoran Desert specialist, ethnoecologist, and new desert crops promoter, sea turtle conservationist and activist, poet, storyteller, and artist; mentor, and friend. (Richard was fond of paraphrasing Mark Twain: Apologies for the long note — I didn't have time to write a short one.)

Richard once told me he was a botanist from the age of eight, when he put a beavertail prickly pear pad in his pocket and discovered glochids. He raised three alligators at his mother's house in Beverly Hills, and when they reached five feet long, "the alligators went to the zoo and I went to the University of Arizona." He chose the U of A because it was close to the coastal Sonoran Desert near Guaymas, Sonora, that had captivated him since a high school field trip. He would go on to write his dissertation on the flora and vegetation of the Sonoran Gulf Coast and nearby islands. He wanted to write about the ethnobotany of the Seri Indians who inhabited the region, but his advisors at the time didn't consider this real science. Years later he coauthored a magnificent book about the Seris with Mary Beck Moser, *People of the Desert and Sea: Ethnobotany of the Seri Indians.* More recently, Richard and coauthor Felipe Molina completed a manuscript on the ethnobiology of the Yaquis of Sonora and Arizona (forthcoming).

Supported by a grant from the Smithsonian Institution, Richard traveled the world researching salt-tolerant food crops for arid landscapes. Closer to home, he championed "nipa" (*Distichlis palmeri*), a grass cultivated by the Cocopah in the tidal waters of the Río Colorado delta. He also promoted low-water, no-till agriculture for crops such as Apache red grass (*Zuloagaea bulbosa*) and mesquite (*Prosopis*) in the Gila region of New Mexico, and harvesting of Sonoran Desert native fruits, including organpipe cactus, desert fan palm, foothills palo verde, and wolfberry (*Lycium*). Richard's mantra for a warming, drying climate was, "Fit the crop to the land, not the land to the crop."

During the 1960s and 70s, Richard forged connections with beat poets Michael McClure, Allen Ginsberg, Gary Snyder, and John Brandi. He wrote poetry, worried about overpopulation, was passionate about wildlife conservation and ecology, and even

continued next page

Pax et Prosopis *continued*

chastised the Japanese minister of finance about whaling at a United Nations Conference on the Human Environment in 1972, earning the thanks of anthropologist Margaret Mead. A book of Richard's poetry, *Dark Horses and Little Turtles and Other Poems from the Anthropocene*, originally published in 1974, was revised and reissued just before his death (**http://polytropos.com**).

In a 2000 essay, "The Seris and the Guy Who Cuts the Tops off Plants" (the title is from the Seris' affectionate nickname for Richard), Richard thanked colleagues and mentors who supported his early research. "You need encouragement, especially when you are young and not sure of yourself," he wrote. Those who were in turn mentored by Richard echo that sentiment: Ben Wilder, who completed a flora of Isla Tiburón—the largest island in the Gulf of California—at Richard's urging and also coauthored several papers and a book (*Plant Life of a Desert Archipelago*) with him, says, "He literally taught me how to be a scientist. He set me on my path. He opened the world to me."

Tucson botanist and plant breeder Mark Dimmitt credits Richard with inspiring his lifelong interest in tillandsias, cycads, and other unusual plants. Ecologist Sula Vanderplank recalls asking Richard to be on her graduate committee, whereupon he made a split-second decision to drive six hours down the Baja Peninsula with her to her study site, collect four specimens, and drive back to the border. Sue Rutman, one of Richard's coauthors for the *Flora of Southwestern Arizona*, notes that he welcomed collaborators on every project and "he had a warm and generous side that too few people experienced… He wanted to help other people love plants the way he did." Jim Verrier, a close friend to Richard and coauthor of the just-published *Field Guide to the Trees of the Gila Region of New Mexico*, adds, "For someone who was so accomplished and prolific, he went out of his way to support and mentor people he liked and saw potential in."

Richard's intensity and productivity were legendary. Frank Reichenbacher recalls, "Richard and I went on a trip to Sonora in 1985, the putative purpose of which was to revisit historic sites for Tumamoc globeberry. Naturally, it devolved into a mass-collecting botanical expedition." Mark Dimmitt recounts a whirlwind trip to the Guaymas region that same year involving a total of 40 hours of driving and collecting over two days in sweltering desert heat. On a field trip to the Pinacate region of Sonora, Dale Turner remembers watching Richard "using the stove in someone's RV to prepare small barrel cactus specimens for pressing. He was dropping them in a big pot of boiling water, muttering cheerfully about shrunken heads." During a precipitous climb up Pinacate Peak, Gene Joseph was getting ready to bail out, but "to my surprise, here was Richard, with two bags stuffed into his belt and another one in his mouth and reaching way out to collect another plant"!

Richard Felger leading a field trip for the Arizona Native Plant Society, Organ Pipe National Monument, March 2016. *Courtesy Doug Ripley*

Along with the productivity came frequent discomfort and misadventure such as drifting all night in a small boat with a motor that wouldn't start; escaping from opium poppy growers in the Sierra Madre; a misstep along a ridgeline and his tumble into the sea halted when he grabbed a cholla. "It wasn't always like that," Richard said in 2017, though he chronicled many of his colorful adventures in a collection of essays called "10,000 Years of Field Notes," several of which can be seen on Richard's website, along with more than 100 peer-reviewed publications, a biography, and photographs: **https://www.desertfoodplants.org**.

Richard's contributions to Sonoran and desert botany, new crops research, and ethnobotany, are broad, deep, and long-lasting. His floras and books—including *Flora of the Gran Desierto and Río Colorado of Northwestern Mexico*; *Oasis at the Desert Edge: Flora of Cañón del Nacapule*; and *The Trees of Sonora*—were thorough, detailed, and built on first-person observations and field-verified data. His identification keys were written for non-specialists. He took great pains to avoid the technical terminology he called "botanical code language." He was loved for his work, his big-heartedness, his humor, and his eccentricities. He could be abrupt, single-minded, even demanding of attention. It was not unusual for him to send 40 or 50 emails in one day to a coauthor. Jim Verrier notes with a chuckle, "his 'flaws' were endearing to those who loved him (but perplexing to strangers)." And as demanding as Richard could be, he was also generous with his thanks, giving full credit to collaborators and acknowledging everyone who helped with a project, from botanical authorities to those who solved his computer issues.

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Figure 1. *Bouteloua diversispicula.* A. Plants. Rancho El Carrizal, Sonora. March 2003. B. Plants with stolons. Near Nácori Grande, Sonora. July 2012. C. Ruby-colored spiklets. Near Cucurpe, Sonora. August 2018. *Photos A and B by T.R. Van Devender, C by Elizabeth Makings.*

SPOTLIGHT ON A NATIVE PLANT *by Thomas R. Van Devender[1], Ana L. Reina-Guerrero[1], John F. Wiens[2], John F. Scheuring[3], and Michael Bauer[4]*

A Keystone Desert Grass Reaches Arizona: *Bouteloua diversispicula* Columbus

Introduction: False Grama Grasses

The genus *Cathestecum* was described by J. Presl in 1830 (Hitchcock 1920). By 1987, eight species of *Cathestecum* had been described. *Cathestecum brevifolium* was described by Swallen (1937) based on a Cyrus G. Pringle collection from Jalisco (Figure 1A). Eventually there were four varieties of *C. brevifolium* described, including *C. b.* var. *sonorense*. *Cathestecum erectum* described by Vasey and Hackel in 1884 mostly occurs in the Chihuahuan Desert in northeastern Mexico and Texas. Swallen (1937) reported both *C. brevifolium* and *C. erectum* in Sonora. These are strange grasses with all kinds of reproductive configurations. Vegetatively they clone by stolons (Figure 1B). Sexually, it is all over the spectrum, with some populations that are dioecious and others monoecious (Figure 1C).

In 1999, Travis Columbus at the Rancho Santa Ana Botanical Garden synonymized the genus *Cathestecum* into *Bouteloua* based on molecular evidence. *Cathestecum brevifolium* became *Bouteloua diversispicula* Columbus and *C. erectum* became *B. erecta* (Vasey & Hack.) Columbus. The false gramas became true gramas!

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Richard Felger: Pax et Prosopis *continued from page 41*

Long-time friend Marc Baker writes, "Richard had an enormous heart and, in spite of his obsession with plant life, was very compassionate and wanted only the best for the natural world, including his own, often undeserving, species." Jesús Sánchez-Escalante, Richard's and my coauthor on *The Desert Edge: Flora of the Guaymas—Yaqui Region of Sonora, Mexico* (forthcoming), says, "lo único que superaba a su extenso conocimiento como botánico era su gran calidad humana" (the only thing that surpassed his extensive knowledge as a botanist was his great quality as a human being). Bill Broyles, coauthor and colleague, exclaims, "How could I ever forget a friend with the productivity and strength of a velvet mesquite, the singularity of a boojum, the curiosity of dodder, the intensity of cholla, the open smile of a Peniocereus, and the legacy of ironwood!" Ed Gilbert, another friend of Richard's, comments, "There was a part of me that thought he was going to be around forever." I think he is still here and will be staying a while. Rather than say good-bye, I'll borrow Richard's favorite sign-off: *Pax et Prosopis.*

Figure 2. *Bouteloua diversispicula.* A. B. *Zacate raiz* grassland and closeup. Rancho El Carrizal, Sonora. March 2003. C. Turf. Near Rayón, Sonora. February 2011. *Photos by T.R. Van Devender*

SPOTLIGHT ON A NATIVE PLANT *Bouteloua diversispicula* Columbus *continued*

Desert Grassland and Grasslands in the Desert

Since about 10 million years ago in the middle Miocene, grasslands have dominated the north-central part of North America in the eastern rain shadow of the Rocky Mountains (Van Devender 1995). The drier western part of this continental grassland —in Texas, New Mexico, Arizona, Chihuahua, and Sonora — is called desert grassland (McLaran and Van Devender 1995). Desert grassland has two faces — one dominated by C4 grasses in periods of sufficient summer rain and another dominated by shrubs in drier periods. Human disturbance, especially by cattle grazing, has favored increases in shrubs. It is important to point out that desert grassland is a distinctive vegetation type, that except for velvet mesquite (*Prosopis velutina*), does not share any important dominant species with the adjacent Arizona Upland Subdivision of the Sonoran Desert (Turner and Brown 1994). An important difference is that fire is a natural ecological process in grasslands and higher woodlands and forests, but not lower Sonoran desertscrub and more tropical vegetation types to the south.

There are few true grasslands in the Sonoran Desert. In the Vekol Valley of Arizona, there is an extensive stand of tobosa (*Hilaria mutica*). Tobosa grass is a widespread dominant in swales in desert grassland to the east. In the Plains of Sonora Subdivision of the Sonoran Desert in Central Sonora, there is true desert grassland dominated by *zacate raiz* (*Bouteloua diversispicula*) that has received extraordinarily little attention (Reina-G. and Van Devender 2012), Figure 2A. This area was designated as Sonoran Savanna Grassland by Brown (1982), presumably dominated by perennial grasses and maintained by periodic fires. This vegetation type is not a valid vegetation type because perennial grasses except for *zacate raiz* are not dominant. In this area, fires have only been recorded in mesquite *bajíos* (broad densely vegetated arroyos) dominated by non-native Johnsongrass (*Sorghum halepense*), and its

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Figure 3. A. Dense *Bouteloua diversispicula* in wet summer. Near Moctezuma. August 2011. B. *Bouteloua diversispicula* and dried annual grasses in Plains of Sonora desertscrub. Rancho San Fermín, Sonora. October 2011. *Photos by T. R. Van Devender*

Figure 4. A. Ragged Top Peak, Arizona. *Photo by J.F. Wiens.* B. *Bouteloua diversispicula* on Ragged Top. August 2013. *Photo by Julie Wiens.* C. Charlotte and John Reeder in University of Arizona Herbarium. March 2003. *Photo by A.L. Reina-G.*

SPOTLIGHT ON A NATIVE PLANT ***Bouteloua diversispicula* Columbus** *continued*

geographic location and climate within the Plains of Sonora (Turner and Brown 1994).

Zacate raiz is a dwarf, tufted, stoloniferous perennial grass that often forms a turf-like ground cover in open areas in desertscrub (Figure 2A, B, C). *Zacate raiz* catches wind-blown particles and anchors the thin desert soils, forming seed and insect banks. During wet summers, *zacate raiz* with 10 cm tall inflorescences and 20 cm tall annual grasses (*Bouteloua aristidoides, B. barbata, Dinebra panicea* subsp. *brachiata, Muhlenbergia microsperma, Panicum hirticaule, Setaria liebmannii, Setariopsis auriculata,* and *Urochloa arizonica*) often form very grassy landscapes without accumulating enough fine fuel to burn (Figure 3A, B). This grass-dominated vegetation type in the Sonoran Desert is a unique desert grassland.

Unfortunately, cattle ranchers and wildlife biologists did not realize that *zacate raiz* was the keystone species in the ecosystem. This soil-binding desert turf is fragile and easily damaged. Clearing to plant buffelgrass (*Pennisetum ciliare*) and treatments with disks and rippers intended to increase grass production of the taller annuals has eradicated the *zacate raiz* grassland in large areas. Without *zacate raiz*, annual grasses dry up and surfaces are typically bare in dry periods.

Bouteloua diversispicula Distribution

In Sonora, *B. diversispicula* is widespread in most of Sonora except the Central Gulf Coast Subdivision of the Sonoran Desert along the Gulf of California and the hyperarid Lower Colorado River Valley Subdivision in northwestern Sonora. It is common in Sonoran desertscrub and foothills thornscrub and open areas in oak woodland. It even trickles into open areas in pine-oak forest near Yécora in the Sierra Madre Occidental in easternmost Sonora (Van Devender et al. 2005). However, its general northern limits are about 34 mi (55 km) south of the Arizona border.

Ragged Top

In October 1989, John Wiens was doing an inventory of the flora of Ragged Top Peak, a spectacularly rugged, isolated peak on the northeast corner of the Silver Bell Mountains about 25 km west of Marana in Pima County, Arizona (Figure 4A, B). The area was included in Ironwood Forest National Monument established in 2000 and managed by the Bureau of Land Management. He discovered a stand of a unique, tufted grass reproducing by stolons (Wiens 1990). John R. Reeder, the renowned grass specialist in the University of Arizona Herbarium (Figure 4C), identified the grass as *Cathestecum erectum*, the eastern Chihuahuan species rather than *C. brevifolium*, the Sonoran species. There are 27 Sonoran specimens in the SEINet database network identified as *C. erectum,* among 425 identified as *C. brevifolium.* The differences between species are relatively minor based on characters that are not easily seen, may be variable, and are possibly influenced by environmental conditions. In this paper, we view all of the Sonoran and Arizona records as *Bouteloua diversispicula*, but wonder if a careful reevaluation might lump the species together under *B. erecta*, the older species. Later, two additional populations of *B. diversispicula* were discovered from within six kilometers west-northwest and southeast of the original population. The Ragged Top population is a disjunction of 96 miles (155 kilometers) north of the nearest (and northernmost) Sonoran record of *B. diversispicula* (Reina-G. 2004-1030, 50.6 km SSW of Sásabe).

In the 1850s, Pedro Aguirre, Jr., started a stagecoach and freight line that would connect Tucson, the mining town of Arivaca,

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Arizona, and the town of Altar in Sonora, Mexico. In 1864, he homesteaded the Buenos Ayres ranch in the Altar Valley, which eventually became the Buenos Aires National Wildlife Refuge. The Aguirre freight business had extensive contracts with the U.S. Army to carry supplies to mines in Arizona. Eventually the Aguirre family became extensive ranch owners as far north as Marana. Ragged Top was originally on an Aguirre Ranch. The Aguirres regularly went back and forth to their family near Altar, Sonora. It is possible that the *B. diversispicula* was introduced into Arizona as a seed contaminant in wild grasses collected in Sonora to feed the mules that pulled the freight wagons. **https://www.fws.gov/refuge/Buenos_Aires/about/history.html** and **https://arizonadailyindependent.com/?s=Pipeline+Altar+Valley**.

Oro Valley

In September 2020, John Scheuring was a volunteer spot-spraying buffelgrass along Arizona 77 between Catalina and Oro Valley, just north of Tucson, Arizona. The roadside plants there are diverse, clearly enriched by the Arizona Department of Transportation (ADOT) hydroseeding. He discovered a population of a grass identified by Michael Bauer as *B. diversispicula* with both male and female plants present. A thriving population is present for at least 2.2 mi (3.5 km) along AZ 77 and west along Tangerine Road. This locality is 31.8 mi (51.3 km) east of the Ragged Top population. The seeds of *B. diversispicula* may have been contaminants in seeds of *B. aristidoides* collected in Sonora for the 2016 ADOT hydroseed project (Thomas Ohmart, AZ Dept. of Transportation, personal communication, 2020).

Discussion

Bouteloua diversispicula is a keystone species in large portions of the Plains of Sonora Subdivision in central Sonora, where it plays an important ecological role in binding fragile desert soils. Widespread clearing for buffelgrass planting has severely impacted these desert grasslands formed by this tufted, stoloniferous grass, although the distribution of the species has likely not changed.

The Wiens and Whittemore report (1990) of *B. diversispicula* in Arizona added a new native species to the United States. We present the possibility that it was an early introduction from Sonora to Arizona in livestock feed for the Aguirre freight line. More recently, *B. diversispicula* was accidentally introduced in Oro Valley north of Tucson by the Arizona Department of Transportation as a probable contaminant in Sonoran seeds in roadside hydroseeding. It was not observed pioneering in adjacent Sonoran desertscrub away from roadsides and has such a unique growth form that it is unlikely to compete with native species in natural habitats. *Bouteloua diversispicula* holds tremendous potential for roadside erosion control and urban landscapes.

Acknowledgements

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