Native shrubs occupy over 90 percent of Utah. These woody plants add to the beauty of the state's valleys, canyons, and mountain land, provide forage for wildlife and domestic stock, and stabilize soil in the state's watersheds. Among Utah's typical beautiful sites is the canyon maple, covering the canyon bottoms, slopes, and ravines of Utah's rugged mountains. This shrub, related to the eastern North American sugar maple, is also a possible source of maple syrup and sugar.
Shrubs in Utah and the Intermountain Region

ARTHUR H. HOLMGREN

SHRUBS, those woody plants that have never become trees, cover more acres in Utah than any other type of vegetation. The Utah flora consists of about 120 plant families in most of our classification schemes and roughly about 40, or one-third, of these contain shrubby members. A botanist often works with a single family or even with a small part of one family. For instance, Dr. Douglas Dewey, who collaborates jointly with the Agricultural Research Service and Utah State University, is working with a single tribe of grasses known as the wheat grasses, and his name is internationally known for his outstanding contributions. Shrubs, as a group, have not received this kind of attention. But much is now being done in Utah and the Intermountain Region to change this situation. Even though Dr. Walter P. Cottam, Perry Plummer, Dr. Howard Stutz, Dr. Cyrus M. McKell, and several others have worked with shrubs in several families and numerous species for many years, much remains to be done.

An International Shrub Symposium held on the Utah State University campus in July of 1971, marked the first attempt to collect our knowledge about this diverse vegetation. As a follow-up of the symposium, a meeting was organized by Dr. Wynne Thorne, Director of the Utah Agricultural Experiment Station to assess the extent of our knowledge about shrubs in Utah and to discuss needs and plans for further research. Those in attendance were called on for reports and the papers that follow are an outcome of that meeting.

In Utah we are learning more about shrubs, the second-class citizens of our plant world, than in most areas. This is natural since shrubs dominate our vegetative cover and we are in the heart or center of North America’s vast shrublands.

SHRUBS ARE WOODY PLANTS

I have already alluded to the fact that shrubs are woody plants. Many plant species are easily recognized as shrubs and placed in this category by botanists without argument; however, the shrub identification of many other species is not so clear cut. As a plant taxonomist, I am concerned with identification, the naming of plants, and classification. Identification is accomplished when we compare an unknown plant with one that is known. Once identified as to species, the plant is placed in a family and the family in groups of families, and so on. This is classification, and here we are dealing with a scheme of classification.

Some herbaceous plants are not at all shrubby, but many species are woody at the base and herbaceous above. The common and widespread matchbrush or snakeweed (Gutierrezia sarothrae) is such a plant and is often referred to as being suffrutescent. Other shrubs may become trees under certain circumstances. The Rocky Mountain maple (Acer glabrum) is described as a tree or a shrub. Woody plants that have several stems are called shrubs and occur in many families. Some genera, such as cinquefoil (Potentilla) are generally herbaceous but may contain a shrubby member, for example, P. fruticosa is a shrub in an otherwise herbaceous group. Many descriptions read “plants herbaceous or shrubby” or “shrub or small tree.” Thus size alone is not helpful, as some shrubs may be larger than some trees and multiple stems are not always definitive since a species considered to be a shrub may actually have a single main trunk.

LOWEST TO HIGHEST

Shrubs range from our lowest and hottest desert areas to the highest mountains. They grow on saline and alkaline areas, as well as on acid peatbogs. Shrubs occupy almost every ecological niche, with some species even tolerating long periods of inundation. Shadscale (Atriplex confertifolia), greasewood (Sarcobatus vermiculatus), winterfat (Eurotia lanata), blackbrush (Coleogyne ramosissima), small rabbitbrush (Chrysothamnus stenophyllus), and the sagebrushes, big sagebrush (Artemisia tridentata) and black sage (A. nova) often occur over large areas in pure stands.

The goosefoot family, in which we find such plants as shadscale, gray molly, greasewood, hopsage and winterfat, is notable in that its members tolerate alkali and salt. On the other hand, members of the heather family (manzanita and blueberries)
grow in acid situations in the cooler parts of Utah and the Intermountain Region.

**SHRUB FAMILIES**

About 40 families of flowering plants include shrubs that grow in our area. The sunflower, or aster, or sagebrush family is the largest from a standpoint of numbers of species and far outnumbers all others in including shrubby plants. It is in this family that we find the sagebrush and rabbitbrush genera (plural for genus), which are so difficult to classify. This plant family contains 25 genera. The rose family is a strong second with 15 genera, while the goosefoot or shad scale family rates third with six important genera. It should be kept in mind that we are talking about genera here and not species. For instance, the sagebrushes comprise a genus of about 20 species with about half of them being shrubs.

Several large families are represented nearly entirely by herbaceous plants with only a very few becoming shrubby. The figwort family, in which we find the familiar snapdragon, is an example of a diverse family where only an occasional penstemon tends to become somewhat of a shrub.

**MAIN ASSOCIATIONS**

Three or four shrub associations may be recognized in Utah and the Intermountain Region:

1. Sagebrush and black sage with combinations of rabbitbrush, bitterbrush, mateheawed, and blackbrush (blackbrush may be considered by itself).

2. Shad scale with combinations of budsage, winterfat and hopsage (Grayia spinosa).

3. Saltsage with two or three species of Atriplex and gray molly (Kochia americana var. vestita).

Many ecologists have concluded that it is better to recognize two major shrub communities in this area, with one being dominated by big sagebrush and the other by shadscale.

Most Intermountain shrubs are widespread species with, as already noted, some occurring in pure stands. Most, however, are found in combinations with other plant species. A shrub known as Vanclevea stylosa, a close relative to gumweed, is perhaps as restricted in its distribution as any of our species. A species having a narrow distribution is often referred to as endemic species. Vanclevea is only known in southeastern Utah and northeastern Arizona.

**NEW USES**

Many species have local biotypes that are recognizable in different ways, and these are often considered to be distinct species by some botanists. These may be important to man because of their vigor, palatability to livestock, or promise as being susceptible to cultivation. Several botanists, range scientists, and horticulturists have been looking for these unusual biotypes and each field season new discoveries are made.

Perry Plummer, Gordon Van Epps, Leonard Pollard, Alvin Hamson, Walter Cottam, and I have been growing native and introduced shrubs with many objectives in mind. We have been interested in the species that are classified as shrubs in terms of what they are and where they grow. We have also been interested in the value of shrubs as browse for wild and domestic animals, and as species for stabilizing soils. We are now also beginning to see our native shrubs as plant material for landscaping around homes, industrial parks, and roadside plantings.

Shrubs soon will no longer be considered second-class citizens of our Intermountain plant world. Accelerated programs in our universities and by our government agencies are changing their status, and we will eventually know shrubs as well as we know grasses.

Let’s briefly consider our kinds of shrublands, the major plants, acreages, distribution, environment, productivities, present and potential uses and value.

**CREOSOTEBUSH TYPE**

The creosotebush areas of Utah are confined to the Dixie Corridor of extreme southwestern Utah. This is the northeastern corner of the Mojave Desert region, which centers in southern Nevada and southeastern California. This is Utah’s hottest and driest portion. Creosotebush occurs at
our lowest elevations, exclusive of the stream bottoms. Rainfall in southwestern Utah averages less than 10 inches and is extremely erratic in distribution. Summer temperatures exceeds 110°F. Snow is rare. The production of even the annual plants is very undependable.

The area's rocky soils, with their caliche layers, have little potential for tillage. Their traditional use has therefore been as year-around livestock range. The carrying capacity, however, is extremely low. Plant productivity is so low and so little of it is available to livestock that the range is considered barely worth using by most ranchers. Sources of water are critical in determining livestock and wildlife use. No game species thrive in creosotebush vegetation, although many interesting plant and animal species are found in the mesquite-dominated vegetation along the washes running through the area. This more productive sub-type is barely mappable in Utah, however.

**BLACKBRUSH TYPE**

The shrubland that occurs just above (altitudinally and latitudinally) the creosotebush zone is dominated by blackbrush. This little-studied type extends from the Dixie Corridor up the Colorado River to Castle Valley above Moab. A major side branch goes up the Green River about 50 miles. The most extensive areas are at the bases of the Beaver Dam and Henry Mountains; in the national parks, monuments, recreational areas; and on the Navajo Indian Reservation. This adds up to a little over 2½ million acres within Utah. Like the creosotebush type the vegetation is nearly a pure stand of the dominant shrubs, since few perennial grasses thrive with precipitation of less than 8 inches and maximum temperatures exceeding 115°F. Snow cover is rare in this shrubland type. Soils are shallow and rocky with bedrock or caliche at a depth of about 12 to 18 inches. Winter season grazing by livestock, mule deer, and desert bighorn sheep has been the main use made of this type. Much of the area is now within new or expanded national parks or monuments, with livestock use being terminated.

**SALT DESERT SHRUB TYPE**

The third shrub type important in Utah are the salt desert ranges. It exceeds all others in total acreage. These ranges are found at lower elevations in the Great Basin portion of western Utah, on the shale badlands of the Colorado Plateau in southeastern Utah, and along the bottom of the Uinta Basin. A minor acreage occurs in Daggett County associated with Wyoming's Red Desert in the upper Green River Drainage. In all these areas the vegetation type is associated with saline and/or alkaline soils that, in western Utah, are characteristically found around the margins of Lake Bonneville or similar ancient lakes. As these lakes evaporated, salts were left behind. The lowest spots became salt flats, free of vegetation, while for several hundred feet above these playas less salty soils occur. Here are found salt tolerant shrubs such as black greasewood, gray molly, shadscale, and winterfat in either pure or mixed stands. Grasses such as squirreltail, Indian ricegrass, and galleta, along with forbs like globemallow add forage value to this area. The temperatures are cool with extremes of —30°F to 90°F common. Precipitation averages between 6 and 8 inches per year. These ranges have provided winter forage primarily for sheep, although pronghorn antelope use the ranges part of the year. The vegetation type is poorly adapted to growing season (spring and summer) use. With brown dominating the herbaceous forage, it is poor cattle feed.

**SAGEBRUSH TYPE**

Areas dominated by various species of sagebrush constitute the second largest of Utah shrub types. These areas comprise about a third of our shrublands, and produce the highest volume of forage. Several species and sub-species of Artemisia are involved on these ranges, which are found all over the state. Sand sagebrush (A. filifolia) frequents sandy soils near the blackbrush and creosotebush shrubland types. Bigelow sagebrush (A. bigelovii) is found up the Colorado, Green and San Juan River drainages above the blackbrush types. Black sagebrush (A. nova), bud sage (A. spinodes), and pigmy sagebrush (A. pygmaea) occur on the wetter fringes of the salt desert shrub or the drier portions of the big sagebrush types. The major species is big sagebrush (A. tridentata) and its various sub-species. Basin big sagebrush (A. tridentata, tridentata) occupies the deepest, alluvial, salt-free soils. This species has been largely displaced by intensive agriculture since irrigation was feasible in its area. Wyoming big sagebrush (A. tridentata wyomingensis) is the major species on the drier sagebrush range-lands. Where soil moisture is adequate in extreme northern Utah, we
might find three-tip sagebrush (A. tripartita). In the mountains of northern Utah longleaf sagebrush (A. longiloba), mountain big sagebrush (A. tridentata vaseyana), silver sagebrush (A. cana), and several species of herbaceous Artemisia grow along the central mountain spine.

The many species of sagebrush and their widespread distribution make it difficult to generalize about the environment and land use of a single type. As a valid compromise, however, we can restrict our attention to the areas dominated by big sagebrush, our most important species. This area includes a cool desert environment with conditions somewhat cooler and wetter than the adjacent salt desert shrub type. Precipitation averages from 8 to 12 inches per year. On the comparatively wetter sites more perennial grasses and forbs occur. With heavy grazing and fire prevention, sagebrush has invaded areas that were previously grasslands. When livestock grazing and fire are combined, the annuals such as cheatgrass invade and expand. The big sagebrush type of range is traditionally used as spring and fall grazing by livestock. Species of game animals such as pronghorns, mule deer, elk, sagegrouse, and chukars spend considerable time in this type.

The shrub types we have discussed so far, have such dry climates and poor soils that little manipulation of the vegetation except grazing management systems can improve the vegetation for animal use. The more favorable climate and soils of the big sagebrush ranges have, however, been variously treated to reduce brush and encourage herbaceous growth. Burning, spraying, raling, chaining, and beating have been commonly used to convert brushland to grass. If native grasses were sparse additional tillage and seeding to various grasses imported from the Russian steppes have proved successful from the livestock industry point of view. Many more acres could be changed if meat production becomes a national goal and objections from environmentalists decline.

**MOUNTAINBRUSH TYPE**

The remaining Utah shrub type, the mountainbrush range, lies either directly below or is interspersed in forest zones on all our higher mountains. The upper elevation interspersions are found on steep, rocky and/or south slopes, which are effectively drier and unfavorable for tree growth. The zonal precipitation of 20 to 40 inches per year is effectively less in most places because of the local modifications that have dried the sites. Temperatures on mountainbrush ranges are often more moderate than along valley bottoms because temperature inversions push cold air to the valley bottoms and warm air upward. This type of shrubland is dominated by various species of oak, maple and mountain mahoganies. Other local names are mountain browse, oakbrush and chaparral.

These ranges are used by livestock in the spring-summer-fall period, depending on the elevation involved. They provide critical forage for deer and elk in fall, winter, and spring. Much of the acreage involved constitutes Wasatch Front and other watersheds. Livestock grazing has been excluded from such areas.

All of our shrublands are being increasingly affected by more people wanting wildland experiences and resources. Recreational vehicles have had impact but this may diminish, at least at distances from population centers, as fuel becomes more expensive. More shrublands will be disturbed by mineral exploration and extraction. All of the newer and older uses can be better planned for and managed when the ecological patterns and relationships are better understood. Several research programs in the Utah Agricultural Experiment Station are designed to expand this knowledge base.

**AG NOTES**

The total mineral intake for cows from both forage and grain supplement should not contain more than twice as much calcium as phosphorous, according to Dr. Samuel B. Guss, Penn State veterinarian.

- The average dairy cow eats about 11 pounds of hay per day.

Australia has moved ahead of Argentina to become the world's largest exporter of red meats, according to the USDA.

- The United States ranks second behind the United Kingdom as the world's largest importer of red meats.

Since 1950, total input manhours of labor on the farm has dropped by 57 percent. During this same period, total output per manhour has soared by nearly 250 percent!

- Today's modern farmer, using a self-propelled automatic bale wagon, can pick up, haul and stack up to 232,500 pounds of hay in an 8-hour day.

Ketosis, displaced abomasums or breeding complications may be brought about as a direct result of feeding cows on diets lacking a proper hay ration, according to Dr. Samuel B. Guss, veterinarian with the Pennsylvania State University.

- Nearly 392 million tons of products are produced each year by United States farms, and most of it requires further handling by our food marketing system before reaching the consumer.
"This canyon looks just like a box of crayons," shouted a young boy to his mother as the family was driving in northern Utah one bright September day. He was responding to the spectacular autumn pageant of a shrubby maple tree that covered the slopes of the canyon, the leaves of which had recently turned to reds and oranges, contrasting sharply with the interspersed grays and greens. The scene is repeated each autumn throughout Utah's northern Wasatch Mountains, with the ruggedness of the mountains adding an extra dimension of grandeur. The Utah scene challenges or even surpasses the beauty of the more widely heralded fall foliage colors of eastern North America.

Utah's maple, *Acer grandidentatum*, is closely related to the sugar maple, *Acer saccharum*, of the eastern United States and Canada (Desmarais, 1952) and indeed was called sugar maple by the first Mormon pioneers who came to Utah in 1847 (Anonymous, 1847), presumably because its leaves resemble those of the sugar maple that they had known in the east. Now it is often called bigtooth maple because of the tooth-like features on the leaves which are smaller lobes on the bigger lobes (figure 1). The internationally-used Manual of Cultivated Trees and Shrubs by Alfred Rehder, published in 1940, states the leaves of this maple are 3- to 5-lobed and the lobes are lobulate, or divided into small shallow lobes.

The bigtooth maple can also be called canyon maple. While this maple occurs in other places too, it
is found so predominantly in canyons of the Wasatch Mountains and throughout its range that the name seems fitting. Moreover, the word “canyon” is as western as is A. grandidentatum itself. Indeed, four major plant taxonomic works list this species but give no common name, while three other works list it as sugar maple with the synonym of bigtooth maple. Six of these works draw attention to the fact that it is most often found along streams and in canyons.

Canyon maple is distributed along the north-south mountain axis of Utah, being abundant from the Wasatch Mountains south to Pine Valley and Beaver Dam Mountains and uncommon in both the eastern and western portions of the state (Erdman, 1970). It sometimes grows on highly basic soils and at elevations as high as 9,000 feet, but recent studies have shown that in the Wasatch Mountains of northern Utah and southern Idaho it generally grows at elevations ranging from 4,600 to 7,000 feet on soils that are slightly alkaline to moderately acid (Ream, 1968). The canyon, or bigtooth, maple endures a relatively harsh environment and is hardy to temperatures as low as $-40^\circ$F. or less. The trees tolerate low summer humidity and as little as 15 inches of rainfall annually, most of which occurs as snow in winter. However, it seldom occupies the drier sites.

In northern Utah this maple shows appreciable variation. One variable is its height. In numerous canyon bottoms and alluvial flood-plains it grows to heights of 40 or more feet and provides excellent overstory for recreation sites. On limestone studded slopes (previous page) and in ravines (figure 2) that vent the west-facing front of the Wasatch Mountains it is much shorter and more shrub-like. Along with Gambel oak, Quercus gambelii, with which it is associated in central Utah, the canyon maple is a dominant woody species of the mountain brush vegetation. At higher elevations on fertile soils, it is often associated with aspen, Populus tremuloides, and is relatively tall and tree-like. Although this maple characteristically grows in clumps with numerous trunks arising from the crown of a single root system, single-trunk specimens are not uncommon. The largest one recorded has a trunk diameter of 21 inches at breast height and a height of 38 feet. This patriarch, located in the Wellsville Mountains about three miles west of Mendon, Utah, has recently been designated the national champion for this species by the American Forestry Association in its National Register of Big Trees.

When and whether their foliage turns color in the fall is likewise a marked variable of canyon maples. A few trees, for example, lack any pronounced fall coloration, making the well-colored ones seem even better. And on the other hand, for the past four years I have observed a shrub-like stand located on a limestone talus slope in Logan Canyon in Cache County, Utah, consistently develop its red brilliance about the last week of August. During the next 10 to 15 days, scattered trees elsewhere in the canyon, always the same ones, have punctuated the canyon slopes with their own fall colors, followed shortly thereafter by the full ensemble of coloration throughout the canyon.

The leaves of some canyon maple trees regularly undergo a color change that is particularly striking. Certain trees near highways, for example, have well-worn paths leading to them, made by people in pursuit of branches clothed with unusually brilliant foliage. This practice is discouraged, of course, as is unauthorized digging of the maple plants for transplanting elsewhere.

The flowers of canyon maples are inconspicuous and appear in early spring along with the newly-expanding leaves. The trees have perfect flowers which possess both the male and female parts, and imperfect flowers which lack the female parts. The proportion of perfect to imperfect flowers varies from tree to tree, with an occasional one having only imperfect flowers and therefore being sterile in terms of fruit production.

The fruit, like that of all maples, is a paired samara. Each samara ordinarily comprises one seed with a thin hard outer shell, to which a wing is attached. The whole samara is frequently called the seed. When this is done here quotation marks will be included, i.e. “seed.” The fruits remain green throughout the summer but on some trees they are rose colored and aesthetically important, resembling, from a distance, clusters of flowers among the green leaves.

The wings of the samaras vary from tree to tree. Some are over two inches long, others as short as ½ inch but the most common length is about 1½ inches. The angle of spread of the two wings of a paired samara is about 85 degrees on the seeds of most of the trees but on a few trees they are practically in a line, or 180 degrees apart, while on others they

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Figure 1. The botanical description of these typical leaves of the canyon maple, Acer grandidentatum, is that they are palmately lobed with three to five lobes, each of which is usually divided into small shallow lobes. Except for being about two-thirds as large, they resemble the leaves of the sugar maple, A. saccharum.
are virtually parallel.

Many of the seeds are infested by a tiny insect larvae, one larva in each seed. One is a moth which is probably the maple seed caterpillar, *Proteroteras aesculana* Riley, that infests the seeds of other maple species, too. Identity of the other insect was unknown until this past spring when we found the adults visiting the flowers and laying their eggs directly onto the rudimentary seed. It has been identified by Rose Ella Warner, U.S.D.A. Agricultural Research Service, as an unnamed species of weevil in the *Euclyptus* genus. We are now studying its life history and have determined that the larvae emerge from the “seed” in August through a tiny hole that they make in the shell. Present evidence indicates that after emergence from the “seed” they drop to the duff beneath the tree where they complete their development to adulthood either in the fall or the following spring. The weevil larvae are most abundant in the seeds in the early part of summer; the moth larvae later.

The prevalence of these silent invaders may be a fortuitous blessing in dampening the spread of canyon maple on lands better suited for range or timber purposes but it is disastrous for anyone desiring seeds for propagation purposes.

Fruit yield is usually light but in 1972 it was exceptionally heavy on the trees in northern Utah, and proportionately fewer seeds were insect-infested. Capitalizing on this favorable situation, we scouted the mountains for trees having outstanding fall foliage coloration or unique form or size and collected “seeds” from over 80 trees. These were air-dried for two or three days, dewinged by rubbing them through the palms of the hands, mixed with moist peat moss, and stored overwinter in airtight plastic bags or glass jars at temperatures slightly above freezing. Marked differences were found in their germination pattern; those from some of the trees germinated while still in storage, others after being sown in seed flats and placed in a greenhouse the following spring although the germination rate varied between seed sources (figure 3), and a few seed sources never did germinate regardless of treatment.

Seedlings grown initially in seed flats grew poorly after being transplanted into larger containers. Seasonal growth was much better on seedlings started, instead, in peat pellets (available from garden stores). Using seed that had already germinated, we put the radicle or rootlet of a germinated seed into a hole made in the pellet and gently pressed the peat medium around the radicle with the thumb and forefinger. The germinated seed-pellet combinations were stored in shallow pans in a greenhouse, flood irrigated, and shifted to soil-filled 1-gallon containers after the roots of the seedlings had penetrated the bottom of the pellets and the first pair of leaves had developed.

Fast growth was not a virtue of these first-year seedlings. Of some 1800 that we produced, few of them grew taller than 3 inches. Four to eight pairs of leaves developed on each seedling but there was little elongation of the internodes. Follow-up studies are planned to determine if internode elongation can be increased by use of plant growth regulators. Naturally-growing trees of these species also generally lack fast growth. For example, a typical tree that was 60 years old, based on a count of the annual rings, had a trunk diameter of only 4 inches. Nevertheless, in considering its benefits to people of future generations, its probable adaptability to a wide range of environmental conditions, long-term durability, and outstanding fall foliage coloration seem to be overriding values and desirable trade-offs for fast growth, particularly where interplanted with faster growing trees.

The canyon maple is a promising candidate for enhancement of the recreational values of lands naturally devoid of trees that surround lakes and

Figure 2. The canyon maple's typical ecological niche is in canyon bottoms and northerly- and easterly-facing slopes and in ravines that frequently dissect the mountains.

Figure 3. Seed germination rate of this maple varies between trees as is indicated by the different number of seedlings in these seed flats. Each flat was sown with an equal number of seeds from a different tree.
water impoundments in the Intermountain region of the United States. Using modern irrigation technology, perhaps these lands, planted with canyon maple and other trees and shrubs, could become an oasis many years hence and then be desirable for recreation site development. Research is needed on this to determine if it is as valid a procedure as is the traditional planting of timber trees for harvest 80 to 100 years hence.

Despite its many virtues and its many possible uses, rarely is the canyon maple, or bigtooth maple, seen in an urban area or offered for sale by a nursery. Indeed, the plant seems to be nothing less than a "sleeper" which man has still to test for its possible use for amenity purposes as has already been done with many of the maples. Research that is underway may alter this situation. We are now studying the mechanism of seedling survival under natural conditions aimed at learning more about this species' life history. Propagation procedures are also being studied as will be silvicultural procedures later on. And progeny derived from the seed collected in 1972 are being grown for a long-term assessment of their heritable traits. Eventually, selections with outstanding merits may be released to nurseries for commercial production and sale to the public.

LITERATURE CITED

WALTER P. COTTAM

It was a gracious act of my good friend Dr. Wynne Thorne to invite me to submit a short paper for this all-botanical issue of Utah Science to which so many of my esteemed associates, some of whom are former students, are also contributing. Especially appreciated is the complete freedom of subject matter granted me. When I began to assemble some of my notes and thoughts on what might be appropriate material for this essay, I happened to review an ancient term assignment that I had prepared during a wonderful tour of the newly created National Parks and Monuments of southern Utah and northern Arizona. The occasion was my first class in field ecology. Near the front of that bound booklet was the picture presented above. It is a portrait of a large and beautiful plant that occupied a prominent place along a horse trail near the river at the bottom of Zion Canyon west of the present campgrounds. The name I placed at the bottom of this picture was "Yucca" followed by a large question mark. The date was July 8, 1923.

Although I had received the A.B. degree from Brigham Young University in 1916, and the M.A. degree in 1918, I had to my credit no classes in plant taxonomy for the simple reason that none were taught at BYU during my student years there. How-

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however, I had grown up in St. George, hardly 50 miles southwest of Zion Canyon, loved the desert flowers and was quite familiar with parochial names associated with the common species. I was certain that this plant was not one of the 3 species of Yucca that were common to the Dixie area.

Years later, after I had done some research at Grand Canyon National Monument, I found this Zion Canyon plant to be common along the canyon rim at Toroweap. It was identified as *Nolina Bigelovii* (Torr.) Wats. The identification on this picture taken at Zion in 1923 was then corrected. The genus *Nolina* and the genus *Yucca* are both members of the Lily family and from their general likenesses are obviously closely related.

When I took this picture in Zion Canyon, I noticed two fine specimens in the general area described above. Our party in 1923 explored the park rather carefully, but saw no other individuals of *Nolina* there or anywhere else in Utah on that two week trip. In 1926, Ivar Tidestrom published his 665 page book on the Flora of Utah and Nevada. In his preface he states that he botanized principally in Utah from 1907 to 1911, and it is known that he spent much of his time collecting plants at Zion Canyon, but the genus *Nolina* is not listed in his treatise. Nor have I, since 1923, been able to locate these plants, despite my many trips there with this specific goal in mind. Is the disappearance of the genus *Nolina* from Utah’s most renowned national park, and very likely from our entire state, of little public consequence, or is it a botanical tragedy, another in the long list attributable to man?

Several other extremely uncommon plants in Utah have come under my observation during the past few decades and deserve some public recognition, if only because their presence helps explain the tenuous nature of plant survival. Many plants are occupying the extreme limits of their distribution and are therefore vulnerable to extinction.

Some uncommon people are also included in my remembrances, among them, a nationally renowned ecologist of a generation ago who greatly endeared himself to many students of the BYU and the Utah State Agricultural College. I refer, of course, to that brilliant teacher, generally considered to be the father of American ecology, Dr. Henry Chandler Cowles, long-time professor of botany at the University of Chicago, who spent the summer of 1923 teaching at BYU and the following summer (1924-1925) at the USAC.

My first contact with this great man occurred in the fall of 1922 while I was returning home from a summer’s term at the University of Wisconsin. In Chicago, where by chance I was confronted with a few hours wait between trains, I decided that it would be nice to visit the campus of the University of Chicago and if possible meet Dr. Cowles, whose reputation as a teacher and ecologist was legendary.

I was glad the ride on the elevated, rapid transit train to the University station of South Chicago was exceedingly brief, because the entire distance traversed some of the most disgraceful, squalid, impoverished human habitation imaginable. It was encouraging to learn that the campus I was seeking was still a quarter of a mile distant. Indeed the contrast between that campus and the poor black quarters of this metropolis was startling. Marveling at the planned arrangements of the many buildings with their unified Oxford architecture, I nearly forgot the real object of my visit and had to race to the botany building, where I was told that Dr. Cowles’ lecture would commence in moments.

It did. And from his first words to his last an hour later, I was as if in a state of hypnotic attention until the sound of a bell signified an end to this mental control. It was a strange experience, the like of which I do not recall ever happening before or since. The urgency of my train ride home outweighed my deep desire to stop and introduce myself to Dr. Cowles, and the pleasure of a personal chat was postponed for several months.

The excitement of the afternoon still lingered, though somewhat subdued, when I boarded the train for home. It was not until the measured,

The Alpine summer school camp where Dr. Cowles taught open air classes in 1923. Located in Aspen Grove at the foot of Mount Timpanogos, the girls dorms are nearly hidden in the forest across the creek to the right. Mens dorms are hidden from view to the left. Dining hall is to the left and the classrooms are the tent shelters.

**March 1974**
rhythmic clicking of rotating steel on solid steel and the forward, homeward thrust of the car became realities that I was able to inquire calmly of myself why this obviously routine lecture, though by an admittedly great scientist, had been the most stimulating and certainly the most satisfying hour of my entire life. After considerable reflection on the delivery and context of the address, I concluded that it was perhaps most stimulating because I was listening to a man of obviously great scholarship, analyzing a highly complex, many-factored phenomenon of plant distribution with great eloquence, clarity and amazing simplicity. It was satisfying in the extreme because for the first time in my educational pursuits to and including the Master’s degree, that fleeting hour told me precisely where I wished to complete my graduate studies leading to the Ph.D., what should be my major subject, and whom I wished to manage my professor.

It was on this train ride, perhaps as a natural sequence of the afternoon experience, that I began to think how wonderful it would be if Dr. Cowles could be induced to teach, some summer in Utah, classes geared directly to the biota of our mountains and deserts. The thought seemed especially appropriate because the BYU had recently established a summer school camp at Aspen Grove, at the foot of Grand Timpansas for the expressed purpose of teaching classes in natural history during the second term.

With such possibilities in mind, I wasted no time presenting this “brain-storm” to the Dean of the Summer School of BYU. He greeted these suggestions with unexpected enthusiasm and assured me that he would get in touch with Dr. Cowles immediately.

Dr. Cowles reported that he was delighted with the possibility of spending a summer in Utah, even though he had been assigned to teach at Chicago during the next summer. He suggested having his class register at Chicago, then accompany him to Utah. He received approval from his administration for this plan, which was joyously received at BYU.

On the morning of July 2, 1923, a small delegation of us at BYU met the train at the Provo station. Dr. Cowles alighted from the train first, followed by his wife and teen-aged daughter, Harriet. Then emerged a gang of 16 students— all women. We gave the group a warm welcome, then reminded Dr. Cowles that on this, his first trip to Zion, he had shattered the record of Brigham Young by 17 women. Dr. Cowles retorted with a flash, “I am perfectly aware of this, and I must further boast that I have two women yet to arrive.” It was quite evident that he had been doing his homework on Utah history and knew that Brigham brought only one wife on the first expedition to Utah in 1847.

The BYU Alpine Summer School session was scheduled to begin on July 21. Thus we had nearly a week for preliminary study of two nearby canyons of the Wasatch Mountains and two days for study of extremely contrasting floras adjacent to the Great Salt Lake and the fresh water Utah Lake. Several more students had joined the class for the great tour of the southern parks and monuments.

More students from BYU, the University of Chicago, and the University of Utah, joined the class at Aspen Grove. To see and hear this great and good man Cowles, visitors frequently came from various communities throughout the state of Utah. One such visitor was Chief Justice of the Utah Supreme Court, James H. Wolfe, an enthusiastic amateur botanist and ecologist. Always present at our class was our beloved local botanist, A. O. Garrett, author of the floral key Spring Flowers of the Wasatch Region, familiar to hundreds of students of the University of Utah. Professor Garrett, who often taught at the BYU summer schools, was a splendid Latin scholar as well as botanist, and the finest critic of scientific papers in botany that I have ever known.

A few days ago as I was writing this essay and was deeply engrossed in the memory of this remarkable man, Henry C. Cowles, whom I admired most and loved best of all my former teachers, there came a letter from an old friend who had entered the University of Chicago the same year that I was leaving it, 48 years ago, and from whom I had received no word since I saw him last in Chicago. This man is now a retired teacher, still unmarried, and living at the old homestead where he has converted his “acre” to an oak-hickory climax forest like that always dear to Professor Cowles. He has written a brochure listing 100 species of plants growing there, some of which are extremely rare and of whose specific locality he learned in a course in Floristic Ecology given by Cowles. My friend Arthur L. Smith said that while teaching at a university in South Bend, Indiana, he frequently took his students in Botany to the sand dunes of Indiana made famous by Cowles in writings and in visits of hundreds of students. In his letter, Smith told me, “Of course the enthusiasm of Dr. Cowles has never left me, and he has my eternal gratitude for his inspiration and masterful teaching.” Isn’t such influence a form of immortality that has in it some basis of fact?

On Transplanting Species

Introduction of a species into an alien but favorable environment, in which normal controls, such as predators, are lacking, can have serious consequences. Australia has been suffering from such a problem for more than a century, ever since a colony of European wild rabbits was released there as an easy source of food and pelts. With no competition, the rabbits spread with such phenomenal rapidity—up to 70 miles per year—that they soon became a serious threat to the country’s vast sheep and cattle grazing lands. Nothing could keep them in check until, after World War II, the virus disease, myxomatosis, was introduced. It swept the rabbits like a scourge, with almost 100 per cent fatalities at first—but lately its effects seem to be waning, possibly because a disease resistant strain is evolving.
The canyon or bigtooth maple, *Acer grandidentatum*, that compose part of the mountain brush vegetation in parts of Utah and elsewhere in the Intermountain Region, is considered the western, parallel species of the sugar maple, *A. saccharum*, of eastern North America. Both species have apparently developed from a common ancestor following long geographic separation after the interior region of the United States became less humid (Little, 1944). Based on gross morphological characteristics, this maple is practically a diminutive of the sugar maple and stands of it growing in association with Gambel oak, *Quercus gambelii*, have been described as having the appearance of a miniature deciduous forest of eastern North America (Ream, 1968).

**EARLY STATEMENT**

Little wonder, then, that the first Mormon pioneers who arrived in Utah in the summer of 1847 and settled Salt Lake City, were advised by their leaders that fall of the potential value of the indigenous *Acer grandidentatum* as follows "...we also wish the green timber and young trees in the mountains to remain as they are, particularly the Sugar Maple, many of which are large enough to yield you sap at the present time, and many are small enough to be transplanted in the city when time will permit, which will be valuable for shade and from which we will hereafter receive an abundant harvest of sweet, particularly until such time as the sugar cane can be introduced..."  

Presumably these early Utah settlers knew the value of the eastern sugar maple as a source of maple syrup and sugar. Yet, despite the strong endorsement of their leaders for the western counterpart of the sugar maple, which we prefer to call canyon maple, records about them or anyone else ever making sugar products from them seem to be nonexistent. Verbal accounts of syrup having been made from the canyon maple cannot be verified.

**COLLECT AND BOIL SAP**

During the spring of 1973 we found that syrup can indeed be made from the sap of the canyon maple.\(^2\)

We tapped 44 trees in mid and late April in a canyon about 7 miles southeast of Logan at an elevation of about 5500 feet. The trees had an average trunk diameter of 5.68 inches and were estimated to be 50 to 70 years old. The tapping consisted of drilling a 5/16-inch hole about 2 inches deep into the trunk of each tree about 1 foot above the ground, using a bit and hand brace (figure 1).

\(^2\)We gratefully acknowledge the assistance of Dr. Joseph Do, C. Charansri, and Keith M. Peterson.

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\(^1\)An Epistle of the Council of the Twelve Apostles to the Saints in the Great Salt Lake City, Great Basin, North America, September 9, 1947, In Journal History of the Church of Jesus Christ of Latter-day Saints, LDS Church Archives, Salt Lake City, Utah.

Figure 1. A hand brace and 5/16-inch bit are all that is necessary to tap the local canyon maple. In this study, 3/16-inch stainless steel tubing was used for spiles to transfer the sap from the hole to handy containers, in this case, a plastic jug.
A spout, fashioned out of a 3/8-inch outside diameter stainless steel tube and tapered at the shoulder, was gently hammered into this hole to a depth of about 1/2 inch. A 2-quart container was placed on the ground beneath the spout to catch the sap which began dripping out almost immediately after the spout was in place. The sap was collected from the containers daily or every other day and taken immediately to the laboratory. There it was boiled first in a steam kettle to evaporate off most of the water and then in a double boiler as the final step in making it into syrup (figure 2). Since sugar maple syrup is reported to have an undesirable “buddy” flavor if made from sap collected after the winter buds begin to swell, we discontinued sap collection in early May just before bud swell began, whereupon the spouts were removed and the tap holes left open to heal naturally.

The daily sap flow was greatest on clear warm days that followed below-freezing nights. Practically no flow occurred without this freeze-thaw cycle. The total sap yield for each tree was not measured but it is estimated to have been 6 to 8 gallons, varying from tree to tree.

The sugar content of the sap, measured with an Abbe-type refractometer, averaged a little more than 2 percent at the beginning of the collection period and dropped to a little more than 1 percent at the end of the season (figure 3). This pattern corresponds to that for sugar maple sap collected in eastern United States, although the sugar maple sap has a slightly higher sugar content, averaging about 2.5 percent. One tree in the study consistently had the sweetest sap beginning at 3.0 percent and dropping to 1.5 percent by the end of the collection period. Even with it, however, we could not taste any sweetness in the sap, possibly because of its slightly acid pH which became more acid as the season progressed (figure 4).

**SYRUP ACCEPTED**

In a consumer preference test comprising 30 panelists, the canyon maple syrup was compared with a Fancy Grade sugar maple syrup (figure 5). Whereas the latter had the typical pronounced maple flavor, many of the panelists described the canyon maple syrup as having a mild flavor, characterized by a delicate fruitiness, almost like pineapple, and faintly sour...
Figure 3. Changes in the soluble solids (sugars) of canyon sugar maple sap during period of sap collection in spring, 1973.

As well as very sweet. The sugar maple syrup was preferred by 56.7 percent of the panelists while 43.3 percent preferred the canyon maple syrup.

OTHER FACTS

The discovery of how to make syrup and other sugar products from the sap of maple trees has never been traced — it is buried in antiquity. Syrup made from maple sap was a well established item of barter among the Indians in the area of the Great Lakes and the St. Lawrence River before white man's arrival in North America (Borgstrom 1968). The Indians would hack wounds in the sugar maple trunk in the early spring, collect the sap into vessels, and concentrate it either by dropping hot rocks into it or by freezing the sap and discarding the upper layer of ice that formed. The early settlers quickly accepted this new food and improved on its production. Subsequently, maple products became important agricultural commodities on the North American continent and are one of the few solely American products. Production has been confined, however, to the eastern parts of the United States and Canada as far west as Wisconsin, wherever Acer saccharum is indigenous.

The amount of land on which canyon maple is either the dominant or codominant species has not been recorded. However, within a 100-mile radius of Logan, Utah, it amounts to an estimated quarter of a million acres. Most of the trees on this land are probably too small to produce enough sap to make syrup production commercially feasible. But tapping the trees, collecting the sap, and making it into syrup on a small scale could become an important recreational activity in the Intermountain Region, particularly since making maple syrup seems to connote a fascinating pioneer spirit that has much appeal. In this respect, numerous students at Utah State University, having heard of this maple syrup study, have enrolled in a special problems course during Spring Quarter, 1974, to work with us on a follow-up
Figure 5. Panelists occupied individual booths while making the sensory evaluation of the two syrups. The curtains, which normally are closed, have been drawn aside to show the interior of the booth.

Rapid Evolution in Western Shrubs

HOWARD C. STUTZ

Because shrubby plants have attributes of herbaceous plants as well as of trees, they are able to respond to a broader spectrum of evolutionary forces than can either of the others. It is probably their evolutionary heterosis more than anything else that has permitted shrubs to be so successful in so many different habitats of the world. In the extensive heterogeneous habitats of the Intermountain West, they dominate most of the entire landscape from the deserts to the tops of the mountains. Hundreds of thousands of acres have little of anything else growing on them.

Although many different families are represented among the shrubs of the Intermountain West, the Rosaceae, Chenopodiaceae and Compositae are, by far, the most successful. The Rosaceous shrubs include such important dominants as blackbrush (Coleogyne), bitterbrush (Purshia), chokecherry (Prunus), mahogany (Cercocarpus), and serviceberry (Amelanchier). Chenopod shrubs include saltbush (Atriplex), winterfat (Erotria), greasewood (Sarcobatus), and hopsage (Gravdia). The two most important Compositae shrubs are sagebrush (Artemisia) and rabbitbrush (Chrysothamnus).

Each of the major evolutionary processes is well exemplified among these highly successful groups. This can probably be best illustrated by describing the evolutionary sequences which are, even now, bringing forth new species.

New species originate by three major avenues:
(1) through the accumulation of new mutations;
(2) as products of sexual recombination; and
(3) via polyploidy.

Each process can be well illustrated among our common shrubs.

NEW MUTATIONS
1. Speciation through the accumulation of new mutations. [Illustrated by speciation in mountain mahogany (Cercocarpus ).]

There are three distinct species of Cercocarpus: (1) Mountain mahogany (C. Montanus ), (2) leather-leaf mountain mahogany (C. ledifolius Nutt.) and (3) narrow-leaf mountain mahogany (C. intricatus Wats). They are morphologically and ecologically quite distinct.

C. montanus is the most abundant of the three. This very valuable range plant is common in the lower mountain brush zone, along with scrub study on making canyon maple syrup during the sap flow period at that time.

Anyone who may be interested in experimenting in making canyon maple syrup themselves should be sure to get permission from the landowner or the government agency that administers the land on which the trees are located.

LITERATURE CITED
oak, chokecherry, snowberry and serviceberry. It has broad deciduous leaves.

*C. ledifolius* grows at higher elevations (6-9,000 feet) in association with ninebark, big tooth maple and aspen. It forms a small tree under which there is very little understory growth and provides consequently, a favorite bedding ground for deer and elk.

*C. intricatus* is most common on exposed limestone cliffs. It is restricted in distribution, being confined almost entirely to Utah and the borders of neighboring states. It is rather short in stature and has small needle-like leaves.

Hybrids between all three species occur in nature. However, the hybrids between *C. ledifolius* and *C. montanus* and between *C. ledifolius* and *C. intricatus* are much more common than hybrids between *C. intricatus* and *C. montanus*. This, together with other evidence, suggests that *C. ledifolius* is ancestral to each of the other species as shown in figure 1.

Leaf size on *C. ledifolius* plants is highly plastic, with some leaves being much longer and broader than others, even on the same plant (figure 2). Under severe water stress, some leaves on a shrub will be very short and narrow; under more favorable conditions, leaves all tend to be large and broad. Such plasticity permits *C. ledifolius* plants to accommodate a wide range of climatic variations.

Laboratory experiments have shown that a characteristic that is normally expressed only under certain environmental situations may attain regular genetically controlled expression, even in normal environments, if it is severely selected for whenever expressed. Such a shift from being a solely environmentally induced characteristic to being under total genetic control is termed genetic assimilation (Waddington, 1953). Waddington, (1953) Bateman, (1956) and others, have demonstrated this in a peculiar “cross-veinless” characteristic in wings of fruit flies which can be induced with heat shocks. If such induced “cross-veinless” flies are severely selected, in just a few generations the character becomes completely “genetically assimilated” and shows up without the heat shock. Lysenko several years ago (1935) also showed this in wheat, where he changed “winter wheat” to “spring wheat” by selecting “spring-like” behavior in winter wheat after it had received cold shocks.

This same phenomenon appears to have been responsible for the origin of *C. intricatus* (narrow-leaf mountain mahogany) from *C. ledifolius* (leather-leaf mountain mahogany). Under consistently dry conditions, *C. ledifolius* plants that develop the most small, narrow leaves would be expected to be highly favored over the broader-leaved forms. Such intense selection would be expected, as with the cross-veinless fruit flies, to eventually lead to regular expression of narrow leaves without the environmental stress. Such genetic assimilation has apparently yielded *C. intricatus* which now genetically produces small, narrow leaves even when growing in very moist conditions. Even plants which sometimes aberrantly grow right along streambanks have leaves almost as small and narrow as plants growing in crevices of adjacent rocky cliffs.

The prerequisites for speciation by genetic assimilation include both plasticity and a rich supply of mutations. *C. ledifolius* contains both. Variations between plants indicate a rich supply of genetic variation and variations in leaf size on single plants indicate wide plasticity.

*C. montanus* (mountain mahogany) may have also been derived from *C. ledifolius* by selection, although the evidence is much more obscure than it is for the origin of *C. intricatus*. The broad leaves of *C. montanus*, which are required for successful competition with oak and chokecherry and serviceberry in moist sites, could have been derived by long term selection from the narrower parental *C. ledifolius* forms. Successful utilization of the broad leaves, however, would require that they drop off each autumn to allow survival through the drought of winter months. *C. montanus* could have acquired this simple, but distinguishing, genetic attribute from new mutations.

New mutations can provide a rich source of variation from which natural selection can derive many, new alternative themes. Sometimes mutations add direct valuable attributes;

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**Figure 1.** The origin of species in *Cercocarpus*, *C. intricatus* and *C. montanus* may have each been derived from *C. ledifolius* by "genetic assimilation."
at other times, they provide the opportunity for genetic assimilation of valuable plastic characters. The numerous races of big sagebrush, rabbitbrush, serviceberry, scrub oak and saltbush indicate that speciation through selection from new mutations is and has been highly significant, probably among all of our native shrubs.

SEXUAL RECOMBINATION

II. New species as products of sexual recombination. [Illustrated by speciation in cliffrose (Cowania) and bitterbrush (Purshia).]

Although cliffrose (Cowania stansburyana Torr.) and bitterbrush (Purshia tridentata Pursh. DC) belong to separate genera and differ in many, many characteristics, they hybridize quite commonly in nature (figure 3). The hybrid is highly fertile and numerous segregating progeny are formed annually throughout the hills of Utah and Nevada (Stutz and Thomas, 1964).

Cliffrose is a small tree (8-12 feet) confined to dry hillsides at elevations of about 5 to 7,000 feet. It grows from northern Utah to central Mexico. It is eaten sparingly by sheep and big game but is otherwise of little economic significance.

Bitterbrush is a very valuable low-growing shrub (2-4 feet), somewhat moist, common on sites from southern Utah and Nevada north into Idaho, Washington, Oregon and British Columbia. Some range specialists rate it as the number one browse plant for sheep and deer.

Since cliffrose ranges from northern Utah southward into Old Mexico, while bitterbrush ranges from southern Utah northward into Canada, the entire state of Utah is an overlap area for the two shrubs. Throughout Utah, hybridization between them is so common that no population of bitterbrush can be found which is free of cliffrose genes. However, although many F₁ and backcross segregants are common, none appear to be as well adapted to the currently available habitats in Utah as are the parents themselves. The phenomenal array of new combinations produced every year from these hybrids are exposed to many diverse habitats throughout Utah; nevertheless, none appear to have found a habitat conducive to major reproductive success.

Immediately south of Utah, however, an unusual environmental niche has provided just the right situation for one of the hybrid segregants. This has been identified as a distinct "species," commonly known as "glandular bitterbrush" and scientifically designated Purshia glandulosa (figure 4). That it is, indeed, a derivative from the interspecific hybrid is clearly indicated by its intermediate characteristics, which match those of some of the known segments in other parts of Utah. In addition, each population of Purshia glandulosa, although characterized by the particular features that define it, possesses a unique collection of other parental characteristics. These, as expected, occur as fortuitous segregants in each isolated population but apparently do not offer any specific adaptive value.

North of Utah another "species" is in the making. The environment being invaded by this potential "species" is the heavily grazed rangelands of Ida-
ho, Oregon and Washington. Exposure to hordes of sheep gives a unique advantage to any bitterbrush population containing lowered palatability genes from cliffrose. Consequently, cliffrose characteristics are present in almost every population of bitterbrush north of Utah. Even as far north as British Columbia one or two plants in each population show evidence of introgression from cliffrose.

So, although cliffrose does not grow north of Utah, its genes are spreading like wildfire because of the intense selective advantage of its lowered palatability. When and if a new, distinct species emerges, depends primarily on the intensity and steadiness of the “environment” being created by the sheep industry.

Similar interspecific hybridization is common among many of our other native shrubs. Natural fertile hybrids have been found between scrub oak of northern Utah (Quercus gambeli) and live oak of southern Utah (Quercus turbinella); between shadscale (Atriplex confertifolia) and Castle Valley clover (Atriplex cuneata); between big sagebrush (Artemisia tridentata) and black sage (Artemisia nova); and as noted above, between the various species of Cercocarpus.

From such hybrids come a host of new recombinations, many of which have already found environmental niches to which they are successfully adaptive. Many others can be expected from such a rich gene pool. Some of them will arise naturally, but with our current knowledge of genetics and plant breeding, we should be able to accelerate the process and obtain a host of new themes specifically adapted to particular habitats, much as we have already done with our domesticated pasture and garden plants.

**POLYPLOIDY**

III. New species via polyploidy. [Illustrated by speciation in saltbush (Atriplex).]

The genus *Atriplex* is a remarkable genus that includes annuals, herbaceous perennials, and several shrubs. The plants are mostly confined to highly alkaline, heavy soils, probably more because competition is low in such places than because they particularly enjoy it.

*Atriplex canescens* (Pursh.) Nutt. (fourwing saltbush) is one of the more important shrubby species with a wide distribution throughout western North America from southern Alberta to central Mexico and from the Dakotas to the Pacific Ocean. It is a variable species but is generally about 2-3 feet high and about 3-4 feet in diameter. It usually grows on better drained and sandier soils than do other *Atriplex* species. It is typically dioecious although monoecious plants are not uncommon.

All in all, it is a bit surprising to find that this widespread, highly successful species is an autotetraploid (Stutz, Melby and Livingston, 1974). A few natural autotetraploid species have been described (e.g., Dunford, 1964; Lewis, 1974) but none are as widespread and successful as *A. canescens*. Just as remarkable is that such a successful autopolyplod derivative occurs in a dioecious species. Almost all other known polyploids have come from highly self-fertilized parentage.

Several lines of evidence prove that *A. canescens* is indeed an autotetraploid. First, at meiosis there is a high frequency of chromosomal multivalents, typical of and almost unique to autotetraploids. Furthermore, fourwing saltbush plants are low in pollen and seed fertility, also characteristic of autopolyploids. Probably the most definitive, as well as the most exciting, evidence is the discovery of a still existing relic diploid population. Although closely similar to its tetraploid derivative, the diploid differs in a few expected characteristics such as higher pollen and seed fertility and regular meiosis, and in several other unexpected characteristics. It has much more plant to plant variation than is found within any population of the tetraploids.

The diploid population is confined to a tiny sand dune island in central Utah occupying only about 300 square miles. Most of the morphological characteristics that distinguish it from its tetraploid neighbors appear to make it uniquely adapted to the sand dune habitat (table 1). Its growth rate is nearly double that of tetraploid plants (figure 5). Mature plants are giants up to 12 feet tall and 15 to 20 feet in diameter. The diploids have larger fruits, larger leaves, and longer, although more slender stems. They have an unusual
Table 1. Contrasting Features of Diploid and Tetraploid Atriplex canescens

<table>
<thead>
<tr>
<th>Character</th>
<th>Diploid</th>
<th>Tetraploid</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Stature</td>
<td>giant</td>
<td>normal</td>
</tr>
<tr>
<td>2. Seed germination</td>
<td>high</td>
<td>low</td>
</tr>
<tr>
<td>3. Growth rate of seedlings</td>
<td>high</td>
<td>low</td>
</tr>
<tr>
<td>4. Growth rate of new twigs</td>
<td>high</td>
<td>low</td>
</tr>
<tr>
<td>5. Distribution</td>
<td>restricted</td>
<td>wide</td>
</tr>
<tr>
<td>6. Polysomaty</td>
<td>common</td>
<td>rare</td>
</tr>
<tr>
<td>7. Root sprouting</td>
<td>common</td>
<td>rare</td>
</tr>
<tr>
<td>8. Time of flowering</td>
<td>late</td>
<td>early</td>
</tr>
<tr>
<td>9. Pollen fertility</td>
<td>higher</td>
<td>lower</td>
</tr>
<tr>
<td>10. Pollen size</td>
<td>dimorphic</td>
<td>one size</td>
</tr>
<tr>
<td>11. Sexuality</td>
<td>always</td>
<td>often</td>
</tr>
<tr>
<td>12. Meiotic chromosomes</td>
<td>bivalents only</td>
<td>multivalents</td>
</tr>
<tr>
<td>13. Fruit size</td>
<td>larger</td>
<td>smaller</td>
</tr>
</tbody>
</table>

propensity for forming adventitious roots and shoots, which probably is of considerable value in habitats characterized by drifting sands.

The origin of tetraploid A. canescens from the strictly dioecious diploid parent is puzzling. Although tetraploid plants are often monocious, diploids are strictly unisexual. Characteristically, dioecious plants and animals "never" give rise to polyploid derivatives. This is because, even though polyploid progeny are produced, as unisexuals they would need to be fertilized by sex cells from a diploid (the only source available) and their progeny would be completely sterile triploids. (This is the principal reason why polyploidy is so rare among animals.)

So, to find a tetraploid Atriplex canescens species derived from a strictly dioecious diploid parent is indeed unusual. Although an explanation has not yet been firmly established, a plausible one seems to be a possible disturbance of the sex-determining mechanisms upon polyploidization. If, for instance, sexuality in the diploid should be determined by X-Y chromosomes, as occurs in many other organisms, then XX = one sex and XY = the other sex. If one such XY plant should form polyploid tissue, it would then be XXYX. If such polyploid tissue grew into reproductive structures, they might, in some situations, be of the same sex that was dictated by the XX in the diploid progenitors. Or, they might be of the other sex, which was determined by the 1:1 X-Y ratio in the diploid. Consequently, XXYY tetraploid tissue might form both male and female reproductive structures depending on subtle environmental variables during its development. In this circumstance, a monocious tetraploid product derived from a strictly dioecious diploid progenitor would be able to self-fertilize, leaving fertile monocious tetraploid offspring and thus escaping the usual dead-end encountered by autotetraploids derived from strictly dioecious parents. Much credence is given this hypothesis by the common occurrence of monocious plants among tetraploid populations. But regardless of whether or not this interpretation proves valid, the successful autotetraploid derivative is a reality. How many others have been formed or how many can yet be formed or how many allopolyploids have been and can even yet be formed from diploid Atriplex species are all exciting questions still awaiting answers.

Atriplex is an unusually rich genus. Nowhere else do so many species and varieties occur as right here in the Intermountain West. Atriplex thus is one of the most rapidly evolving groups in the world. Almost every valley contains unique ecotypes, some of which appear to be segregants from interspecific hybridization, while others seem to have accumulated unique batteries of adaptive mutations, and still others were probably derived as polyploid themes.

(Continued on page 33)
SHRUB SEED PRODUCTION—
A POTENTIAL ENTERPRISE

GORDON A. VAN EPPS

Native shrubs are an important renewable resource on most of our rangeland in the West. Several have the desirable attributes of wide adaptability and palatability. In addition, some grow rapidly, recover well from grazing, and spread naturally. One reason for limited extension of their populations has been the lack of good seed.

The only seeds presently available come from wildland stands. Since collecting is done by hand, it is slow, tedious, and can be expensive. Further, the quality of the seed is not as good as desired, with the amount of viable seed obtained varying widely from one year to the next. Spring frosts cause untold losses from species that flower early. Drought and plant competition are other major factors.

As harvesting from wildlands must continue, at least for the immediate future, it is important to increase the efficiency of the process. At the same time, we want to learn how to make shrub seed production a profitable enterprise on agricultural land. This will become increasingly possible as improved ecotypes are selected and the demand for seed increases. Production of shrub seeds on agricultural land could insure high quality seed of a desired strain adapted for particular conditions. By furnishing an alternate cash crop for agriculturists, shrub seed production could help substantially on marginal lands that are presently producing low returns. Good returns might also be obtained from plantings on some of the best farm lands. In addition, lands converted to shrub seed orchards should also furnish valuable grazing for livestock, particularly during the winter period.

Production and management methods are now being explored for certain species (the saltbushes (Atriplex spp.) especially fourwing saltbush (A. canescens); sagebrush (Artemisia spp.); rabbitbrush (Chrysothamnus spp.); antelope bitterbrush (Purshia tridentata); and winterfat (Eurotia lanata). Trials have shown that the species being studied can be grown for their seed under cropland conditions if their growth needs are met. The shrubs in question are important to game and livestock ranges. Further, they have high merit for revegetating disturbed sites such as road cuts and corridors, energy transportation right of ways, quarries, and mines.

FOURWING SALTBUSH

Fourwing saltbush grows in most counties of Utah and in the surrounding states. The plant prefers an alkaline soil with some ecotypes adapted to sandy soils such as sand dunes. Male and female flowers tend to occur on separate plants, although this varies a great deal depending on plant source. Some individual plants have various percentages of both sexes.

Predicting the sex of a plant prior to blooming is not yet possible. This presents a problem in establishing a seed orchard. It would be especially advantageous when mechanical harvesting is developed to have most plants female with only enough male plants to insure fertile seed. One good solution would be to use vegetative propagation with the sex being predetermined. This procedure could also assure perpetuation of desired vegetative and adaptive characteristics. Other methods would be to hill or row plant and then thin to the desired proportion and spacing of female and male plants.

Hedge pruning of 4-year-old plants to various degrees in the fall and spring proved that female plants pruned during the fall or winter will not produce seed the following year. This is true even though the fruiting bodies are developed toward stem ends on current-year growth. Two years following pruning, flower development was less on pruned than unpruned female plants. The date of pruning had no visual effect on vegetative plant growth. Combine harvesting if practical, would entail one seed crop every two years at the best.

Even when cut back to stumps over a period of several years, plants generally produce excellent regrowth the following growing season. Young, 1- to 2-year-old transplants have a greater tendency to winterkill if the tops are pruned the fall or winter following a spring field planting as compared to transplants not pruned.

Four-year-old fourwing saltbush plants in a spacing trial on the Nephi Field Station, where the average annual precipitation is 12 to 13 inches, showed moisture stress when spaced 2 feet apart on rows that were 6 feet apart. Such stress would become more apparent as the plants aged. Possible effects on seed yield could not be determined due to an early winter followed by severe winterkill of the plants.

Ecotypes from a specific location showed varied cold tolerance following the harsh winter of 1973. Even some local indigenous plants winter-killed. Warm-climate ecotypes may grow in colder areas over a short span of years, only to be largely eliminated during colder years. Cold tolerant ecotypes can be planted in warmer climates successfully for seed orchards, but not the reverse. Winter hardiness is therefore essential to plants being selected for increase.

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Figure 2. Fourwing saltbush in a 4 foot row spacing for seed production.

Fourwing saltbush nurseries for transplant material are easily established. Seeds (which remain viable for 5 years or longer) that are planted shallow during June with the topsoil kept moist by sprinkling for a week to 10 days or until emergence will produce excellent nursery stock for early planting the following spring. Such plants generally begin producing a seed crop 3 to 4 years after planting.

Individual plants vary tremendously in the amounts of total and viable seed they produce, apparently regardless of utricle size or number. Good plants should produce 1 to 1½ pounds of clean seed including the single-celled pod (the utricle) although some large plants have produced 5 pounds or more of seed. The utricles vary in size and wall thickness, and generally have 4 wing-like appendages. These wings are removed in cleaning, but the small seed remains encased in the utricle for planting. The variations in seed dormancy that we’ve seen may be due to variations of the utricle.

Diseases and insects can be real problems in shrub seed orchards. Preliminary studies indicate this species is susceptible to the fungus Verticilium, which injures or kills young to mature plants. Some ecotypes are susceptible to mite damage. Occasionally, plants have been completely defoliated by insects that also destroy developing floral parts.

Seed orchards should possibly be located in areas with little or late winter snow, since the seeds mature in late fall and winter. This would be even more important as mechanical harvesters that will remove the seeds from the plants without injury to the branches are developed.

The effects of supplemental moisture and soil fertility on seed production have not been studied.

SAGEBRUSH

Species of the genera Artemisia contain many ecotypes, perhaps over 100 in Utah. Natural hybridization between species frequently produces numerous variants, especially in those areas where 2 or 3 species grow together. Ecotypes within species can vary in vegetative characteristics, seed production, adaptability, and palatability. Ecotypes of some species transplant readily.

Wildings of several species from numerous sources, when planted for observation on cropland, showed great variation in seed production. Flowers of some such as A. rothrockii seem to blast and are non-seed productive when moved from their normal environment. Ecotypes from other species such as A. cana appear to produce normal flowers, but few if any seeds are viable, at least in those studied. This also appears to be true with some sources of A. tridentata, A. tridentata vaseyana, A. nova, A. biglovi, and others. On the other hand, several representatives of each of these noted are excellent seed producers with many seedlings being produced around the mature seed plants.

Seeds vary in size depending on the species, but all are extremely small causing special problems in harvesting and in cleaning where clean seed is necessary. Most seed is moved commercially on a 10 percent purity basis. Flowers of most species bloom late, with seeds maturing in late fall. A. longiloba and A. spinescens are exceptions that bloom in early summer. This late maturity of seed will create problems in harvesting from seed orchards established where fall snowstorms occur.

Cutting off and removing all inflorescent stems during the winter for seed appeared to have a detrimental effect on plants of some ecotypes within several species. Additional work along this phase is needed as several species could be combine-harvested for seed, providing it did not injure the plants. An adjustable collecting pan on the front of a jeep
or tractor with a power driven reel-beater accompanied by air suction for seed removal from the pan might be more suitable.

The effects on seed production of insects and diseases need to be explored. Some ecotypes seem more susceptible to the fungus *Verticillium* than others, especially when grown on cropland, though evidence of this occurring on the range has also been found. Even young seedlings 1 to 2 years old have been observed dying from what is attributed to be this fungus. The effects vary from only a part to the entire plant being killed. Symptoms may occur throughout the growing season but seem more prevalent in the spring. Another fungus that causes black lesions on the leaves seems to affect nearly all species during the fall and winter. Various insects are known to cause damage but how detrimental this is to seed production is not presently known.

**RABBITBRUSH**

Several ecotypes within species of the Rabbitbrush group are more palatable than their close relatives. One of these is an ecotype (or probably a variant) within the subspecies *C. nauseous salicifolius*. Others due to their characteristic growth habits and ease in establishment and natural spreading show value for revegetating, disturbed sites.

Though nothing is known as to their cultural needs for seed production on cropland, rabbitbrush is a prolific seed producer wherever it occurs naturally. This is borne out by the rapid spread of seedlings from mature plants. Their ability to increase in established grass plantings may become an asset as palatable strains are developed. Seeds from this genus generally germinate upon maturity without treatment, and seem to germinate in the field whenever moisture conditions are adequate. Seeds have a rather short life of from 2-3 years. The percentage of empty seeds produced is generally high. A better than average plant should produce approximately 1/4 lb. (100-125 g.) of clean seed each year. Cleaning is difficult and time consuming due to the number of papery bracts, the tuft of bristles attached to the crown of the seed, and floral parts that need to be separated from the small slender seed. It may be possible to harvest some ecotypes with a combine harvester, though an adjustable collecting pan including a combination beater with air suction may be more practical.

**ANTELOPE BITTERBRUSH**

Antelope bitterbrush is one of the more important deciduous browse shrubs for wildlife and livestock. Though not so fast in regrowth as some others being studied, it definitely has a place due to its wide adaptability, the different forms produced, and its usefulness for erosion control. It may also provide an ornamental for landscaping in addition to producing forage. Differences in palatability to deer have been observed at the Nephi Field Station. Tremendous variations in vegetative characteristics between plants have been observed in the 8-year-old Station plantation. The particular ecotype being used has an intermediate growth form. The seed was obtained from indigenous plants on the divide near Fountain Green. Approximately 8 years must lapse after planting before a seed crop can be obtained. Seed yields are expected to increase as the plants age.

This species prefers a well-drained soil for normal healthy growth. Plants become chlorotic in heavy soils and generally die.

Eight-year-old plants spaced 2 to 4 feet apart in rows that are 4 feet apart show moisture stress quite early in the summer with yellowing and shedding of leaves. The effect that this might have on seed production is not known at present but may be slight as seeds normally mature the middle part of July in Central Utah. The entire seed crop in 1973 was destroyed by Say's green stink bug (*Chlorochroa sayi* Staal.).

Only a few days are available for harvesting this species as the seeds shatter readily on maturity. For this reason, seed orchards should be established in areas subject to little wind during the period of seed maturity. The effect on seed yield from pruning the lower branches for cultivation and ease in harvesting seed is not presently known. Good mature plants should produce 1 or more pounds of clean seed.

Mechanical methods of harvesting when developed may possibly include a blower exerting enough wind force to blow the seeds off the plant into a hopper, or a device to shake the seeds off onto a tarp or tray.

Fall or winter planting will break the seed dormancy and be followed by spring emergence. Where spring planting is desirable, dormancy may be broken by a cold-moist stratification or by treating with a 3 percent solution of thiourea for 5 minutes. Mice can be a real problem after a fall planting.

**WINTERFAT**

Winter or white sage is widely spread and varies in plant height from a few inches to 5 feet or more depending on source of the ecotype. It grows rapidly following normal grazing where moisture is available. It produces an abundance of viable seed under cultivation. The growth form of this plant is generally adapted to combine harvesting for seed. Seeds are developed in a rather thin-shelled, cottony covered utricle. They are planted in the utricle as it is difficult and expensive to remove the cottony material from the utricle or the seeds from the utricle. This cottony material causes substantial problems in sowing the seed in rows by machine drilling. A good method of planting other than by hand has not been found. Seeds normally mature in the fall.

Additional collection trips are needed to provide us with more ecotypes of this valuable plant for nursery establishment and selection. Seed production studies dealing with these valuable and useful shrubs are just beginning. We know they can be grown. Now we need to learn the necessary mechanics for plant establishment, practices for producing high yields of viable seed, and efficient methods of harvesting. The demand for the resultant seeds will inevitably increase as improved strains are selected for various uses.
KOCHIA PROSTRATA: a shrub for western ranges?

**WESLEY KELLER AND A. T. BLEAK**

*Kochia prostrata* (L). Schrad, prostrate summer cypress, a member of the Chenopodiaceae or Goosefoot family, may become a valuable forage plant on western ranges. It is widely distributed throughout the arid and semiarid parts of Russia and westward to the Mediterranean Sea and Central Europe. This species (figure 1) has been observed under conditions ranging from favorable to very severe in Central Asia. Larin (1956) describes kochia as, "an undershrub having thick roots with numerous branches, which penetrate deeply into the soil." Kochia is a long-lived, morphologically variable species that ranges in height from less than 1 to over 4 feet. Native species, *K. americana* and *K. californica*, are low forage producing perennial species that are present on western ranges. An introduced annual, *K. scoparia*, is widely distributed and under some conditions is a high forage producer, but this annual is generally classed as a weed. Desirable members of the Goosefoot family native to the western ranges include saltbrush (*Atriplex*), and winterfat (*Eurotia*), but this family also contains many species which accumulate dangerous levels of oxalates that can be poisonous to livestock. *Haloege*ton is a poisonous member of this family.

**PLANT INTRODUCTION**

Kochia was observed in 1959 (USDA, 1961) in the V. I. Williams soil museum at the Timiryazev Academy in Moscow by the senior author. The space devoted to kochia in the soils museum indicated that it was an important species to the Russians. Kochia was widely recommended for seeding on sandy soils with crested wheatgrass. Seeds were requested and received by the New Crops Research Branch of the Agricultural Research Service. The collection was increased at the ARS Regional Plant Introduction Station at Pullman, Washington. Additional seeds were requested in 1965, and we have received and planted seed of 18 accessions.

**RUSSIAN LITERATURE ON KOCHIA**

The literature contains widely conflicting views of the value of kochia. In the *Flora of the USSR*, Vol. 6 (1936) Aleksandrovskii and Begichev assessed kochia "... as poor forage, little superior in value to winter rye straw." The *Flora* further commented that differing opinions were a result of marked variability of the species, and offered the following evaluation: "The plant is used for fuel by nomads in semidesert and desert regions. Horses and camels show a great liking for it. Kazaks esteem it as a fattening feed for sheep, goats, and camels, but the plant is of little value for milk production." Larin (1956) was highly favorable to kochia: "It is one of the most drought resistant and halophytic plants, and is the most valuable and potentially most important plant of the whole goosefoot family. It is eaten readily by sheep, goats, and camels and somewhat less so by other kinds of livestock... It is one of the best known fodder plants on solonet soils in the semidesert and on serozems in the desert." Larin and Gordeeva (1960) reported that kochia declined in productivity following harvest at 1 or 2 inches above the ground. They also noted that fairly heavy grazing thinned the stand. Nechaeva and Prikhod'ko (1966), working in Turkmen SSR, reported that germination of kochia occurred in their seedings; but the stands did not persist.

Gaevskaya et al. (1969) advocated mid-winter seeding, at .5 to 10 pounds per acre depending on the seeding...
method and the intended use. Generally good results were obtained from broadcasting on the soil surface but the stands were improved if the seeds were covered.

WHAT WE HAVE LEARNED ABOUT KOCHIA

In 1968 we established small plots of two morphologically different accessions, PI 314929 and PI 358941. Seedlings started in a greenhouse were transplanted to a field site in the foothills northeast of Logan. The plants were spaced 2 feet apart, and the plots were kept weed-free. Seed has been harvested from these plots during the past 5 years.

The seed yields ranged from 75 to 250 pounds per acre. Kochia seeds are quite small with about 500,000 seeds per pound, which is about twice the number in a pound of alfalfa seed. The uniform appearance of progenies indicates that this species is self-pollinated.

In 1968 we established a study that afforded a direct comparison of kochia with Ladak alfalfa. Each was grown in association with Nordan crested wheatgrass. In the first harvest year, kochia yielded almost as well as alfalfa, and both were substantially more productive than crested wheatgrass. In subsequent harvest years, however, the yield of kochia dropped markedly. We believe that the kochia was injured by too close harvesting. Even so, excluding the first year, the yield of kochia over the following 5 years was substantially greater than the yield of the associated grass.

On the basis of our experience, kochia is relatively easy to establish from seed. It appears to be deep rooted, drought resistant, and productive. Plants are weakened by close harvest. Kochia seeds are short-lived. Seeds stored in a cool, dry place remain viable for about 1 year. Plot seed harvest occurred from late October to early November.

WHAT WE NEED TO KNOW

Two important questions remain to be answered before kochia is fully evaluated for possible use on western rangelands. (1) Is the species sufficiently well adapted to this environment that it will survive and be productive under rangeland management in the west? (2) Is kochia a desirable feed for all grazing animals?

The summers in kochia's native habitat are long and hot, and the winters are short and cold with low, highly variable precipitation (Borisov, 1959). Elevation of these areas in Central Asia is about half of that in the Intermountain Region. The diurnal temperature range is relatively low in Central Asia. Although this plant appears to be well adapted to the climate of the Intermountain Region, additional time will be required to verify this assumption. To determine the behavior of kochia under a wider range of conditions we have supplied small quantities of seed to other researchers and to agencies interested in its use.

If the first question asked above is answered affirmatively, we will still need to know whether dangerous levels of oxalates accumulate in this species. We have found no mention in the Russian literature that kochia is poisonous to any class of livestock. Nevertheless, we supplied kochia forage to the ARS Poisonous Plant Laboratory located on the campus of Utah State University. Personnel of the Poisonous Plant Laboratory have determined a water soluble oxalate content ranging from 4.8 to 6.3 percent in four accessions. These are not necessarily dangerous levels, but they do warrant further investigation.

CONCLUSIONS

Kochia is a very drought resistant and salt tolerant species native to Central Asia. It is easily established from seed, and it is productive. We have not subjected it to grazing, but we know it does not tolerate close harvest. The nutritional qualities of kochia are not known, and potentially dangerous oxalates were found in four accessions recently examined. Because the species is highly variable, all possible strains or accessions should be examined. If a strain with acceptable forage qualities can be found, we may have a new species for use on our arid range.

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OLD MAN WORMWOOD

to Stabilize Disturbed Areas

A. PERRY PLUMMER

Oldman wormwood (Artemisia abrotanum), sometimes called southern wood, European sage, and ornamental sage, is a European shrub that was successfully introduced into the United States a century ago. Over the past 35 years, it has proved well-adapted to the wide variety of soils that range from fairly alkaline to fairly acid in the Intermountain West. Oldman wormwood can be a good ornamental shrub on private premises, but it can also play an important role in erosion control on such disturbed areas as road cuts and fills (figure 1). It provides esthetically pleasing cover for these scars as well as for places where topsoil has been removed by bulldozers and similar equipment. In addition, it is palatable browse for sheep and big game.

Oldman wormwood is readily established in the early spring by sticking cuttings into saturated soil. Ease and speed of establishment make its use for such purposes especially appealing. Planting the species as nursery stock is also successful; however, establishment is much slower, and such plantings are warranted only on severe sites.

Ordinarily the plant grows from 3 to 5 feet in height. It has a pleasing aromatic fragrance and bright green, finely divided foliage that gives it a feathery appearance. If oldman wormwood is planted singly, numerous shoots develop rapidly on stems, and the plant assumes an appealing, characteristic spheroid form. The shrub responds well to hedging, where hedges of varying heights are desired. It is used extensively for this purpose on the plains of Canada and the United States.

Over the past 35 years, plantings have been made at many different sites on the Wasatch Plateau and in the Wasatch Mountains of central Utah, to help provide cover for disturbed areas. Cuttings that rooted successfully were able to withstand both the long periods of drought in the big sagebrush-juniper zone (5,000 feet) and the extremely short growing season of high mountain elevations (10,500 feet). Average annual precipitation varies from 12 to 40 inches at the different sites. Under favorable conditions of precipitation, at least 75 percent of cuttings can be expected to establish and grow. Growth is rapid and new stems can reach a height of from 2 to 4 feet in one season. Regrowth after spring or early summer grazing is rapid, even in the heat of the summer, if moisture is available.

Because it can root quickly and develops an unusually deep and extensive root system, oldman wormwood obtains water and soil nutrients from a considerable area and depth. Its rooting characteristics allow it to establish and maintain itself in raw subsoils and makes the plant useful for erosion control. The author has found no cuttings from other shrubs, including willow, that can compare to oldman wormwood in rapid rooting (figure 2). One principal value of this shrub is the favorable microclimate it provides for establishment of other plants. Plants spaced about every 2 to 4 feet in staggered rows provide a good ground cover on disturbed sites.

Cuttings 10 to 18 inches long from stems one-eighth to one-half inch in diameter give good results. Smaller cuttings root well, but are difficult to stick into the ground. All leaves

Figure 1. Oldman wormwood after 4 years on this central Utah road cut. Plants were established in 1963 by sticking cuttings into the ground in early spring. As soil sloughs against the established plant, stems merely root at higher levels.
and small twigs should be trimmed from cuttings. The large end of the cutting should be sharpened to facilitate penetration of a hard soil surface without damage to the cutting. Planting should preferably be within a few hours after cuttings are taken. If it is necessary to keep them for any length of time, cuttings should be wrapped in burlap or placed in a plastic bag and kept moist in a cool place. Cuttings have rooted well following 6 weeks in refrigeration. The best time for setting out cuttings is early spring, when the soil is still wet from winter snows. Generally, roots will be forming and new buds leafing out 2 to 4 weeks after planting.

Oldman wormwood loses its leaves and young twigs after the first heavy frost. Killing back of branches during the winter is common, but generally less severe at high elevations because a blanket of snow protects plants from dry, freezing winds. Only the few stems that protrude through the snow will be killed at these elevations. At low elevations, where the snow mantle is thinner and intermittent during the winter, a considerably larger portion of the plant is exposed to freezing temperatures and many branches are killed. In either case, when growth commences in the spring, the amount of winterkilling has little or no effect on the rapid regrowth of the plant. Experience indicates that an annual cutting back of the branches to the crown will keep the species in a desirably thrifty and vigorous condition. The author has had no success from planting seed in any of several experimental plantings on wildlands. So far, little if any seed has been observed to mature in established plantings, and, except in one instance, no reproduction has been seen.

Small rodents such as meadow mice, pocket gophers, and rabbits often girdle the plant near the base beneath the snow. Grasshoppers show an especially high preference for this shrub. Protective measures against these damages may be helpful in maintaining the shrubs; however, plants have resprouted well in most instances.

Instructions for planting cuttings follow:

1.—Cuttings should be from 10 to 18 inches in length and one-eighth to one-half inch in diameter. Cuttings of smaller diameter can be used if they are stiff enough to stick into the ground.

2.—The large end of a cutting should be sharpened if the surface soil is hard. A sharp steel probe can be used to make a hole so that a cutting can be more easily inserted.

3.—At desired locations, cuttings should be inserted into the ground to a depth at which they are in contact with fairly continuous moisture for at least 6 weeks. A depth of 6 inches is usually sufficient.

4.—If possible, cuttings should be planted within 48 hours after being taken. They should be kept moist until planted. If it is necessary to hold them, they should be put in cold storage (32° to 40°F).
Shrubs for Restoration and

E. DURANT McARTHUR, BRUCE C. GIUNTA, AND A. PERRY PLUMMER

Shrubby plants dominate or characterize the vegetation of more than 40 million acres in Utah. Moreover, shrubs characterize the ground cover of as many as 800 million acres in the Western States. Shrubs are found at all longitudinal and latitudinal limits except where the ground is permanently covered with snow. They provide habitat for wildlife, nutritious browse for livestock and big game, beauty to landscapes, and stability to disturbed soils or eroding sites. Shrubs constitute the major sustenance of most big game animals in winter. Yet much shrub research over the past four decades has been directed toward eradication of shrubs by fire, and by chemical or mechanical means.

A rationale has gradually developed that some shrubs are bad and some are good based on differences in aggressiveness, forage value, fire susceptibility, water consumption and other attributes. In our recent studies of shrubs, however, we have discovered that the different shrub characteristics can be exploited for specific purposes. We therefore classify areas (rather than shrubs), and consider them suitable or not suitable for planting shrubs.

In the course of 20 years, we have studied more than 100 species of shrubs — some much more intensively than others. We have been primarily concerned with environmental adaptations — their soil, climatic, latitudinal, and ecological tolerances.

Emphasis has been directed toward establishing these species in association with other classes of vegetation on diverse range sites. Other studies have included: collecting, producing, processing, storing and germinating seed; vegetative propagation of cuttings and root stocks; plant production and survival under various management programs; and recently, genetic and chemical analysis. The importance of shrubs to grazing animals has been closely scrutinized. Our work has demonstrated that many ecotypes (or strains) exist in most species and subspecies of shrubs that have special values under particular conditions.

The paucity of knowledge about shrubs is immense. In the following review of findings and observations, we can only attempt to point out the attributes of some important shrubs that are of significance to society.

SAGEBRUSH SPECIES (Artemisia)

Outside of North America, Artemisia's common name is wormwood, not sagebrush. But whatever the popular designation, Artemisia is technically divided into four sections or subgenera. In North America the primary section is the Tridentatae, which quite likely had its origin in the Great Basin. With some exceptions, the most important characteristic in recognizing members of this group is the three-lobed leaf (figure 1).

Big sagebrush (A. tridentata) incorporates an assortment of highly variable shrubs in the western United States which are tremendously important in Utah. We recognize three subspecies — basin big sagebrush (subsp. tridentata), mountain big sagebrush (subsp. vaseyana), and Wyoming big sagebrush (subsp. wyomingensis). One or another of these subspecies can grow well from valley floors to mountain tops (table 1, figure 1). Each subspecies includes ecotypes that may be restricted to a particular geographic area. Some of the leaves of big sagebrush plants stay green and usually remain on the shrub through the winter. Big sagebrush is nutritious and is especially rich in protein in the winter when other plants are low in nutrients. Palatability, or desirability from the grazing animals' point of view, varies with subspecies and ecotype (table 1). These palatability differences are thought to reflect differential concentrations of essential oils and phenolics of various sagebrush types.

Because of its wide distribution and abundance, big sagebrush is the most important winter forage on foothill areas for big game and livestock in Utah and the Intermountain West. Its value is further enhanced by its usually rapid growth and exceptional ability to reproduce and spread rapidly from seed. It establishes well when included in aerial seeded mixtures of herbs.

Wildings and seedlings are transplanted easily to variable sites that need cover. Its ease of establishment makes big sagebrush outstanding for stabilizing gullies and other disturbed places. Transplants reproduce and spread readily from their seeds within 3 to 7 years.

Extensive ranges and particularly lowland valleys in the western states have had their associated grasses and forbs overgrazed. Such areas often become closed stands of the less palatable basin big sagebrush. Large tracts of these closed stands have

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1Federal aid in wildlife restoration funds was provided through Project W-82-R.
been thinned; more will be thinned in the future. After thinning, adapted herds have been seeded to provide a more balanced cover to better support livestock and game. When big sagebrush is grazed so as to keep it appropriately balanced with herbs and other browse, it is unexcelled for providing adequate soil cover and desirable and abundant forage. Proper management includes encouraging intense winter grazing of the sagebrush and allowing sufficient growth to remain on the associated herbs during spring and summer grazing so they can retain their vigor and maintain themselves.

Many big sagebrush ecotypes are available for range restoration. This means that a type may be available that is especially adapted to the particular restoration site under consideration. We are currently trying to gain an understanding of pollination processes in sagebrush so that we can exploit its inherent variation through selective breeding. Our aim is to breed strains that will be superior for range restoration and soil stabilization.

Relatives of big sagebrush are effective soil stabilizers as well as outstanding range plants. These species, which are readily established from seed or by vegetative means, include: black sagebrush (A. nova), low sagebrush (A. arbuscula), silver sagebrush (A. cana), threetip sagebrush (A. tripartita), alkali sagebrush (A. longiloba), and Bigelow sagebrush (A. bigelovii). Collectively, they occur over a wide range of habitats and we are considering them as genetic material for breeding and selection with big sagebrush. More distant cousins of big sagebrush, fringed (A. frigida) and sand sagebrush (A. fllifolia), are especially useful for stabilization of disturbed soils. The fringed type is well adapted to northerly cool climates, whereas sand sage thrives in the warm, sandy areas of southern Utah. An introduction, oldman wormwood (A. abrotanum) is particularly valuable for stabilizing disturbed sites.

<table>
<thead>
<tr>
<th>Subspecies</th>
<th>Habitat</th>
<th>Smell</th>
<th>Palatability</th>
<th>Leaf shape</th>
<th>Height</th>
</tr>
</thead>
<tbody>
<tr>
<td>tridentata</td>
<td>Foothills and valley floors (2,000-7,000 ft.)</td>
<td>Bitter pungent</td>
<td>Low</td>
<td>Narrowly cuneate to oblanceolate</td>
<td>3.5-15 ft.</td>
</tr>
<tr>
<td></td>
<td>Foothills (5,000-7,000 ft.)</td>
<td>Bitter pungent</td>
<td>High</td>
<td>Cuneate</td>
<td>1.5-2.5 ft.</td>
</tr>
<tr>
<td>wyomingensis</td>
<td>Foothills and mountains (5,000-10,000 ft.)</td>
<td>Mint-like</td>
<td>Medium to high</td>
<td>Cuneate</td>
<td>2.5-4 ft.</td>
</tr>
<tr>
<td>vaseyana</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
However, it must be propagated from stem cuttings since no viable seed has been produced in Utah.

**RABBITBRUSH SPECIES**

(*Chrysothamnus*)

Like the sagebrushes, rabbitbrushes belong to the sunflower family. Rubber rabbitbrush (*C. nauseosus*) is normally from 2 to 10 feet tall. The species is widely distributed in western North America and is particularly common in the Great Basin. The many subspecies and ecotypes of rubber rabbitbrush occur over an extensive variety of soils and sites as well as over a wide elevational range. Rubber rabbitbrush matures rapidly and is nutritious. Its forage value varies with subspecies, ecotype, and season of the year. In general, the white or greyish subspecies (*C. nauseosus salicifolius* and *C. nauseosus albicaulis*) are more palatable to game and livestock than the green subspecies (*C. nauseosus consimilis* and *C. nauseosus graveolens*) (table 2, figure 2).

Initial establishment of rubber rabbitbrush from seed is good to fair. Once established, however, growth is rapid and natural spread will occur if conditions are favorable. Like big sagebrush, rubber rabbitbrush is readily established by aerial seeding in mixtures with grasses and it maintains itself well with them. For these reasons, it is an important shrub for furnishing browse on depleted game ranges throughout the state and is equally useful for erosion control. Rabbitbrush seedlings transplant readily from container stock when 3 to 5 months old. Wildlings and nursery stock are easily transplanted on disturbed areas.

Rubber rabbitbrush is not overly competitive with herbaceous species in most environments, but rather it tends to enhance the growth of herbs. On favorable sites, the production of herbaceous cover as well as the percent of site covered have been notably greater in association with rabbitbrush than without the association.

Another tall rabbitbrush (*C. liniolius*) exhibits a strong underground spreading characteristic which makes it particularly valuable for stabilizing disturbed soil. It occurs in habitats that range from extremely dry to fairly moist. It is most abundant in the Colorado River drainage.

Other species of rabbitbrush are also common on western ranges. Low rabbitbrush (or yellowbrush) (*C. viscidiflorus*), which has several subspecies, is one of the most widely occurring shrubs on western ranges. The various subspecies of low rabbitbrush are adapted to different altitudes and soil types. Some forms are palatable, others are not. Parry rabbitbrush (*C. parryi*), generally a palatable species, is usually found at elevations between 6,000 and 8,000 feet in Utah. It is intermediate in many respects between rubber rabbitbrush and low rabbitbrush.

**SALTBUSSH SPECIES** (*Atriplex*)

Woody saltbushes are important inhabitants of the alkaline soils of western rangelands. Fourwing saltbush (*A. canescens*) grows in conjunction with a greater number of vegetal types than any other saltbush species. It is palatable and produces an abundance of nutritive forage. It grows from southern Canada to northern Mexico and from the Great Plains to the Coast Ranges. Most often, the saltbush plants are scattered among other dominants where soils have plentiful supplies of calcium. Big game, livestock and rabbits, as well as many rodents graze fourwing saltbush in all seasons. It has an amaz-

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**Table 2. Distinguishing characteristics of the four common subspecies of rubber rabbitbrush**

<table>
<thead>
<tr>
<th>Subspecies</th>
<th>Habitat</th>
<th>Palatability</th>
<th>Color</th>
<th>Leaf width</th>
</tr>
</thead>
<tbody>
<tr>
<td>albicaulis</td>
<td>Foothills (2,000-7,000 ft)</td>
<td>Medium to high</td>
<td>White</td>
<td>0.5-1.5 mm</td>
</tr>
<tr>
<td></td>
<td>Mountains (6,000-9,000 ft.)</td>
<td>Medium to high</td>
<td>Grey-green to white</td>
<td>3.0-10.0 mm</td>
</tr>
<tr>
<td>salicifolius</td>
<td>Foothills and valleys (3,000-6,000 ft.)</td>
<td>Medium to low</td>
<td>Green</td>
<td>1.0-3.0 mm</td>
</tr>
<tr>
<td>graveolens</td>
<td>Dry alkaline lowlands (2,000-6,000 ft.)</td>
<td>Low</td>
<td>Green</td>
<td>1.0 mm</td>
</tr>
<tr>
<td>consimilis</td>
<td></td>
<td>Low</td>
<td>Green</td>
<td></td>
</tr>
</tbody>
</table>
ing ability to recuperate from abusive grazing.

As implied by its wide but discontinuous distribution, fourwing saltbush exhibits a high degree of variability. Fourwing saltbush characteristically produces pistillate (female) and staminate (male) flowers on separate bushes. This habit provides maximum opportunity for selection through artificial hybridization. Preliminary experiments and our observations of natural populations indicate that several other saltbush species can contribute valuable germ plasm to fourwing saltbush.

We have located a few ecotypes that have favorable characteristics, e.g., good establishment, wide adaptation, high forage yield, high seed set, reasonable tolerance to cold, and winter greenness or succulence. We have initiated a selection program for one of these, and have obtained first generation progeny of some inter- and intraspecific hybrid combinations. In addition, we have located some natural hybrid swarms containing a wide assortment of hybrids as well as backcrosses which constitute important "shortcuts" in our selection program.

Other saltbush species are valuable in their own right. In many highly alkaline areas species such as shad-scale (A. confertifolia), cuneate saltbush (A. cuneata), mat saltbush (A. corrugata), and Gardner saltbush (A. gardnerii) provide the principal forage. All of these can be used in range restoration and soil stabilization projects — especially in the large alkaline and saline areas of Utah and the West.

ANTELOPE BITTERBRUSH, DESERT BITTERBRUSH, CLIFFROSE, AND APACHE-PLUME
(Purshia tridentata, P. glandulosa, Cowania mexicana stansburiana, and Fallugia paradoxa)

These shrubs are in the Rosaceae family and are closely related despite their different generic names. Natural hybrids between the first three are common and a few putative hybrids between Stansbury cliffrose and Apache-plume have been located. Artificial hybridization has been successfully achieved between all of these species (figure 3). These shrubs grow more slowly than sagebrushes, rabbitbrushes or saltbushes. Since some forms of bitterbrush layer readily and Apache-plume spreads aggressively underground, they are particularly good for soil stabilization.

Antelope bitterbrush is the most widely distributed of the group, occurring over much of temperate western North America. The other three species are more southwestern in their distribution. All are valuable browse plants. Stansbury cliffrose is an upright shrub that sometimes becomes treelike (figure 3). Antelope bitterbrush grows in varied forms ranging from low, layering shrubs to almost treelike plants. Desert bitterbrush is considered to be a derivative species from a natural hybridization between antelope bitterbrush and Stansbury cliffrose and displays many traits of each of its putative parents (table 3). It usually has an upright growth habit but includes prostrate ecotypes. Apache-plume is a spreading shrub about 3 to 5 feet tall. Root nodules that harbor nitro-
Table 3. Distinguishing characteristics of the bitterbrush-cliffrose-Apache-plume group

<table>
<thead>
<tr>
<th>Taxon</th>
<th>Patatability</th>
<th>Recovery from fire</th>
<th>Winter leaf retention</th>
<th>Leaf lobes</th>
<th>Fruits in recepticle</th>
</tr>
</thead>
<tbody>
<tr>
<td>Antelope bitterbrush</td>
<td>High</td>
<td>Medium to none</td>
<td>Low to none</td>
<td>3</td>
<td>1-2</td>
</tr>
<tr>
<td>Desert bitterbrush</td>
<td>Medium</td>
<td>High</td>
<td>High</td>
<td>3 (rarely 5)</td>
<td>1-3</td>
</tr>
<tr>
<td>Stansbury cliffrose</td>
<td>Medium</td>
<td>None</td>
<td>High</td>
<td>3-5</td>
<td>4-12</td>
</tr>
<tr>
<td>Apache-plume</td>
<td>Medium to low</td>
<td>High</td>
<td>Low to high</td>
<td>3-7</td>
<td>Many</td>
</tr>
</tbody>
</table>

Gen-fixing microorganisms have been discovered in antelope bitterbrush and Stansbury cliffrose and may occur in desert bitterbrush and Apache-plume as well. This nitrogen fixing ability likely helps these species grow on raw soils.

**MOUNTAIN SNOWBERRY (Symphoricarpos oreophillis)**

Mountain snowberry is a low-growing shrub. It occurs over a tremendous variety of sites, from the lowland sagebrush ranges to the subalpine high mountains. There are many variants that grow on diverse sites. Long-flower (or desert) snowberry (S. longiflorus) has similarly adaptive attributes but favors drier sites than does mountain snowberry. It is most frequently found in the juniper-pinyon types of Utah and Nevada.

Though snowberry is usually less preferred by game and livestock in winter than other shrubs, it leaves out early in the spring and is eagerly sought out by all grazing animals. All forms of snowberry establish readily from seed, wildings, and nursery stock. Wildings can be readily pulled or dug by hand from thick, native stands. Such wilding material is especially useful for erosion control on roadcuts and fills as well as on open mine spoils. Because of its waxy greenery, it is well suited as an ornamental on roadsides and recreational areas. Plants spread rapidly by layering as well as from seed that mice and other small rodents place in their caches.

**PROSTRATE KOCHIA (Kochia prostrata)**

Prostrate Kochia, brought back from Russia by American plant explorers about 8 years ago, is proving to be a valuable multiple-purpose shrub on basic soils. Its natural range is the south central part of Eurasia (central Europe to Manchuria), where it is a relatively common associate of grasses, including crested wheatgrass and Eurasian Artemisia species. It is noted for its polymorphism. Most of kochia's ecotypes are valued as forage and for their ability to establish and make good cover on severe sites. In the Soviet Union, prostrate kochia is sometimes cut, baled, and used for winter feed. It is also used for fuel by nomads. Prostrate kochia is 0.5 to 2.5 ft. high. It is quick growing, reaches sexual maturity in one year, and reproduces aggressively by seed.

Table 4 comparatively presents adaptive characteristics of 34 native and exotic shrub species now being used to varying degrees in restoring wildland sites in Utah. The table can not, however, show the immensity of subspecific and ecotypic variation; rich variation is present in all wildland shrubs.

Table 4. Shrubs useful for range restoration and soil stabilization

<table>
<thead>
<tr>
<th>Species</th>
<th>Value for:</th>
<th>Range Restoration</th>
<th>Soil Stabilization</th>
<th>Adaptation to vegetal types</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apache-plume (Fallugia paradoxa)</td>
<td>Medium</td>
<td>High</td>
<td>JP, BB, BS, MB</td>
<td></td>
</tr>
<tr>
<td>Bitterbrush, antelope (Purshia tridentata)</td>
<td>High</td>
<td>High</td>
<td>JP, MB, BS, BB</td>
<td></td>
</tr>
<tr>
<td>Bitterbrush, desert (Purshia glandulosa)</td>
<td>Medium</td>
<td>High</td>
<td>JP, BS, BB, MB</td>
<td></td>
</tr>
<tr>
<td>Bladdersenna, common (Colutea arborescens)</td>
<td>Low</td>
<td>High</td>
<td>MB, JP, A</td>
<td></td>
</tr>
<tr>
<td>Ceanothus, martin (Ceanothus martini)</td>
<td>Medium</td>
<td>High</td>
<td>MB, JP, A, BS</td>
<td></td>
</tr>
<tr>
<td>Chokecherry, black (Prunus virginiana)</td>
<td>Medium</td>
<td>High</td>
<td>MB, JP, A, BS, SA</td>
<td></td>
</tr>
<tr>
<td>Cherry, Bessey (Prunus besseyi)</td>
<td>Low</td>
<td>High</td>
<td>MB, JP, A</td>
<td></td>
</tr>
<tr>
<td>Currant, golden (Ribes aureum)</td>
<td>Medium</td>
<td>Low</td>
<td>MB, JP, BS, WM</td>
<td></td>
</tr>
<tr>
<td>Elder, blueberry (Sambucus cerulea)</td>
<td>High</td>
<td>High</td>
<td>MB, JP, A, BS</td>
<td></td>
</tr>
<tr>
<td>Honeysuckle, tatarian (Lonicer a tatarica)</td>
<td>Medium</td>
<td>High</td>
<td>MB, JP, BS</td>
<td></td>
</tr>
<tr>
<td>Kochia, prostrate (Kochia prostrata)</td>
<td>High</td>
<td>High</td>
<td>BS, BG, SS, IS</td>
<td></td>
</tr>
<tr>
<td>Lilac, common (Syringa vulgaris)</td>
<td>Medium</td>
<td>High</td>
<td>MB, JP, BS, A</td>
<td></td>
</tr>
<tr>
<td>Mahogany, birchleaf (Cercocarpus montanus)</td>
<td>Medium</td>
<td>High</td>
<td>JP, MB, BS</td>
<td></td>
</tr>
</tbody>
</table>
This dynamic panorama of rapidly evolving *Atriplex, Purshia* and *Cercocarpus* is merely illustrative of the extant evolution occurring in most of our native shrubs. The heterogeneous habitats of the Intermountain West provide maximum evolutionary opportunity. The rich gene pools constitute an extensive evolutionary potential. The unique half-tree-half-herb shrubby growth habit permits utilization of almost all evolutionary pathways. In combination these factors lead to evolutionary tempos of cataclysmic proportions. Given these circumstances, the explosive evolution we are witnessing among our native shrubs in the Intermountain West was virtually inevitable. With our current understanding of evolutionary processes and our present expertise in genetic manipulation, we should be able to extract and also concoct almost untold permutations to suit our future economic and esthetic needs.

LITERATURE CITED


Rangeland Shrub Regrowth Bane or Benefit?

CYRUS M. MCKELL AND E. EARL WILLARD

Shrub regrowth is a common occurrence and may take place at the beginning of each new growing season or after some type of major disturbance. This capacity for regrowth is one of the most important survival adaptations of many important range shrubs that are browsed by game and domestic livestock in Utah.

The resprouting habit may be looked upon by some range managers as a distinct disadvantage while others may view vigorous shrub regrowth as a benefit. The point of view taken by land managers depends entirely upon the uses they see for the new plant material produced. Those who see vigorous shrub regrowth as a disadvantage will think of the thicket type appearance that is produced which may cause a shrub-dominated area to impede the passage of livestock, horses, or mechanical equipment. Others may see the rapid recurrence of plant growth as a new source of fuel for rangeland fires thus cancelling out the benefits of an earlier fire which reduced the fuel density and the fire danger. Still others may see in rapid regrowth the return of competition for desirable forbs and grasses. In such cases, the regrowing shrub is probably low quality for browse or livestock feed.

MORE FOOD VALUE

Some of the benefits from shrub regrowth include the new amount of palatable and nutritious stems that can be used by livestock and wildlife for feed. The crude protein content on new stems is generally much higher than old wood or leaves. Some examples of crude protein levels reported in feed composition tables are from 12 to 18 percent in new stems. Livestock and big game show a high preference for the new growth of many shrub species. This is particularly true at certain times of the year. For big game, the presence of new twigs from previous years’ growth constitutes a large portion of their diet. Another benefit of shrub regrowth is the ground cover that it affords for watershed areas thus retarding soil erosion. Shrub regrowth also restores the natural beauty of the hillsides when they are scarred by fire or other disturbances. All in all, shrubs are vital to the natural beauty of Utah’s hills and mountains.

WHAT CAUSES SHRUB REGROWTH

Shrubs support many dormant buds which may remain in an inactive state for one to several years. These buds may be terminal, axillary, or adventitious. Terminal buds are located at the tips of branches whereas the axillary buds are located at the base of a branch or a leaf from the stem. Those buds which are adventitious may be located along stems but are generally more predominant at the base of a plant.

Buds may remain dormant because of environmental conditions which do not favor active growth for a period of time. Some of the environmental factors which keep buds in an inactive stage are high and low temperature, unfavorable day length, and other harsh environmental factors. Another reason for the dormancy of buds is their inhibition by plant hormones. It is well-known that the auxin produced in the apical buds may cause buds further down the stem to remain dormant. Other plant hormones may also cause buds to remain dormant but their mechanisms are not as clearly known as is the control exercised by auxin.

A third type of bud dormancy is associated with seasonal growth and plant activity. Generally there is a cyclic change in many physiological functions related to the increased activity of plants at the beginning of the growing season. At this time, some of the dormant buds are induced to begin activity along with the increased level of plant growth.

The second type of dormancy mentioned above is of most concern to range managers because it can be manipulated or is subject to the influence of activities over which man may have some control. Any disturbance of plants which tends to remove tissues at the stem apex or which removes the top portion of a shrub will immediately cause a loss of apical dominance and result in activation of lateral and basal buds. Loss or disturbance of the top portion of the plant may occur through the damaging effects of fire, cutting, mechanical treatments, herbicidal action, or from an extreme defoliation caused by grazing livestock or browsing big game. In any case, such top removal or disturbance stimulates dormant buds to active growth.

Some of the important range shrubs which produce considerable regrowth include rabbitbrush, snowberry, bitterbrush, gambel oak, bigtooth maple, service berry, elderberry and many others. Active regrowth following disturbance or abundant new shoot growth at the beginning of a new growing season offers many benefits for browse to livestock and
Not all range shrubs are active in regrowth, however. One of the best examples is big sagebrush. Big sagebrush is easily controlled by fire primarily because of its inability to regrow from the surviving stem after fire. The same inability exists after a cutting treatment.

**REGROWTH CAN BE MANIPULATED**

Any action that will remove top growth or cause a plant to lose apical dominance may be used to stimulate shrubs to more active regrowth than would normally occur under seasonal stimulation. In addition to controlled burning and mechanical treatments with cutters, choppers and range discs, it is also possible to stimulate range shrubs by defoliation at appropriate times and intensities of livestock or wildlife grazing. As more intensive systems of grazing are designed to make use of range forage and allow plants a period of rest, it is possible to time such grazing treatments to coincide with the most appropriate response period for shrub regrowth. Some of the more common grazing periods include early spring, mid-spring, early summer, and late summer. Rest-rotation grazing employs an intense period of grazing during the early or the late season but offers a period of rest during a following season to regain vigor and produce seeds. Such rest rotation treatments may also be used to stimulate shrub regrowth. Recent results from a clipping experiment point out which of the various times of the year and combinations of grazing treatments will serve to stimulate shrub regrowth to the greatest extent. The following treatments were applied to little rabbitbrush and snowberry in Logan Canyon for a period of 5 years:

1. No clipping.
2. Clipped annually on June 1.
3. Clipped annually on July 15.
4. Clipped annually on September 1.
5. Deferred-rotation, clipped annually, with a rotation of dates.
6. Alternate-rest, clipped every other year on June 1.
7. Alternate-rest, clipped every other year on July 15.

8. Rest-rotation, clipped once each year at different seasons for 2 consecutive years and rested the third year.

At the end of the 5-year treatment, the number and length of sprouts were measured and counted in the spring and again in the fall. The difference between the number of sprouts in the spring and in the fall represented those surviving to the end of the growing season.

**DEFOLIA TION TREATMENTS**

With the exception of little rabbitbrush plants clipped annually on June 1, the average number of new sprouts per plant was greater for clipped than for unclipped plants (figure 1). By fall, the number of live sprouts had decreased in all clipped plants and in a lesser degree in non-clipped plants. Plants receiving the July 15 alternate-rest treatment had more sprouts than all systems except the deferred-rotation and rest-rotation treatments. The control and July 15 alternate-rest treatment plants had the lowest percent sprout mortality from spring to fall.

Average length of new sprouts of little rabbitbrush in the spring was significantly less on plants clipped by various schedules than for unclipped ones (figure 2). Plants clipped annually on June 1, July 15, or September 1, or by the June 1 alternate-rest treatment had shorter sprouts than had plants on the other clipping schedules. Most clipping schedules allowed recovery of sprout vigor during the growing season. Only those plants clipped annually on June 1 or July 15 had shorter sprouts than unclipped plants had in the fall.

Snowberry plants clipped by the deferred-rotation and July 15 alternate-rest clipping schedules had more new sprouts in the spring than control (figure 3). No other differences were observed. By fall, the number of sprouts had declined for all but one clipping treatment, and were essentially the same for control plants. Only those plants receiving the July 15 alternate-rest clipping schedule had more sprouts in September than the controls. Control plants and those of the July 15 alternate-rest treatment had the smallest percent of sprout mortality from spring to fall.

No differences in average sprout length in the spring or fall were found in snowberry plants clipped under any clipping schedules used in this investigation (figures 2 and 3).

The high degree of sprout mortality on these two species indicates that the shrubs produce more initial sprouts than can be supported. Activated buds on the root crown of a
shrub are dependent on the stored carbohydrates for initial elongation and leaf development. Limited carbohydrate reserves available to these young sprouts may result in only the more competitive or favorably-located sprouts being able to develop to self-sufficiency. Those sprouts which have not attained self-sufficiency by the time of maximum depletion in the spring probably die soon afterward.

GRAZING MANAGEMENT IMPLICATIONS

Certain precautions should be observed in developing a grazing schedule for these shrubs. Annual grazing in June or July may be harmful to the plants through a reduction of carbohydrate reserves. Browsing to favor these shrubs should be planned for late summer or early fall if the grazing season is the same every year. Otherwise, schedules should include deferment from browsing in June and July. Such a grazing scheme would also allow important associated forage species the opportunity to recover from initial spring carbohydrate depletion. The associated grasses and forbs were observed to complete most of their growth by the first of September so late grazing should help maintain the stands of these important forage species.

Little rabbitbrush plants may be browsed lightly in July, August, or September to increase sprouting the following spring. Browsing in July on alternate years would result in the maximum number of live sprouts in the fall.

Heavy browsing of snowberry in August or September may result in the initiation of a maximum number of sprouts. However, browsing in July on alternate years would result in the maximum number of live sprouts in the fall.

These studies indicate that defoliation through grazing or browsing in a rest-type grazing system will stimulate some shrubs to produce greater than average regrowth in the following year. This new growth, high in protein and palatability, offers additional forage and browse benefits from rangelands.
Wynne Thorne Research Award

Established

The USU Division of Research is establishing the “Wynne Thorne Research Award.” This annual prize of $500 will be given to the individual or group on the USU campus that completed the most outstanding research within the previous 5 years. The recipient for each year will be chosen by a special committee appointed by the Research Council. The award is to be financed by a fund that is being developed through gifts from alumni, students, scientists, agriculturists, industry groups, and other individuals.

In his 1965 paper “Research and the University (A Modern Dilemma)”, Dr. D. Wynne Thorne was again pleading the cause of research — a cause to which he has devoted his professional career. Whether as practicing scientist or administrator, Wynne Thorne has consistently promoted the worth and quality of research at Utah State University.

His research as a professor of agronomy at Iowa State and Texas A&M in the 1930’s and later at Utah State (1939-55) produced valuable publications on the identification of minor element deficiencies in Utah crops and on various soil-water relationships. The insights gained through such research eventually culminated in a book that has gone through several editions, has been published in several languages, and has withstood the tests of time. Since its 1954 publication, “Irrigated Soils — Their Fertility and Management,” co-authored with H. B. Peterson, has been a classic in its field, perhaps as much of anything because it clarified the importance of soil, climate, crop, fertilizer, and water interactions.

NAMED DIRECTOR

In 1955, Dr. Thorne returned to Utah State University after a 1-year stint as Chief of the TVA’s Soil and Fertilizer research branch. Also in 1955 he relinquished his position as Head of the USU Agronomy Department and became Director of the Agricultural Experiment Station and Director of the newly created Division of Research. That transition marked his semi-abandonment of a personally productive scientific career and the assumption of a role in which he was to vigorously promote the scientific careers of others. Through his creation and leadership of USU’s Division of Research he was able to implement his belief that research must be defined to encompass all scholarly creative activities, including those within the humanities and arts. Simultaneously, the accomplishment of Agricultural Experiment Station personnel gained new recognition and appreciation as he facilitated their research and helped publicize their results. Virtually everyone involved in Utah agriculture, from the growers to the processors, has benefitted from research that Wynne Thorne has influenced either directly or indirectly.

While fulfilling the responsibilities of leading the Station and the Division (1955-65), Dr. Thorne also participated in various state, national, and international agricultural and science organizations, committees, and missions. Within Utah, this included extensive work on the problems of industry-generated air-borne contamnats.

INTERNATIONAL SCENE

On the international scene, he was instrumental in establishing the U.S./Russia agricultural scientist exchanges and was the only non-USDA member of the first U.S. delegation to Russia. While in Russia he was presented with a translated version of his book on irrigated soils. His initial written presentation describing a possible Russian/U.S. scientist exchange program has been widely used as a model by other government agencies. At various times between 1955 and 1965 he acted as a consultant on soil and water problems for countries such as Iraq, Venezuela, Ecuador and Bolivia.

During that same decade he continued to publish technical and semi-technical articles and edited (and
wrote a chapter for) the American Association for the Advancement of Science book, "Land and Water Use." In everything he did or promoted, his goal was to achieve scientific quality and productivity.

RESEARCH VICE-PRESIDENT

In 1965 he became USU's first Vice-President for Research. A little later he relinquished directorship of the Station in order to concentrate more effectively on the University's broader research concerns.

During the late 1960's, Dr. Thorne became involved in attempts to help India solve her food problems. This work led to his 1972 appointment to the Board of Governors of the "Consultative Group" of the International Crops Research Institute for Tropical Agriculture in India. His 1968-70 efforts helped provide the foundation for India's present agricultural research program. Late in 1970 he participated in the National Academy of Science evaluation of the World Bank's development program for East Pakistan (now Bangladesh), and ultimately prepared the NAS report.

As Vice President for Research, Wynne Thorne correctly interpreted national scientific trends and strongly urged interdisciplinary work at USU. The Ecology Center, International Biological Programs' Desert Biome, various Institutes, and the Environment and Man Program are representative of the results of his commitment to the interdisciplinary research on campus.

AGAIN DIRECTOR

In 1973, Dr. Thorne resigned as Vice President for Research in preparation for his impending retirement and re-assumed directorship of the Agricultural Experiment Station. As Station Director in these unpredictable times he has eliminated costly duplication of research efforts and is emphasizing an imaginative team approach to solving practical problems. In particular, Station personnel are being urged to respond creatively to the renewed need for agricultural productivity, pollution problems, and questions of optimizing land use. Recently, he became a member of the Agricultural Board of the National Research Council of the National Academy of Science, an organization that vitally affects national agricultural policy.

Throughout his career, Wynne Thorne has earned sustained recognition for his productivity as a scientist and as an administrator — and has evidenced an unflagging ability to inspire others to excell. His contributions to the status of research at Utah State University will be difficult to surpass.

Donations to the fund that will support the annual Wynne Thorne Research Award can be directed to office of the USU Development Fund at the Logan campus.

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